SPATIAL AND SOCIAL VARIATIONS IN TRAVEL BEHAVIOUR

Incorporating lifestyles and attitudes into
travel behaviour-land use interaction research

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SPATIAL AND SOCIAL VARIATIONS IN TRAVEL BEHAVIOUR

Incorporating lifestyles and attitudes into
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RUIMTELIJKE EN SOCIALE VERSCHILLEN IN VERPLAATSINGSGEDRAG

Het opnemen van leefstijlen en attitudes in onderzoek naar
de interactie tussen ruimtelijke ordening en verplaatsinsgedrag

(met een samenvatting in het Nederlands)

Proefschrift

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"Wat we het hardste nodig hebben in het leven is iemand die zorgt dat we doen wat we kunnen."

Ralph Waldo Emerson (1803-1882)

"Geloof degene die naar de waarheid zoekt.
Wantrouw degene die de waarheid heeft gevonden."

André Gide (1869-1951)

1. INTRODUCTION

1.1 Background

Messages such as "Traffic infarct is a fact" or "Even more cars until 2020" appear on a regular basis in newspapers and magazines, indicating the everlasting concerns about our daily mobility. These concerns are supported by figures and statistics indicating the substantial increase in the overall amount of travel. Like in many countries, car travel in Belgium has more than doubled between 1970 and 1990, from 40 billion passenger-km's to 90 billion passenger-km's (http://www.mobilit.fgov.be). Nowadays, travel is still rising although at a decelerating rate, and this increase likely continues. Prognosis studies predict another 30% increase in passenger-km's by 2030 (http://www.plan.be).

Various economic, social and spatial aspects contribute to this mobility increase. Influenced by its housing policy and transportation policy, a commuting culture has always existed in Belgium. Due to inexpensive public transportation season tickets and a well-established network of railways and tramways, people were no longer forced to reside nearby their jobs which were mainly located within the city. This was encouraged by the housing policy which promoted inexpensive social house-construction in garden cities, and provided subsidies and fiscal compensations for individual home-ownership. As a consequence, some form of suburbanization already existed in Belgium from the second half of the nineteenth century (Lauwers, 1991; Verhetsel *et al*., 2007). Due to technological advances, travel costs for passenger transport considerably decreased in the first half of the twentieth century (Rietveld and Vickerman, 2004). Combined with rising prosperity in the post World War II period, car ownership came within reach of many middle-class households. Especially from the 1950s onwards the automobile became a truly mass consumption product and the main mode of individual transportation in the Western world (Schafer, 1998; Kenworthy *et al*., 1999; Rodrigue *et al*., 2006). Moreover, commuters in Belgium could benefit from a compensation for their commuting costs by their employers (Verhetsel *et al*., 2007; Boussauw *et al*., 2009). This mass motorization together with improvements in the road network has strongly stimulated further suburbanization (Kesteloot, 2003). The private car provided unprecedented access to formerly unreachable destinations and it enlarged people's action space or the area within which persons can undertake activities (Dijst, 1995; 1999). Combined with a subsidy policy encouraging house ownership, people were no longer compelled to reside near their workplace and they moved toward green, safe and quiet residential neighbourhoods outside the city centre. Despite all kind of subsidies and loans, buying a house and a car remain important investments for most households. It often necessitates having a double-income. This increases labour participation of women which partly explains the rising travel figures of the last decades. These rising figures might also be the result of the absence of an adequate spatial planning policy for many years. Spatial planning policy in Belgium merely emerged in the 1960s-1980s with the design of regional zoning plans (Saey, 2005; Leinfelder, 2007; Allaert, 2008). However, functions such as living, working, shopping and recreating were already spatially separated by then. As a result, participating in these activities necessitates travel. Furthermore, activity patterns have also changed. Increased economic productivity enabled shortening of working time (i.e., more holidays, less working hours a day), resulting in more free time that could be spend on shopping or leisure activities. Whereas commuting is often considered as the most important travel motive, shopping and leisure are nowadays each responsible for almost one third of all trips (Ministerie van de Vlaamse Gemeenschap, 2005).

Increasing mobility is not necessarily something bad. After all, it offers people scopes to develop and it encourages social and economic development (e.g., Church *et al*., 2000; Preston and Rajé, 2007; Cebollada, 2009). Nevertheless, expanding mobility is nowadays perceived as undesirable because of its various negative externalities. In 2002, 26.2 billion km's were covered on Belgian motorways, which is about one third of the total amount of vehicle-km's travelled on Belgian roads. Due to congestion, 9 million hours were lost in traffic and this will increase by 36% until 2020. Since 'time is money' these lost vehicle hours equals to 114 million euros on an annual basis or to 460,000 euros for each working day (Logghe and Vanhove, 2004; Maerivoet and Yperman, 2008). Another problem relates to environmental damage. Due to strict emission standards and technological improvements in the construction of combustion engines, pollution by traffic has considerably decreased. Nevertheless, traffic remains responsible in Belgium for 59% of the emissions of nitrogen oxides (NO_x) and 23% of the emissions of carbon dioxide (CO_2) in 2007. NO_x is associated with the acidification of the environment, whereas CO_2 is considered as one of the major causes of global warming. Moreover, despite all efforts, CO_2 emissions are still increasing. Although various types of 'clean' cars nowadays exist, its share in the total amount of vehicles remains small. Moreover, each year the total amount of travelled distance increases. This combination results in the emission of 12,860 kton CO_2 in 2007, or an increase by 10% compared to 1990. Transportation in Belgium also produced 18% carbon monoxide (CO), 14% volatile organic compounds (VOC) and 23% total suspend particles (TSP), all of which cause serious health problems (Vlaamse Milieumaatschappij, 2008). These statistics can also be expressed in monetary terms. Environmental damage caused by motorway traffic only is worth 360 million euros of which 80% is due to fine dust (Logghe and Vanhove, 2004). Besides congestion and environmental pollution, other well-known examples of negative externalities of increasing mobility are problems with traffic safety (e.g., Flahaut *et al*., 2003; Kopits and Cropper, 2005; Eksler *et al*., 2008) and the damage to landscapes caused by transecting transport infrastructure (e.g., Serrano *et al*., 2002; Antrop, 2005, 2007).

The aforementioned mobility problems urge policymakers to respond by undertaking appropriate actions and measures. During several decades, transportation policy in Europe and the USA focused on the supply side of transportation by extending the road network. Belgian road infrastructure expanded spectacularly in the 1970s and 1980s, mainly by the construction of motorways. As a consequence, with 57.76 road km per 1000 sq. km Belgium has nowadays the most densely built transport infrastructure in Europe (www.plan.be) and even ranks third place in the world (http://web.worldbank.org). In the 1990s, the focus of transportation policy shifted from the supply side toward the demand side of transportation, introducing shorter-term infrastructure management strategies so that the existing road network could be used more efficiently. This shift is, without doubt, inspired by the report *Our Common Future* of the Brundtland Commission. That report launched the concept of 'sustainable development': a social and economic development meeting today's needs but without compromising the ability of future generations to meet their needs (World Commission on Environment and Development, 1987). It led to the first Earth Summit, the UN Conference on Environment and Development, at Rio de Janeiro in 1992, and the formulation of *Agenda 21* (United Nations, 1992). This conference discussed, among others, the use of sustainable development in transportation. It states that countries should develop an efficient and environmentally sound urban transport system that reduces transport demand, stimulates public transport and encourages walking and cycling. This can be achieved by, among others, the integration of land use and transportation planning (Banister, 1999). In correspondence with the Brundtland report and Agenda 21, Belgium formulates since 2000 each four years a federal plan on sustainable development. The first federal plan of sustainable development in Belgium acknowledges the derived nature of travel demand. Although some people sometimes travel just 'for fun' (Mokhtarian and Salomon, 2001; Ory and Mokhtarian, 2005), people mainly travel in order to participate in activities such as working, shopping and recreating at spatially separated locations. Thus, it seems logical that controlling mobility might be achieved by a better organized spatial structure in which people reside nearby their activity locations (FOD Mobiliteit en Vervoer, 2000). The more precise and practical interpretation of this is not a federal, but a regional matter. For example, for several decades, spatial planning was regulated by regional zoning plans that tended to offer juridical certainty, but land uses were defined without reference to a global vision on Flanders' spatial structure. This changed in 1997 with the approval of the Spatial Structure Plan for Flanders (Ministerie van de Vlaamse Gemeenschap, 1998). This plan offers a spatial vision and a framework against which spatial choices can be balanced. It recognizes the derived nature of travel: the need to travel is caused by the increasing spatial dispersal of activities such as living, working, shopping and recreating. As a consequence, travel behaviour can be influenced by changing the spatial organization of these activities. Therefore, the plan introduces several spatial principles of which decentralized bundling might contribute to the achievement of sustainable mobility. An important step in achieving this so-called decentralized bundling is the delineation of the urban regions. The renewal of these urban regions must counter further suburbanization and re-attract people toward the cities. The Mobility Plan Flanders (Ministerie van de Vlaamse Gemeenschap, 2001) recognizes that these spatial principles might result in more sustainable travel behaviour characterized by less (long-distance) trips, less car use, more public transport and more cycling and walking. These and similar policy initiatives are not restricted to Belgium or Flanders. For example, such initiatives were already introduced at the end of the 1980s in the Netherlands, resulting in well-known spatial policies such as the A-B-C location policy, the compact city policy, and the VINEX neighbourhoods (Schwanen *et al*., 2004; Geurs and van Wee, 2006). The New Urbanism movement in the USA has similar goals: reducing car use and travel distances through spatial planning (for a review, see, e.g., Ewing and Cervero, 2001).

The basic idea of all the abovementioned policy initiatives is that sustainable travel behaviour is associated with residing in high-density and mixed-use neighbourhoods; hence, indicating a clear existing relationship between land use and travel behaviour. Numerous academic studies tried to measure and explain the strength of this relationship, but the results remain equivocal. Therefore, more research is needed into the extent to which land use patterns affects people's daily travel pattern (Verroen *et al*., 2000).

1.2 Research into the land use-travel behaviour interaction

Studies on the land use-travel behaviour interaction are part of a rather long-lasting field of research dating back to the 1950s and 1960s. It was first articulated in 1954 in Mitchell and Rapkin's *Urban Traffic: A Function of Land Use,* but today it remains highly researched. Several complete and detailed overviews of the literature recently appeared (e.g., Badoe and Miller, 2000; Crane, 2000; Stead *et al*., 2000; Ewing and Cervero, 2001; Stead and Marshall, 2001; van Wee, 2002; Handy, 2002, 2005; Van Acker and Witlox, 2005; Bartholomew and Ewing, 2009). Furthermore, some chapters in this dissertation also summarize relevant parts of the existing literature (e.g., the literature specifically on land use and commuting in Chapter 5). The general literature review presented in this first chapter, therefore, only focuses on the relevant topics for this dissertation and the issues that are addressed in the other chapters of this dissertation. Since this dissertation is about the spatial and social variations in *people's* travel behaviour, this general literature review will only focus on the results of disaggregate individual-based studies. Consequently, more aggregated studies such as Kenworthy and Laube (1999) and Kenworthy *et al*. (1999), that compared patterns of automobile dependence among various cities, are no part of this general literature review.

1.2.1 Measuring spatial variations

Empirical studies mix up terms such as 'land use', the 'built environment' and the 'physical environment' when referring to the spatial influences of the residence, the origin of many trips, and important destinations such as the workplace. 'Land use' refers to the spatial distribution of functions such as living, working, shopping and recreating, and determines the relative proximity of different types of activities. In Flanders, for example, land use patterns are represented in regional zoning plans. The 'built environment' is a broader concept than the frequently used term 'land use'. The term 'urban form' is often used as a synonym for the 'built environment'. Both terms combine land use patterns with characteristics of the transportation system and urban design features. The transportation system consists of the transport infrastructure and transport services, and links the different activities or land uses with each other. Design refers to the aesthetic and visual details of the built environment, and in particular to the design of buildings and streetscapes. The built environment combined with the natural landscape and the human use of public spaces defines the general concept of the 'physical environment' (Handy, 1996, 2005). This dissertation tends to use the term 'land use' since spatial databases in Flanders or Belgium mainly contain information on the spatial distribution of various activities and land use types, and less on other aspects such as design features. However, sometimes other terms than 'land use' are used, this in correspondence to the preferences of the journals in which the chapters have been or will be published.

Land use patterns and the built environment can be characterized by a variety of variables and dimensions. Important and frequently mentioned spatial characteristics include density, diversity and design (referring to the 3D's according to Cervero and Kockelman, 1997). Density measures such as residential density and employment density refer to the intensity of land uses such as living and working. The mix of different types of land uses and the proximity to each other is captured by various diversity measures, whereas design variables refer to the physical layout of different land uses. Another important spatial characteristic is accessibility, which can be defined as the ease with which activities or locations can be reached by means of a (combination of) travel mode(s) (Geurs and van Wee, 2004). All of the aforementioned spatial characteristics are measured at various geographical scales ranging from the building, street/block level, the neighbourhood level to the municipality level. Other spatial characteristics such as urban size and the division monocentrism/polycentrism are measured at larger scales such as metropolitan areas and regional levels such as the Flemish Diamond in Flanders and the Randstad in the Netherlands (Schwanen, 2003; Handy, 2005). These macro-scaled zones and the related aggregated spatial variables are less relevant for the individual-based analyses reported in this dissertation. The empirical analyses in this dissertation only include spatial variables measured at micro-scaled zones such as census tracts which approximate to the direct neighbourhood of important locations such as the residence and the workplace. The effects of different zonal sizes and the partitioning scheme of these zones, the so-called modifiable areal unit problem (MAUP) (Openshaw and Taylor, 1979; Unwin, 1996), could affect the empirical results and findings. Although one should be aware of the possible biases caused by the MAUP, the focus of this dissertation is on explaining the influences of spatial and social variables to travel behaviour rather than on examining the influence of various spatial scales.

The use of different geographical scales is one of the reasons why some empirical studies agree on the extent of the land use influences on travel behaviour while other studies do not. Although numerous studies exist, the literature on the effects of density, diversity, design and accessibility on travel behaviour remains somewhat ambiguous and inconclusive. Some studies confirm the importance of land use effects even when accounting for other influences such as the socio-economic background of the traveller (e.g., Frank and Pivo, 1994; Kockelman, 1997; Dieleman *et al.*, 2002; Abreu e Silva *et al.*, 2006) and his or her personality traits (e.g., van Wee *et al.*, 2002; Schwanen and Mokhtarian, 2005a, b; Scheiner and Holz-Rau, 2007; Chen *et al.*, 2008). Nevertheless, equally as many studies can be found that state the opposite (e.g., Cervero and Kockelman, 1997; Krizek, 2000; Schwanen *et al.*, 2002; Pinjari *et al.*, 2007). Another reason for these conflicting results is that not all studies use the same set of spatial variables in relation to the same travel behaviour aspects. For example, it seems obvious that high densities, more diversity and a pedestrian-oriented design discourage car use in favour of walking and cycling, and encourage shorter travel distances (e.g., Handy, 1996; Kockelman, 1997; Meurs and Haaijer, 2001; Dieleman *et al.*, 2002; Naess, 2005). This is also one of the reasons why most empirical analyses described in this dissertation focus on modal choice. However, it is less self-evident that the same land use patterns would result in shorter travel times (e.g., Ewing *et al.*, 1994; Schwanen *et al.*, 2005). If travel times are mainly the result of travel distance, then land use patterns might have the desired effect on travel times. However, the reverse is likely to be true when travel times also depend on the velocity of the chosen travel mode. Moreover, land use influences might depend on travel motives. Meurs and Haaijer (2001), for example, found that spatial characteristics of the immediate home environment were more important for shopping trips than for working trips. This confirms the assumption that land use patterns are of greater importance for optional or discretionary trips than for routine or recurrent trips. The conflicting results can also be partly attributed to the use of different theoretical and conceptual frameworks. For example, using the utility maximization principle from microeconomics, Crane (1996) and Boarnet and Crane (2001) argued that daily travel decisions are based on the assessment of travel costs which are partly influenced by land use patterns. However, other scholars (e.g., Verplanken *et al.*, 1994, 1998; Gardner, 2009) underline that not all travel decisions are well-reasoned. Unreasoned travel behaviour due to habits and impulsive behaviour might occur as well. Moreover, some studies question the supposed causal relation between land use and travel behaviour (e.g., Handy *et al.*, 2005; Chatman, 2009; van Wee, 2009). Households can self-select themselves into neighbourhoods that support their residential and travel preferences. The land use variables used in the empirical studies are in that case merely a proxy for these underlying preferences. Analyzing these issues would involve other research designs than the one's that are mostly applied. Most empirical studies use readily available travel data which are mostly cross-sectional, and apply basic statistics such as regression and analysis of variance (ANOVA). However, as mentioned before, the relationship between land use and travel behaviour is much more complex. Consequently, more complete datasets (e.g., including longitudinal data or information on travel preferences) and more advanced statistics such as structural equation models (SEM) are necessary. For example, studies that perform a regression analysis often find a significant direct effect of land use on travel behaviour (e.g., Frank and Pivo, 1994; Kockelman, 1997; Dieleman *et al.*, 2002), whereas SEM studies are able to distinct direct form indirect influences. Several SEM studies (e.g., Bagley and Mokhtarian, 2002; Naess, 2005; Cao *et al.*, 2007a) point out that land use has a significant influence on travel behaviour, but mainly indirectly because of issues such as residential self-selection (e.g., Mokhtarian and Cao, 2008; van Wee, 2009) and mediating variables such as car ownership (e.g., Schimek, 1996; Scheiner and Holz-Rau, 2007). Another possible reason for differences in the conclusions about the relative importance of land use is the fact that studies are performed in various geographical settings. Most evidence is based on USA data with well-known study areas such as the San Francisco Bay Area and the Puget Sound Area. However, the urbanization patterns of these North American cities significantly differ from European cities (Schwanen, 2002).

Consequently, the results of these North American studies cannot be extrapolated without any problem to the European context. European studies remain scarce, although during the last decennia a lot of research has been done in countries such as the Netherlands (e.g., Snellen, 2002; Schwanen, 2003; Maat, 2009), Great-Britain (e.g., Stead, 1999) and Switzerland (e.g., Schönfelder, 2006; Beige, 2008). Nevertheless, results may differ across European countries as well due to various urbanization patterns, spatial planning systems, and cultural factors (e.g., Simma and Axhausen, 2001; Martens *et al*., 2002; Schwanen, 2002). Therefore, additional research from a European context which considers the complexity of travel behaviour is deemed important.

1.2.2 Measuring social variations

Most studies control their results for objective or 'hard' socio-economic and demographic (SED) characteristics, thereby minimizing the possibility that a third factor, e.g., income creates an accidental or spurious relationship between land use and travel behaviour. However, van Wee (2002) points out that different travel patterns might still exist within socio-economically and demographically homogenous population groups, indicating that more subjective or 'soft' variables such as personal attitudes, personality traits and lifestyles are involved as well. Ignoring these subjective variables leaves unanswered the aforementioned question of causality (Handy *et al*., 2005; Bhat and Guo, 2007). Do urban land use patterns characterized by high densities, more diversity, a pedestrian-oriented design and high accessibility really result in less car use, more public transport and more non-motorized trips? Or are underlying characteristics such as personal urban lifestyles, and residential and travel attitudes more important? Only recently, those type of subjective variables were introduced in empirical work on the relationship between land use and travel behaviour (e.g., Kitamura *et al*., 1997; Bagley and Mokhtarian, 2002; van Wee *et al*., 2002; Schwanen and Mokhtarian, 2005a, b; Scheiner and Holz-Rau, 2007). It also indicates that researchers are aware that travel behaviour is not strictly defined by land use patterns and can deviate from it. Common land use-travel behaviour interaction studies might come across as environmentally deterministic, referring to one important theoretical movement in geography (Holt-Jensen, 1980; Saey, 1990; De Pater and van der Wusten, 1991). However, by accounting for subjective influences such as attitudes, preferences and lifestyles, more attention is paid to the behavioural mechanisms, motivations and intentions underlying travel decisions and daily travel patterns. The significance of these subjective influences is also recognized by policymakers. For example, the Mobility Plan Flanders (Ministerie van de Vlaamse Gemeenschap, 2001) emphasizes that influencing attitudes by information campaigns or by consciousness-raising programmes is one possible way to change existing travel behaviour and achieve more sustainable travel patterns. Nevertheless, land use-travel behaviour interaction studies that also control their results for subjective influences are mainly based on a North American context. The fact that empirical evidence from Europe remains limited calls for additional research. After all, due to the aforementioned differences in, among others, urbanization patterns but also in culturally defined norms and values, it remains unclear to which extent conclusions based on USA evidence are also valid in a European context.

1.2.3 Measuring daily travel behaviour

Most empirical studies analyze the land use effects on one specific aspect of travel behaviour, of which trip frequency, modal choice and travel distance received the bulk of attention. However, interrelations might exist between several travel behaviour aspects and, thus, it might also be useful to consider several aspects simultaneously. For example, some studies indicated that car ownership mediates the relationship between land use and modal choice (e.g., Schimek, 1996; Simma and Axhausen, 2003; Chen *et al*., 2008). Others found that modal choice is influenced by travel distance, and travel time is influenced by both travel distance and modal choice (e.g., Schwanen *et al*., 2002; Susilo and Maat, 2007; Scheiner, 2010). Another example of interrelations among travel behaviour aspects relates to tour complexity. Tour complexity can be considered as influenced by car ownership and travel distance, whereas tour complexity on its turn influences modal choices. Studies suggest that the tendency to undertake complex or simple tours varies systematically with car ownership and travel distance (e.g., Krizek, 2003; Maat and Timmermans, 2006) and that the participation in complex tours increases the propensity to use the car (e.g., Hensher and Reyes, 2000; Ye *et al*., 2007; Chen *et al*., 2008). These examples indicate that travel behaviour is complex and multidimensional. In order to obtain a better understanding of how land use influences travel behaviour, more research is needed on the interrelations among travel behaviour aspects instead of focussing on one specific aspect. One way to simultaneously study the aforementioned interrelations is the estimation of a structural equation model (SEM). Contrary to traditional multivariate statistics such as regression analysis, SEM can handle and estimate complex models including mediating variables. Only recently, this method has increasingly been used in travel behaviour studies (Golob, 2003), but especially in applications of Ajzen's theory of planned behaviour (Ajzen, 1991; based on Scheiner and Holz-Rau, 2007). This dissertation will, therefore, evaluate the practicability of SEM in land use-travel behaviour interaction research.

Furthermore, many studies measure the aforementioned dimensions of travel behaviour without reference to a specific travel motive (e.g., daily total travel distance, daily trip frequency) or, on the other hand, specifically for commuting trips (e.g., commuting distance, commuting time). Out of all travel motives, attention is mainly paid to home-to-work travel. This is no surprise since the temporal and spatial clustering of commuting is related to congestion, one major concern about travel and mobility. Moreover, the habitual and regular character of commuting acts as a peg around which other non-work activities such as shopping and recreating are scheduled. Consequently, the principle that the work activity determines the other non-work activities is a basic principle in many empirical activity-based modelling studies to date (e.g., Damm, 1980; Bhat and Koppelman, 1993; Bowman and Ben-Akiva, 2000; Pendyala and Goulias, 2002; Yeranguntla and Bhat, 2005). However, travel surveys such as the 2000-2001 Flanders Travel Behaviour Survey (Onderzoek Verplaatsingsgedrag (OVG) Vlaanderen) indicate that non-work trips are as important, or even outnumber, commute trips. Moreover, some studies (e.g., Meurs and Haaijer, 2001) found that spatial characteristics of the residential neighbourhood have a larger impact on optional or discretionary trips (such as shopping) than on routine or recurrent trips (such as commuting). Consequently, more research is also needed on how land use characteristics influence travel for non-work purposes.

1.3 Aims and research questions

Although our understanding on the interaction between land use and travel behaviour has certainly increased, there are still opportunities for further research. Three major aims can be formulated which are subject of this dissertation. First, the existing research debate on land use-travel behaviour interaction will be extended by empirical evidence from a European context, especially from Flanders where no such long-lasting spatial planning tradition exists as in other European countries such as the Netherlands. Second, the land use-travel behaviour interaction analyses will not be limited to one specific travel behaviour aspect such as modal choice or travel distance, or to one specific travel motive such as commuting. On the contrary, the interdependencies among various travel behaviour aspects such as car ownership, modal choice, tour complexity, travel distance and travel time will be estimated, and especially travel for non-work purposes will be analyzed. Third, whereas common studies control their results for SED differences among individuals, this dissertation will also control for the influence of subjective characteristics such as attitudes and lifestyles. Or in general, the overall aim of this dissertation is:

To ascertain the effects of land use patterns on the complexity of travel behaviour for Flanders (Belgium) while controlling for the traveller's objective and subjective characteristics.

This major aim can be refined into seven more specific research questions.

1. *Which theoretical framework justifies a relationship between daily travel behaviour and land use, while accounting for socio-economic and demographic influences as well as socio-psychological influences?*

Numerous empirical studies exist that try to measure the land use effects on travel behaviour. However, almost none of them (explicitly) refer to a theoretical or conceptual framework that justifies why a relationship should exist after all between land use and travel behaviour. One exception is Crane and colleagues (Crane, 1996; Boarnet and Crane, 2001) who, inspired by the maximization principle from microeconomics, argue that travel opportunities are assessed against its travel costs. However, they tend to neglect other behavioural processes such as unreasoned behaviour (e.g., habits, impulsive decisions). Establishing a more comprehensive framework, thus, involves combining theories from different backgrounds. This research issue is dealt with in Chapter 2.

2. *How is travel behaviour influenced by land use characteristics and objective socio-economic and demographic characteristics related to social status and responsibility within the household? And if land use remains important, what is the joint effect of land use patterns on travel behaviour?*

A commonly formulated issue in land use-travel behaviour interaction research is whether land use characteristics are just as important as, or even more important than, objective SED characteristics. Several studies measure the relative importance of spatial characteristics compared to other objective SED characteristics. Some studies (e.g., Frank and Pivo, 1994; Kockelman, 1997; Dieleman *et al*., 2002) found that land use influences remain important even after controlling for SED characteristics, whereas other studies state the opposite (e.g., McNally and Kulkarni, 1997; Boarnet and Sarmiento, 1998; Schwanen *et al*., 2002). Moreover, most studies analyze the effects of land use characteristics separately from each other, for example, by including population density and land use mix as two independent variables in a regression analysis that explains travel behaviour aspects such as travel distance. Doing so, the joint effect of all spatial characteristics together is not considered. One possible solution is the use of a categorization of neighbourhoods, mostly urban versus suburban (e.g., Friedman *et al*., 1994; McNally and Kulkarni, 1997; Dieleman *et al*., 2002; Schwanen *et al*., 2002). However, simplifying complex land use patterns into a few number of neighbourhood categories is a distortion of reality (Bagley and Mokhtarian, 2002). Another way to tackle this problem is the construction of latent variables that also capture the multidimensionality of land use patterns but which are continuous rather than categorical. These questions are addressed in Chapter 3, and refer to the spatial and social context in which travel behaviour occurs.

3. *What is the role of car ownership within land use-travel behaviour interaction research?*

Land use-travel behaviour interaction research cannot be reduced to analyses of a simple and one-way relationship between land use and travel behaviour. Instead, various kinds of interdependencies should be accounted for (Maat, 2009), of which car ownership as a mediating variable is one example. After all, car ownership can be considered as a medium-term decision which is influenced by long-term decisions such as residential and workplace location choices. The spatial characteristics of these locations, e.g., having access to public transport, might constrain or facilitate car ownership (e.g., Kockelman, 1997; Abreu e Silva *et al*., 2006; Maat and Timmermans, 2007; Chen *et al*., 2008). On the other hand, car ownership affects the individual's and household's daily decisions on travel behaviour, such as modal choice. However, empirical studies do not always account for this dual relationship of car ownership. Most studies regard car ownership as one of the predictors (or explanatory variables) of travel behaviour (e.g., Dieleman *et al*., 2002; Schwanen *et al*., 2002; Krizek, 2003), whereas others only consider car ownership as the outcome variable that is explained by various spatial and SED variables (e.g., Dargay, 2002; Bhat and Guo, 2007; Cao *et al*., 2007b). Chapter 4 combines both research approaches and discusses the dual relationship of car ownership in land use-travel behaviour interaction research.

4. *Should tour complexity be considered as an endogenous variable to be explained or not?*

Many studies presume the trip as the basic research unit and, therefore, conceptualize travel behaviour in terms of modal choice or travel distance per trip (e.g., Rajamani *et al*., 2004; Guo *et al*., 2007). Other studies aggregate these aspects into measures such as total daily travel time (e.g., Ewing *et al*., 1994; Schwanen *et al*., 2002). However, activity-based studies point out that travel decisions are not made for each single trip, but people rather optimize their entire daily activity pattern and consider tours instead of separate trips (Bhat and Koppelman, 1999; Primerano *et al*., 2008). Similar to car ownership, tour characteristics such as tour complexity (i.e., the number of trips per tour) intervene the relationship between land use and travel behaviour. Tour characteristics are influenced by land use patterns (e.g., Ewing *et al*., 1994; Krizek, 2000; Maat and Timmermans, 2006), and on their turn also influence other travel behaviour aspects (e.g., Hensher and Reyes, 2000; Ye *et al*., 2007; Chen *et al*., 2008). The dual relationship of tour complexity is, therefore, questioned in Chapter 5.

5. *How to measure lifestyles and how to incorporate lifestyles in land use-travel behaviour interaction research?*

Land use-travel behaviour interaction studies generally control their results for objective SED characteristics. Nevertheless, different travel patterns might still occur within socio-economically and demographically homogenous groups (van Wee, 2002) indicating that more subjective variables are involved as well. Lifestyles are one example of such subjective variables, but various definitions of lifestyles exist. Some definitions equal lifestyles to specific patterns of behaviour by which the individual wants to elucidate his or her social position (e.g., Driessen and Goossens, 1993), whereas other definitions stress the underlying opinions and motivations, or orientations mainly toward work, family and leisure (e.g., Pinkster and van Kempen, 2002). Since this confounds our understanding of the lifestyle concept, lifestyles as underlying orientations which are internal to the individual and hard to observe by an outsider should be distinguished from observable patterns of behaviour reflecting someone's lifestyle or lifestyle expressions (Munters, 1992). This distinction justifies the use of lifestyle expressions as indicators of the underlying lifestyles in empirical land use-travel behaviour interaction studies. Despite these theoretical considerations, the term 'lifestyle' is frequently used whether it is relevant or not. Some land use-travel behaviour interaction studies (e.g., Salomon and Ben-Akiva, 1983; Cooper *et al*., 2001; Hildebrand, 2003) analyze the effect of so-called lifestyles, but in fact combine various objective SED characteristics thus referring to stage of life or household composition rather than to lifestyles. In order to clarify these issues, Chapter 6 specifically focuses on the measurement of lifestyles and the interdependencies between long-term lifestyle decisions, medium-term decisions on residential location and car ownership, and short-term travel decisions.

6. *How are attitudes related to medium-term decisions on residential location and car ownership?*

Attitudes are another type of subjective influences for which land use-travel behaviour interaction studies should account. Various definitions exist, but all refer to attitudes as the evaluative response toward some stimuli which influences the individual's behaviour (Gärling *et al*., 1998; Brehn *et al*., 2005). Attitudes are thus considered to be reasoned influences underlying, among others and of particular interest for land use-travel behaviour interaction research, medium-term decisions on residential location and car ownership which influence daily travel decisions. The attention for attitudes in travel behaviour research is not completely new: transport behavioural analysts (e.g., Dobson *et al*., 1978; Gärling *et al*., 1998; Parkany *et al*., 2004) already discussed the role of attitudes in travel behaviour but they tend to neglect the spatial context in which travel occurs. Information on attitudes was only recently introduced in land use-travel behaviour interaction research (e.g., Kitamura *et al*., 1997; van Wee *et al*., 2002; Schwanen and Mokhtarian, 2005b). Many of these studies merely analyze the direct effect of all these variables on travel behaviour, and tend to disregard the complex interdependencies among long-term lifestyle decisions, medium-term decisions on residential location and car ownership, and their underlying reasoned influences. Chapter 7, therefore, introduces travel and residential attitudes into the complex relationships between lifestyles, residential location decisions and car ownership.

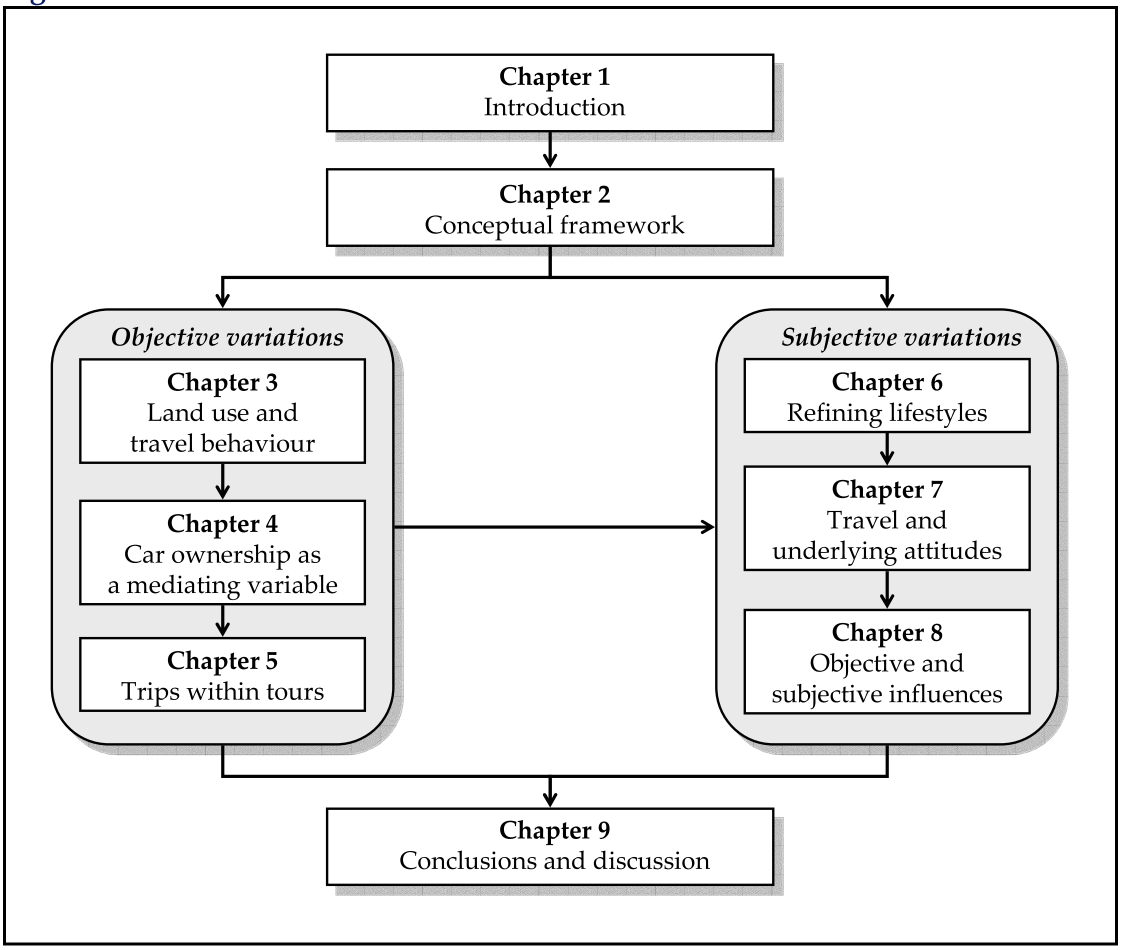
7. *Is daily travel behaviour influenced by objective spatial and socio-economic and demographic characteristics, or just as much by subjective lifestyles, travel attitudes and residential attitudes?*

Although some studies might find that, for example, increasing density is related to less car use and more non-motorized traffic, this finding might mask more important underlying processes. After all, it remains possible that people who prefer to bike or walk self-select themselves in high-density neighbourhoods that offer many opportunities within walking or biking distance. These residential neighbourhoods, thus, corresponds with their travel preferences. Consequently, the formerly specified relationship between density and modal choice is more likely the result of underlying travel and residential preferences than the land use characteristics of the residential neighbourhood on it selves. Moreover, van Wee (2009) points out that people not only self-select them with respect to residential location choices, but also to other aspects such as travel behaviour and the exposure to transport externalities. The latter has, so far, received little attention. For these reasons, Chapter 8 focuses not only on the influences of residential self-selection but also on the travel consequences of the attitude-related self-selection with respect to car ownership and daily travel behaviour. By assessing the influence of objective and subjective variables on modal choice against each other, it tries to answer the question the question whether it is really land use that influences travel behaviour, or rather underlying processes of self-selection (Handy *et al.*, 2005; Bhat and Guo, 2007; Mokhtarian and Cao, 2008; van Wee, 2009).

1.4 Organization of the dissertation

This dissertation comprises seven academic papers that have been published in international peer-reviewed scientific journals, or are forthcoming, or have been submitted. Each paper discusses one of the seven previously mentioned research questions. In order to allow someone to read these papers independently from each other, there is some inevitable overlap in the individual chapters with regard to the literature reviews, and the descriptions of the methodology used and the applied research designs. Also please bear in mind that differences in terminology and spelling reflect the preferences of the particular journals.

Figure 1.1 Dissertation outline



The dissertation is organized as follows (see also Figure 1.1).

In Chapter 2, which is forthcoming in *Transport Reviews* as Van Acker *et al*. (2010a), a comprehensive conceptual model of travel behaviour is developed which specifies why travel behaviour is related to spatial, SED background characteristics, and socio-psychological variables. Comparable to customary theories in transport geography, the conceptual model places travel behaviour within a hierarchy of decision choices. It considers travel behaviour as derived from activity behaviour (short-term behaviour), location behaviour (medium-term behaviour) and lifestyle (long-term behaviour). Furthermore, these behaviours are explained by underlying reasoned influences (i.e., perceptions, attitudes and preferences) as well as unreasoned influences (i.e., habits and impulsiveness), and the individual is placed within a social context (e.g., the household) and a spatial context (e.g., the residential neighbourhood). In the subsequent chapters, the conceptual model is (partly) estimated by means of structural equation models which can handle the complexity between various components of the proposed conceptual model.

A first attempt to explain travel behaviour in relation to activity and location behaviour is reported in Chapter 3, published as Van Acker *et al*. (2007) in *Transportation Planning and Technology*. Based on data from the 2000-2001 Travel Behaviour Survey Flanders (Zwerts and Nuyts, 2004), a SEM with latent variables is developed which not only capture the complexity of the relationships between land use and travel behaviour, but also the multidimensionality of land use patterns. The proposed model estimates the influence of land use patterns on travel behaviour characterized by trip frequency, travel distance and travel time. Whereas the third Chapter analyzes the complexity of various travel behaviour aspects, most subsequent chapters focus on modal choice to some extent. Chapter 4, published as Van Acker and Witlox (2010a) in *Journal of Transport Geography*, then discusses the role of car ownership in land use-travel behaviour interaction research. It first presents a causal model which underlines the dual role of car ownership by assuming that car ownership mediates the relationship between the residential environment and car use. Then, data from the 2000-2001 Ghent Travel Behaviour Survey (Zwerts and Nuyts, 2001; Witlox, 2007) are used to perform a path analysis of the proposed causal model. Doing so, the fourth Chapter reports how density, diversity and accessibility influences car ownership and car use, while controlling for issues such as residential self-selection and differences in the individuals' SED background characteristics. Chapter 5, under review in *Transportation*, proceeds by extending the causal model of the fourth Chapter with two aspects (Van Acker and Witlox, 2010b). First, beside the influence on car ownership and car use, it also analyzes the land use influences on and the interdependencies between tour complexity, commuting distance and commuting time. Moreover, it discusses the results of a multiple group SEM which highlights the differential influence of land use patterns on commuting behaviour across simple home-work-home tours and more complex work tours that combine working with non-working trips.

Whereas Chapters 3 to 5 only use objectively measured variables, the subsequent three chapters also consider the underlying subjective influences. Doing so, the interaction between land use and modal choice is explained by objective as well as subjective variables. Information on these subjective influences was collected through an Internet survey during the period May-October 2007. Chapter 6, submitted for publication in *Transportation Research A*, focuses on the definition and measurement of lifestyles (Van Acker *et al*., 2010b) which refer to the longest-term decisions that influence modal choices. The Internet survey contained various questions on leisure orientation and the assessment of the work-family balance, which are believed to be two important aspects of lifestyle expressions and which can be used as proxies for lifestyles. These data are then factor analyzed in order to obtain the appropriate lifestyle factors, and used as input for a path model that explains modal choices (i.e., car use, public transport, cycling and walking) for various types of leisure trips (i.e., fun shopping, family visits, active leisure activities). Chapter 7, submitted for publication in *Transport Policy* (Van Acker *et al*., 2010c), continues and adds attitudes as another type of subjective influences. It, therefore, introduces travel and residential attitudes into the formerly mentioned hierarchy of decisions, and considers the direct as well as indirect effects of attitudes on car ownership. Chapter 8, based on Van Acker *et al.* (2010d) and which is submitted to *Environment and Planning A*, concludes the empirical analyses by assessing whether modal choices are as much as influenced by objective as by subjective variables. It builds on the previous seventh Chapter, and attitudes are this time related to modal choices for leisure travel. Doing so, this chapter points out whether land use itself influences modal choices or rather the underlying processes of self-selection with regard to residential location, car ownership and travel. Moreover, the discussion is not only limited to the influence of attitudes on (travel) behaviour, but also on the feedback mechanisms and the opposite relationship from behaviour to underlying attitudes.

Chapter 9, finally, relates the most important findings of the former chapters to the seven research questions. Avenues for further research are also pointed out. The chapter ends with a discussion of the practical implications for spatial planning policies and transportation planning policies in Flanders, Belgium.

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“Ik vind niets uit, ik ontdek opnieuw.”

Auguste Rodin (1840-1917)

2. WHEN TRANSPORT GEOGRAPHY MEETS SOCIAL PSYCHOLOGY

TOWARD A CONCEPTUAL MODEL OF TRAVEL BEHAVIOUR

Van Acker, V., van Wee, B., Witlox, F. (2010) When transport geography meets social psychology: Toward a conceptual model of travel behaviour. Transport Reviews, doi: 10.1080/01441640902943456 (forthcoming).

Abstract Many studies model the effects of the built environment on travel behaviour. Usually, results are controlled for socio-economic differences and sometimes socio-psychological differences among respondents. However, these studies do not mention why after all a relationship should exist between travel behaviour and spatial, socio-economic and personality characteristics. Answering this query involves combining and linking theories stemming from transport geography (e.g., time geography, activity-based approach) and social psychology (e.g., Theory of Planned Behaviour, Theory of Repeated Behaviour). Using key-variables from these theories, this paper aims to develop a conceptual model for travel behaviour. Comparable to customary theories in transport geography, this conceptual model considers travel behaviour as derived from locational behaviour and activity behaviour. But the conceptual model adds concepts such as 'lifestyle', 'perceptions', 'attitudes' and 'preferences' which indirectly influence travel behaviour.

2.1 Introduction

Living, working, shopping and recreating are spatially separated activities. In order to participate in these activities, people have to travel. Policymakers try to control and manage this daily travel behaviour, for instance through urban planning. In this respect, concepts of the New Urbanism in the USA and the Compact City Policy in Europe aim at reducing car use and travel distances because high-density and mixed-use neighbourhoods are believed to be associated with shorter trips and more non-motorized trips.

Numerous empirical studies try to measure the effects of the built environment on people's daily travel behaviour. Literature reviews such as van Wee (2002) or Ewing and Cervero (2001) distinguish various built environment characteristics, ranging from aggregated measures such as density and diversity calculated within zones such as census tracts, to more disaggregated measures such as characteristics of the respondent's dwelling. The results are generally controlled for socio-economic and demographic differences among individuals and households. A limited number of studies takes attitudes and preferences toward urban form and/or travel into account as well (e.g., Handy, 1996; Kitamura *et al*., 1997; Bagley and Mokhtarian, 2002; Collantes and Mokhtarian, 2007). Consequently, key-variables in these empirical travel studies refer to: (i) spatial characteristics, (ii) socio-economic characteristics and (iii) socio-psychological characteristics.

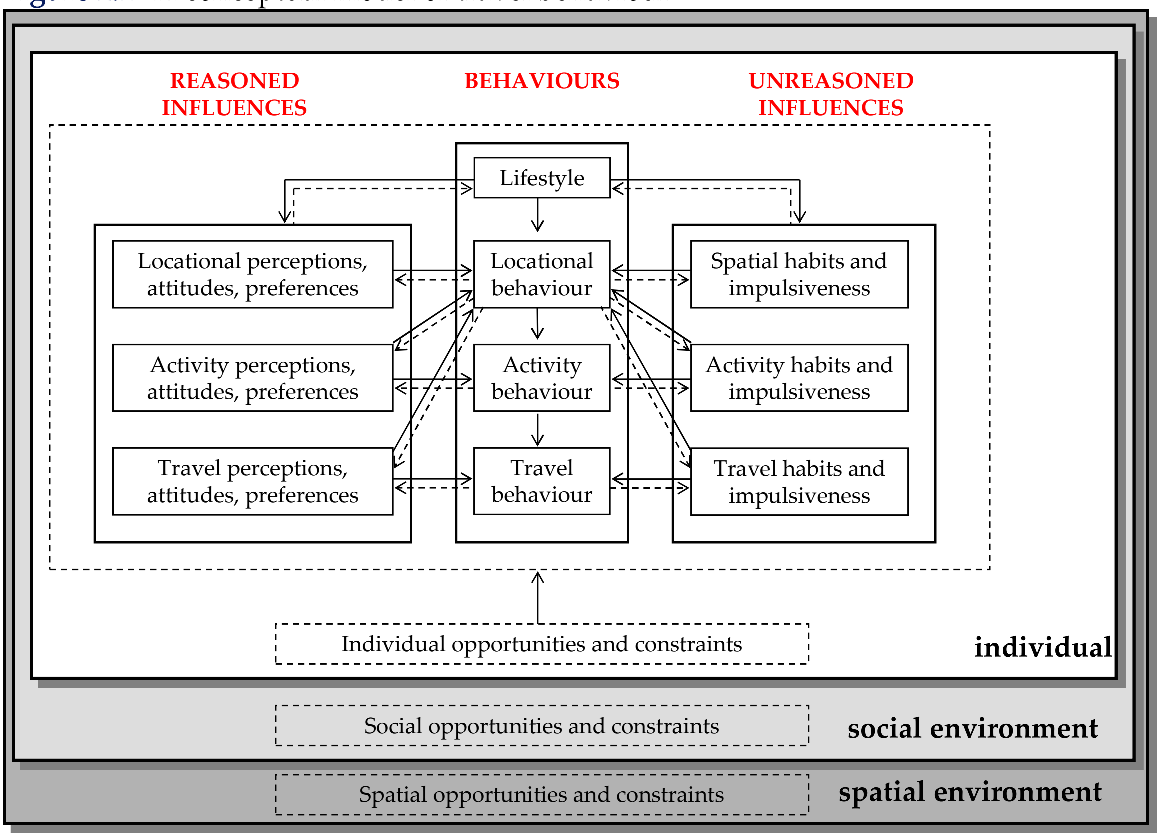
Nevertheless, almost none of the empirical studies presents a theoretical framework that justifies the relationships between daily travel behaviour and spatial, socio-economic and socio-psychological characteristics. One exception is Boarnet and Crane (2001) and Crane (1996) who developed a simple theoretical framework in which they argue that the built environment influences travel behaviour through its influence on travel costs. Based on the utility maximization principle of microeconomics, they reasoned that travel choices are based on an assessment of (i) the individual's preferences for particular trips or travel modes and (ii) the relative costs of making those trips or choosing those travel modes. Doing so, they tend to consider travel choices as well-reasoned choices whereas other studies (e.g., Verplanken *et al*., 1994, 1998; Gardner, 2009) stress that unreasoned behaviour appears as well. Moreover, utility maximization does not totally encompass the motivation of human behaviour (Talvitie, 1997). Establishing a more comprehensive framework would, therefore, involve combining and linking theories stemming from not only microeconomics, but also from transport geography and social psychology. According to Handy (2005), theories in transport geography refer to the mechanism determining travel behaviour, whereas theories in social psychology define specific factors influencing travel behaviour. This paper aims to develop a conceptual model of travel behaviour by using key-concepts and variables from these theories. We clearly do not restrict ourselves to one particular disciplinary perspective. The resulting conceptual model will unravel the relationships between people's daily travel behaviour and spatial, socio-economic and socio-psychological characteristics. Doing so, we try to provide an authoritative and up-to-date review of theories and research on daily travel behaviour.

The paper is structured as follows. First, we briefly explore the theoretical concepts from transport geography in which daily travel behaviour is considered as part of a decision hierarchy. Because we are interested in a better understanding of how *people* travel, we limit our approach to disaggregate theories. Theories with an aggregated approach such as gravity models do not provide enough insights into the mechanisms underlying people's travel behaviour (Hanson and Schwab, 1986). Next, we introduce the quintessence of those theories in social psychology focussing on underlying factors which influence the previously described decision hierarchy. Then, we consider the conceptual framework within a social and spatial context. This is followed by a discussion of the conceptual and modelling implications of our conceptual model of travel behaviour. Finally, we summarize our main findings and point to some avenues for further research.

2.2 Why travel behaviour is part of a decision hierarchy

Daily travel patterns are often suggested to be the result of a hierarchical decision structure (e.g., Ben-Akiva, 1973; Salomon, 1981; Salomon and Ben-Akiva, 1983). This hierarchy ranges from short-term decisions on daily activities and travel, to long-term decisions on lifestyle. Our conceptual model of daily travel behaviour also departs from this notion and, therefore, the decision hierarchy is at the centre of Figure 2.1. In this section, we provide a theoretical justification of this decision hierarchy. In addition, some empirical results are summarized that support the theoretical justification and illustrate some recent developments.

Figure 2.1 A conceptual model of travel behaviour



2.2.1 Short-term activity decisions and implications for travel behaviour

Nowadays, travel is generally considered as a derived demand. Although sometimes people might travel just 'for fun' (e.g., Mokhtarian and Salomon, 2001; Mokhtarian *et al*., 2001), people mainly travel in order to access desired activities in other places. After all, activities such as living, working, shopping and recreating are in most cases spatially separated and, thus, encourage the need to travel. Consequently, activity behaviour which refers to the spatial and temporal characteristics of the performed activities must be studied first in order to understand travel behaviour (Pas, 1980; Jones *et al*., 1990; Axhausen and Gärling, 1992; McNally, 2000). This idea has been further elaborated in the activity-based approach, which emerged in the 1970s following changes in the transportation policy environment. This is to say that in transportation policy the emphasis shifted from long-term infrastructure expansion strategies to shorter-term infrastructure management strategies such as alternate work schedules, telecommuting and congestion pricing. Understanding travellers' responses to such short-term transportation policies needed a more behavioural-oriented activity-based modelling approach which was lacking in the previously used trip-based models (Jones *et al*., 1990; Bhat and Koppelman, 1999a; McNally, 2000).

Seminal theoretical contributions have been made by Hägerstrand (1970), Chapin (1974) and Cullen and Godson (1975).

Hägerstrand (1970) advanced time-geography in which constraints on activity participation are highlighted within a spatiotemporal framework. Researchers should focus on the spatial aspects of the individual's activity pattern as well as the temporal aspects of it. Therefore, Hägerstrand (1970) introduced the concepts of space-time paths and space-time prism. The space-time path traces the spatiotemporal position of the individual's activity pattern and travel behaviour. The path is a three-dimensional representation where a two-dimensional horizontal plane embodies geographic locations and a vertical axis embodies time. Contrary to a vertical line, a sloped line of the path symbolizes movement over space. This path is, however, limited in space and in time. For example, due to difference in velocity different locations are within reach of the pedestrian compared to the motorist. Thus, only a particular set of locations in space and time is available. This set is known as the space-time prism and is determined by the location and duration of activities, an individual's time budget, and the travel velocities allowed by the transportation system. Whereas the path describes the observed movement throughout space and time of an individual, the prism indicates what portions of space are accessible for an individual at each moment in time (Lenntorp, 1976; Miller, 1991; Neutens *et al*., 2007a).

Such a space-time prism is easy to construct for one person. However, it becomes more difficult when the activity pattern of several persons must be analyzed. Hägerstrand and most studies in time geography, therefore, focus on constraints that influence time-space paths and prisms. These constraints are (i) capability constraints, (ii) coupling constraints, and (iii) authority constraints. Capability constraints refer to limitations because of physiological necessities such as sleeping, eating and personal care. Coupling constraints define where, when and for how long an individual can interact with other individuals. Authority constraints limit access to either space locations or time locations (e.g., business hours of a shop).

Whereas Hägerstrand (1970) explained the observed activity patterns within a spatiotemporal framework, Chapin (1974) described a motivational framework in which activity patterns result from the interaction between individual propensities and perceived opportunities to engage in activities. He argued that individuals perform activities to meet their basic needs, which determines the propensity to engage in activities. These engagement propensities are not autonomous; they can be facilitated as well as constrained. Facilitating factors refer to individuals' motivations and ways of thinking that predispose individuals to participate in activities, whereas constraining factors do the opposite. Examples of constraining factors are role and personal characteristics such as household responsibilities, gender and age. As a result, Chapin (1974) suggested that different socio-economic groups adopt different activity patterns. This fact clearly justifies the incorporation of a socio-economic component in empirical studies on travel behaviour. In addition to propensity factors, opportunities are important as well to understand activity patterns. Doing so, Chapin (1974) considers activity patterns not only as the result of a 'demand' phenomenon, but also of a 'supply' consideration. Opportunities refer to the availability of facilities and services, as well as the quality of those facilities and services. By taken opportunities into account, Chapin could assess the impact of the built environment on activity patterns. However, he never fully developed this line of thought. Due to data limitations, Chapin's empirical research primarily concentrated on the propensity factors (Ettema and Timmermans, 1997).

The theoretical frameworks of Hägerstrand (1970) and Chapin (1974) seem complementary: Hägerstrand focussed on spatial and temporal constraints, whereas Chapin emphasized the influence of opportunities and choices (Ettema and Timmermans, 1997). Cullen and Godson (1975) attempted to combine both frameworks. They characterized the spatial and temporal constraints identified by Hägerstrand by varying degrees of flexibility. Temporal constraints are less flexible than spatial constraints. Moreover, flexibility is closely related to activity type. For example, work-related activities are less flexible than leisure activities, and routine-like activities tend to be fixed in space and time. Whereas most other activity-based studies analyze the revealed activity patterns, Cullen and Godson (1975) also tried to explain the underlying activity scheduling process. Particular activities, such as working activities, act as "pegs" around which other activities are arranged according to their flexibility. They also suggested that activities can be planned consciously or more routine-like (Ettema and Timmermans, 1997; Bhat and Koppelman, 1999b; Lee and McNally, 2003).

Since the 1970s, considerable progress has been made in activity-based travel research (for a recent review, see, e.g., Algers *et al*., 2005; Buliung and Kanarogloy, 2007). One important development is the focus on intra-household and social interactions. The individual is the primary unit of analysis in most activity-based travel studies, but attention recently shifted toward the complex interactions between household members and how this influences activity and travel behaviour (e.g., Scott and Kanaroglou, 2002; Voysha *et al*., 2004; Gliebe and Koppelman, 2005; Srinivasan and Bhat, 2005; Schwanen, 2007, 2008a; Schwanen *et al*., 2007). Moreover, the individual also interacts with individuals outside the household, such as friends and colleagues. It is conceivable that the use of telecommunication technologies such as cell phones and the Internet alter joint activities with friends and colleagues and, thus, also influence travel behaviour. A growing research body exists on the performance of these joint activities (e.g., Neutens *et al*., 2007b, 2008; Páez and Scott, 2007; Srinivisan and Bhat, 2008). Another important development highlights day-to-day variability in activity and travel behaviour. Since data from long-duration travel diaries become available (e.g., 6-week travel diary Mobidrive in Germany), it is possible to analyze how activity and travel behaviour varies from day to day. Research indicates that travel behaviour is neither totally variable nor totally routine. Activity and travel behaviour of workers is relatively stable on weekdays, contrary to nonworkers' weekday activities and travel behaviour and to all individual's weekend activities and travel (Schlich and Axhausen, 2003; Susilo and Kitamura, 2005; Kitamura *et al*., 2006).

2.2.2 Medium-term location decisions and implications for travel behaviour

In the previous section travel behaviour is considered as the result of daily decisions on activity participation. However, medium-term decisions on locational behaviour such as more significant location choices such as residence and workplace also influence daily travel behaviour. Fried *et al*. (1977) and Cullen (1978) provided a theoretical justification for this.

In their synthesized theory on travel behaviour, Fried *et al*. (1977) related travel behaviour directly to activity behaviour. The distribution of activity opportunities is considered an important influence of activity and travel behaviour. Nevertheless, it is possible that the available activity opportunities do not match the individual's current activity needs. In this case, an adaptation process tries to reduce this imbalance. Adaptations range from short-term travel and activity adjustments to longer term changes such as residential or workplace relocation. Such longer term changes only occur if short-term adjustments do not sufficiently reduce the imbalance between activity opportunities and needs. Cullen (1978) stressed that longer term changes are not frequently made, but are well-reasoned and determine the context in which daily activity behaviour is performed. Consequently, longer term changes have a considerable influence on everyday activity and travel behaviour. Contrary to longer term behaviour, Cullen (1978) considered daily activity behaviour as routinely. Activity patterns can, thus, be studied by focussing on habits or recurrent routine activities. After all, daily activities are frequently made and, therefore, are not always consciously well-considered.

Since the 1970s, empirical research continued on the relationship between travel behaviour and these medium-term location decisions. Particularly, the influence of residential location choice attained attention. A number of studies (e.g., Levinson, 1997; Clark *et al*., 2003; Scheiner, 2006) point out that mode use, travel distances and activity behaviour all change after a residential relocation. At the same time, residential relocations can occur because of dissatisfying routines of mode use, as well as distances and locations of daily activities. The complex interdependencies of travel and residential location choices challenge the question whether the characteristics of the residential neighbourhood it selves influence travel behaviour. Several recent studies (e.g., Schwanen and Mokhtarian, 2005a, b; Bhat and Guo, 2007; Cao *et al*., 2007a, b; Pinjari *et al*., 2007; Chen *et al*., 2008; Mokhtarian and Cao, 2008) argue that attitudes and preferences toward travel, activities and residential neighbourhoods are the true determinants of travel patterns. This refers to the self-selection mechanism: individuals and households self-select themselves into a residential neighbourhood that is consistent with their attitudes and preferences. Consequently, location behaviour is not only influenced by locational preferences but also by activity and travel preferences. For example, a household with public transport preferences will likely choose a residential neighbourhood with good public transport services.

Most empirical studies do not simultaneously consider the residential and workplace location choice. One choice is assumed exogenous and influences the other choice dimension. A recent example of integrating both spatial choices is Waddell *et al*. (2007). By combining latent market segmentation with discrete choice models, they were able to model the interdependencies of residential and workplace location choices within the context of an integrated activity location and travel forecasting framework.

Previously mentioned studies are cross-sectional. During the last decades, more longitudinal data became available, which resulted in the emergence of a new research field in transportation research namely the analysis of 'mobility biographies'. This research field focuses on changes in travel behaviour over the individual's life course. Daily travel behaviour is assumed to be relatively stable, but it changes significantly in the context of key events in the life course, such as residential or workplace relocation. Mobility biographies are, thus, embedded in other biographies such as a residential biography, an employment biography and a household biography (Prillwitz *et al*., 2007; Scheiner, 2007; Beige and Axhausen, 2008; Frandberg, 2008).

2.2.3 Long-term lifestyle decisions and implications for travel behaviour

The longest term decision is the choice of a lifestyle. Short-term activity decisions and medium-term location decisions are made by the individual to satisfy his or her lifestyle decision. This way, lifestyle also influences daily travel behaviour. The concept of lifestyle refers to an individual's way of living and is influenced by his or her outlook of life and motivations, including beliefs, interests and general attitudes. The impact of lifestyle on travel behaviour has certainly increased. During the last decennia, prosperity increased, resulting in more available possibilities to choose from. Moreover, the social burden to behave uniformly disappeared because of increasing individualization and decreasing social control. These processes allow people to lead a personal lifestyle (Ferge, 1972; Bootsma *et al*., 1993). Consequently, taking lifestyles into account may result in interesting insights in travel behaviour.

Despite its frequent colloquial use, a distinct lifestyle theory is hard to find. Lifestyle is elaborated pragmatically, rather than theoretically. Especially marketing studies (e.g., Mitchell, 1983) use the concept of lifestyle in order to retrieve market sectors. These studies generally analyze numerous data by explorative statistics, such as cluster analysis. Each cluster is then referred to as another lifestyle. Because a sound theoretical basis is lacking and results are data-dependent, each study 'finds' new lifestyles. This pragmatic approach is criticized by Sobel (1983) among others. Nevertheless, some theoretical contributions to the lifestyle concept are made by Weber (1972), Bourdieu (1984) and Ganzeboom (1988).

Weber (1972) is one of the first sociologists that contributed to the debate on lifestyles. He criticized Marx' class theory, in which behaviour is determined by the economic position of the individual (i.e., the possession of means of production). Weber (1972) concluded that behaviour cannot be explained by social class exclusively. Therefore, he added the concept of status, which refers to a group of people that shares the same prestige and obtain a similar lifestyle. Lifestyle is considered as a pattern of observable and expressive behaviours. Consequently, people with the same status, and thus the same lifestyle, will tend to behave similarly.

Following Weber (1972), Bourdieu (1984) considered lifestyle as a pattern of behaviours indicating the social position of the individual. Each individual occupies a position in a two-dimensional social space which is defined by the amount and the composition of capital. The amount of capital ranges from no capital to much capital, the composition of capital ranges from economic capital to socio-cultural capital. Thus, capital not only refers to economic capital such as money and real estates, but to cultural capital (i.e., education, knowledge, skills) and social capital (i.e., relations, networks) as well. Within this two-dimensional space, traditionally used socio-economic variables define the 'space of social position', whereas specific patterns of behaviour define the 'space of lifestyles'. Based on this, two hierarchies can be distinguished. One category reaches from the traditional lower status groups to the economic elites. Another category reaches from the same lower status groups to the cultural elites. Thus, various lifestyles only appear among social groups with high capital levels. The economic elites pursue material welfare and obtain rather traditional aesthetic and moral beliefs. The cultural elites display their knowledge, for example on contemporary art.

Ganzeboom (1988) elaborates further on the work of Bourdieu (1984) in order to analyze lifestyles in the Netherlands. Ganzeboom (1988) assumes that people symbolize and clarify their social position through a pattern of behaviours. This behaviour is determined by lifestyle. However, lifestyle indirectly influences behaviour through preferences. Based on their lifestyle, people have preferences on how to present themselves socially. These preferences are balanced against available opportunities and constraints, which results in the actual behaviour. In order to obtain a more precise definition, Ganzeboom (1988) discusses the origins and function of lifestyles. Lifestyle is related to the individual's socio-economic characteristics. However, this relationship is influenced by intermediate variables which refer to opportunities and constraints offered by time budget, income, cognitive skills (i.e., knowledge, skills) and status considerations (i.e., the influence of the social context, the aim to obtain social appreciation). Time budget and income can be measured objectively, whereas cognitive skills and status considerations are rather subjective. These four intermediate variables are internal to the individual. An additional, but external, intermediate variable consists of institutions (i.e., rules, regulations). Lifestyles must not be considered as unambiguous types. Ganzeboom (1988) stresses the existence of a continuum between lifestyle types rather than the occurrence of unambiguous lifestyle types. This continuum is determined by three dimensions: (i) an economic dimension, (ii) a cultural dimension, and (iii) a stage in life-dimension. The first two dimensions are inspired by Bourdieu (1984). However, Ganzeboom (1988) considers economic and cultural capital as two separate dimensions instead of the extremes of one dimension. The third dimension originates from Bourdieu's 'space of social positions', which is based on traditionally used socio-economic variables. Ganzeboom (1988) distinguishes stable socio-economic background variables (e.g., gender) from changeable characteristics of stage in life (e.g., household composition, profession). He argues that some socio-economic variables have a dynamic nature and must, therefore, be treated differently. What resembles to be a free choice on a particular moment may restrict long-term choices. For example, educational choice may restrict further professional choices. As a result, an additional dimension, referring to stage in life, is added. This dimension operates in another way than the economic and cultural dimensions. No arguments can be put forward to consider one particular stage in life more important than another. In other words, no hierarchy can be found based on stage of life. Nevertheless, stage in life influences behaviour and preferences.

Weber (1972), Bourdieu (1984) and Ganzeboom (1988) agree on the communicative character of lifestyle: the individual elucidate his or her social position through specific patterns of behaviour. However, lifestyle includes more than observable patterns of behaviour. According to Ganzeboom (1988), lifestyle also refers to opinions and motivations, including beliefs, interests and attitudes. This may confound our understanding of the lifestyle concept. For that reason, Munters (1992) distinguished lifestyles from lifestyle expressions. He considered lifestyles as the individual's opinions and motivations, or orientations. Salomon and Ben-Akiva (1983) distinguished three fields of orientations: (i) family orientation, (ii) work orientation, and (iii) leisure orientation, whereas Bootsma *et al*. (1993) discerned five similar orientation fields: (i) household/family orientation, (ii) work orientation, (iii) housing orientation, (iv) consumption orientation, and (v) leisure orientation. Consequently, lifestyles are internal to the individual and, thus, are unobservable. A lifestyle, then, manifests itself in observable patterns of behaviour, or lifestyle expressions. In this way, observable patterns of behaviour (= lifestyle expressions) are explained by underlying opinions and orientations (= lifestyles). Location behaviour, activity behaviour and travel behaviour are some behavioural patterns in which lifestyles are expressed. For example, a family-oriented lifestyle manifest itself through living in a child-friendly residential neighbourhood, participating in family activities such as picking up the children from school and travelling by car rather than by public transport.

From the above, it should be clear how to measure lifestyles. Briefly summarized, lifestyle refers to the individual's opinions and orientations toward general themes such as family orientation, work orientation and leisure orientation. Some empirical studies (e.g., Salomon and Ben-Akiva, 1983; Cooper *et al*., 2001; Hildebrand, 2003) analyze what they would call lifestyles, but in fact they combine various objective socio-economic and demographic characteristics of the individual and the household. Consequently, these studies refer to stage of life cycle or household composition rather than to lifestyles. Although a lifestyle is partly influenced by stage of life cycle or household composition, lifestyle has a different meaning. Socio-economic and demographic variables are, therefore, separated from lifestyles by including them as opportunities and constraints at the individual and social level of our conceptual model (see Figure 2.1).

Recently, several empirical studies try to include the individual's lifestyle within travel behaviour research. Most studies (e.g., Kitamura *et al*., 1997; Redmond, 2000; Bagley and Mokhtarian, 2002; Lanzendorf, 2002; Collantes and Mokhtarian, 2007) confirm that the lifestyle concept adds explanatory power to travel analyses. Scheiner and Holz-Rau (2007) and Scheiner (2006) refined these conclusions. They remarked that lifestyles do influence activity and travel behaviour. Nevertheless, the influence of objective socio-economic and demographic characteristics exceeds the influence of subjective lifestyles.

2.3 Why homogeneous groups behave differently

The previously described decision hierarchy might come across as 'physicalist', as considering only the observable locational, activity and travel behaviours and not the underlying individual's motivations and intentions. Although some general motivations and intentions are included in the decision hierarchy by the lifestyle concept, research indicates that individuals of socio-economic homogenous groups may still behave differently. This might be due to individual perceptions, attitudes and preferences toward location, activity and travel behaviour (van Wee, 2002; Mokhtarian and Cao, 2008). Perceptions refer to the way various aspects of the built environment, activities and travel are considered by an individual, whereas attitudes include an evaluation of these characteristics. Preferences are then formulated based on these attitudes and perceptions. This includes a ranking of different spatial, activity and travel opportunities (Allaman and Tardiff, 1982; Golledge and Stimson, 1997). These specific subjective characteristics are different from the general one's that define lifestyle. Most empirical activity-based travel studies do not incorporate these factors. Some researchers argue that perceptions, attitudes and preferences are difficult to measure and, therefore, cannot be taken into account (e.g., Borgers *et al*., 1997; Golledge and Stimson, 1997; Gärling *et al*., 1998), whereas other researchers state the opposite (e.g., Camstra, 1996; Kitamura *et al.*, 1997; Bagley and Mokhtarian, 2002; Lanzendorf, 2002; Parkany *et al*., 2004; Collantes and Mokhtarian, 2007).

Insights from theories in social psychology can help us to operationalize perceptions, attitudes and preferences. After all, social psychology focuses on how people think, feel and behave toward other people, and how these thoughts, feelings and behaviours may be influenced by other people (Brehn *et al*., 2005). For this reason, combining insights from social psychology and previously described concepts from transport geography seems auspicious. Moreover, certain theories in social psychology argue that behaviour is not always well-reasoned through perceptions, attitudes and preferences. Behaviour has, thus, a reasoned component as well as an unreasoned component. These two components underlie the decision hierarchy in our conceptual model of travel behaviour (see Figure 2.1).

2.3.1 Reasoned behaviour

The study of attitudes is a core topic in social psychology. Several definitions exists, but an attitude generally refers to a positive, negative or mixed evaluative response to some stimuli (issues, objects or persons) which influences the individual's behaviour (Gärling *et al*., 1998; Brehn *et al*., 2005). Triandis (1971) stresses three aspects of attitudes consist: (i) a cognitive aspect involving perceptions and knowledge of the stimuli, (ii) an affective aspect involving feelings, emotions and values, and (iii) a behavioural aspect involving acting in response to the two other aspects. As such attitudes bring together someone's internal mental life and behavioural responses within one framework (Gold, 1980). Attitudes have always been an important research subject in social psychology. Since the late 1920's, researchers have tried to measure attitudes (e.g., Thurnstone, 1928), which resulted in more than five hundred published measurement methods (Fishbein and Ajzen, 1972). Nevertheless, research indicates that the relationship between attitudes and behaviour is not perfect at all (e.g., LaPierre, 1934; Ajzen and Fishbein, 1977). Attitudes are not the only decisive factors of behaviour and, therefore, attitudes and behaviour must be treated within a broader context. This basic assumption is elaborated by Fishbein and Ajzen (1975) and Fishbein (1980) in the Theory of Reasoned Action. Ajzen (1991) has specified this theory into the Theory of Planned Behaviour.

In the Theory of Reasoned Action (TRA) behaviour is considered as the result of rational choices. People are considered as rational human beings. By categorizing, transforming and interpreting information on a stimulus (issue, object or person), an individual forms a perception about this stimulus (Golledge and Stimson, 1997). In the TRA this perception is called a belief. Several beliefs (or perceptions) are associated with one specific stimulus, because several attributes of this stimulus are evaluated. The sum of all related beliefs determines the attitude toward that stimulus. For example, an individual may perceive cycling as healthy, environment-friendly, etc. Because of these beliefs, the individual adopts a positive attitude toward cycling. However, this does not automatically results in a travel pattern characterized by more cycling trips. Attitudes do not directly influence behaviour. According to the TRA, intentions intervene in the relationship between attitudes and behaviour. The attitude toward a stimulus is considered as related to various intentions to behave with respect to that stimulus. For example, the individual's positive attitude toward cycling results in a set of intentions which, in their totality, are positive as well. This person may intend to commute by bicycle, to spend a cycling holiday, etc. Or in other words, that person will prefer the bicycle above all other travel modes. We argue that the concept of intentions is thus closely related to preferences. This is inspired by Golledge and Stimson (1997) who consider preference as an activity that expresses or identifies how an individual desires or intends to behave.

Intentions are influenced by attitudes as well as by other factors. The TRA also considers the subjective norm as a factor influencing the intention to behave in a particular way. The subjective norm is the sum of normative beliefs which refer to the perceived social pressure to perform or not perform a particular behaviour. The TRA is only suitable for behaviours which are under a person's volitional control. However, the theory is inappropriate to explain and predict uncontrollable behaviour. In order to overcome this problem, Ajzen (1991) developed the Theory of Planned Behaviour. This theory considers a third determinant of intention, namely perceived behavioural control which refers to the perceived ability to perform a behaviour. For example, despite a positive attitude toward cycling, an individual considers himself or herself physically unable to commute by bicycle. Therefore, this individual might intend to commute by car. Perceived behavioural control directly influences behaviour as well. For example, someone commutes by car because he or she thinks that no public transport services are available on the route toward work. However, perceived behavioural control might be inaccurate. Consequently, the theory distinguishes perceived behavioural control and actual behavioural control.

The foregoing explains how specific characteristics such as perceptions, attitudes and preferences are related to behaviour. Those characteristics account for consistent patterns of behaviour and, therefore, can be considered as a part of someone's personality (Pervin and John, 1997). For example, Baron and Byrne (1991) consider personality as "the combination of relatively enduring attitudes that are expressed consistently and predictably in various situations" (Redmond, 2000, p. 11). However, personality research does not focus on how characteristics such as attitudes are constructed, but rather on how individuals differ in those characteristics and how this influences their behaviours. Consequently, it provides limited insights in someone's behavioural reasoning and decision-making and for this reason the notion of personality is not mentioned in Figure 2.1.

2.3.2 Unreasoned behaviour

Nevertheless, the Theory of Reasoned Action and the Theory of Planned Behaviour remain subject to criticism. Both theories assume that behaviour results from rational decisions, but individuals are not constantly conscious of their behaviour (Pred, 1967; Simon, 1950). Triandis (1980, p. 204) mentions the influence of habits which he defined as "situation-specific sequences that are or have become automatic, so that they occur without self-instruction". Moreover, he suggested a trade-off between attitudes and habits in the prediction of behaviour (Triandis, 1977). If habits are strong, the attitude-behaviour relationship is weak, and vice versa. Empirical studies such as Bamberg *et al*. (2003) and Verplanken *et al*. (1994, 1998) confirmed this trade-off between habits and attitudes also exists in travel behaviour.

Ronis *et al*. (1989) formulated the Theory of Repeated Behaviour (TRB). Initial behaviour remains the result of relevant attitudes and beliefs. But once the behaviour is repeated, it becomes a habit and decision-making is no longer based on attitudes and other well-reasoned influences. Repeated behaviour is, therefore, assumed to be mainly influenced by habits rather than by attitudes. Thus, three main categories of variables directly influence behaviour: (i) unreasoned influences, (ii) resources or enabling variables, and (iii) reasoned influences. One could also consider the correspondence between the TRB and the concept of transaction costs in economics (Menard, 1997). For example, although car-users might be motivated to switch to other travel modes, habits prevent them from doing so. Switching to other travel modes necessitate learning new routines. In order to do so, someone has to search and process information about the alternative travel modes. The costs associated with this may exceed the additional benefit of a better decision so that behaviour is more a matter of habits or routines. Consequently, it is logical that behavioural decisions are not always well-reasoned (Gärling and Axhausen, 2003).

Recent advances in activity-based research account for unreasoned behaviour by studying activity scheduling and rescheduling processes (e.g., Doherty and Miller, 2000; Joh *et al*., 2004, 2005; Doherty, 2005; Lee and McNally, 2006; Zhou and Golledge, 2007). Activities are planned over varying time horizons. Activities such as working or shopping are weekly or daily recurrent activities. Planning such activities into a daily activity schedule is, thus, more a matter of routines or habits than of well-reasoned behaviour. These repeated activities (or habits) establish an initial skeleton schedule, in which well-reasoned decisions related to pre-planned activities as well as impulsive decisions related to events-of-the-day activities are fit in. As a result, activity schedules consist of a reasoned and an unreasoned component.

2.4 Interdependencies, opportunities and constraints

Previous sections describe travel behaviour from the perspective of the individual. Despite recent advances, external factors such as the social environment and the spatial environment are generally ignored in studies on travel attitudes and habits. Nevertheless, accounting for the influence of the social environment and the spatial environment would help us clarifying the complex nature of travel behaviour. After all, the individual does not act within a 'vacuous space'. The individual is a member of a social network of family, friends and colleagues, lives within in a particular neighbourhood and travels to a specific destination. Consequently, the individual decision hierarchy and its underlying components must be considered within a social environment and a spatial environment (see Figure 2.1). A theoretical explanation of the influence of the social environment can be found in social cognitive theory. Ecological and environmental psychology provides a theoretical framework for the influence of the spatial environment.

2.4.1 Interdependencies due to the social environment

Social cognitive theory (Bandura, 1986) considers reciprocal relationships between behaviour, personal characteristics, and the environment. Within the social cognitive theory, the environment mainly refers to the individual's social environment of which the household is the most important one. These three factors all operate as interacting determinants of each other. The reciprocal relationships are not perfect symmetrical: relationships may differ in strength and may occur on different points in time. Because of this aspect, it is possible to decompose the triadic reciprocity. Thus, studies are able to focus on some (segments of) bidirectional relationships without having to consider the whole model.

The social dimension of travel has been ignored for a long time (Axhausen, 2005). Only recently, some activity-based travel studies analyze the link between the individual's travel behaviour and their social network (e.g, Miller and Roorda, 2003; Dugundji and Walker, 2005; Carrasco and Miller, 2006; Paéz and Scott, 2007; Arentze and Timmermans, 2008; Dugundji and Gulyás, 2008; Schwanen, 2008b). These studies assume that travel behaviour cannot be understood solely by individual characteristics such as age, gender or income. One must also consider social network characteristics emerging from the interaction among social network members such as network composition and physical distance between network members. The results indicate that measures of the individuals' social networks can provide insights about travel behaviour.

Previously described studies generally focus on the objectively quantifiable characteristics of the social network, which corresponds with the notion of 'environment' in social cognitive theory. However, this theory also stresses the influence of the 'situation' which refers to the person's perception of the objective environment. For example, empirical travel studies indicate that the presence of young children in the household influences the parents' travel behaviour. This relationship can be measured by an objective variable such as 'the number of children aged below 6 years' or by a subjective variable referring to the parents' attitude toward having and raising children.

2.4.2 Interdependencies due to the spatial context

Whereas social cognitive theory focuses on the social environment, ecological psychology and environmental psychology stress the influence of the spatial environment. However, ecological psychology and environmental psychology have another scope. Ecological psychology studies collective processes by which groups adapt themselves to spatial and social characteristics of the environment, whereas environmental psychology analyzes the micro level, namely intrapersonal processes such as perception, cognition and learning behaviour, which influence the relationship between environment and behaviour (Stokols, 1977). Since individual decisions (and not group processes) are at the centre stage of our conceptual model, mainly insights from environmental psychology (and not ecological psychology so much) may contribute to our discussion.

Environmental psychology questions the role of basic psychological intrapersonal processes, such as perception and cognition, in mediating the relationship between human behaviour and the environment. Intrapersonal processes such as perception indicate that behaviour is not only influenced by objective characteristics of the environment, but by the subjective evaluation of these characteristics as well (Stokols, 1977). For example, in his famous work *The Image of the City*, Lynch (1960) described how individuals perceive the spatial environment in terms of paths, edges, districts, nodes and landmarks. This also relates to the issue of spatial cognition which can be defined as "the knowledge and internal or cognitive representation of the structure, entities and relations of space; in other words, the internalized reflection and reconstruction of space and thought" (Hart and Moore, 1973, p. 248). By the mid 1960s geographers adopted the idea of spatial cognition and they represented how spatial information is perceived in some map like form, so-called mental maps (Golledge and Stimson, 1997). An individual selects, organizes and puts a meaning to a limited number of features in the environment. These features are the focal points around which the individual constructs his or her mental map of the environment (Golledge and Zannaras, 1973). Research indicates that those internal models of the environment or mental maps influence our daily travel behaviour (e.g., Arentze and Timmermans, 2005; Mondschein *et al*., 2006; Dziekan, 2008; Chorus and Timmermans, 2009). As such, the spatial environment in our conceptual model resembles objective as well as subjective characteristics of the wider environment in which daily travel behaviour occurs. This environment does not necessarily coincide with locational decisions discussed earlier.

Although ecological psychology and environmental psychology have different scopes, they converged toward each other. Behaviour is, thus, considered as the result of internal and subjective (personal) and external and objective (situational) characteristics. This was already noted by Lewin (1936) who stated:

$$B = f\left(IP, ED\right) \qquad [2.1]$$

where B = behaviour; IP = subjective intrapersonal processes (physiological and psychological); and ED = objective environmental dimensions (physical, social and cultural).

Consequently, current environmental-behavioural research examines various categories of antecedents of behaviour. Moreover, environmental-behavioural research must deal with multiple levels of analysis, ranging from micro, intermediate to macro levels. The micro level refers to the individual and intrapersonal processes which affect the influence of the direct environment on the individual behaviour. The intermediate level refers to the social environment and interpersonal processes, i.e. individual and small-group behaviours, in a specific behaviour setting and institutional environment. Finally, the macro level refers to the community level of influence in the context of large-scale environmental units such as neighbourhoods and cities (Stokols, 1977; Handy, 2005). These interdependencies are symbolized by a multilevel structure in our conceptual model (see Figure 2.1). More specifically, the individual level is embedded in a social level and a spatial level.

2.4.3 Individual, social and spatial opportunities and constraints

The central box in our conceptual model refers to how the individual's reasoning determines travel behaviour. Habits as well as subjective characteristics, such as perceptions and attitudes, are important factors. Nevertheless, because of a lack of appropriate data most empirical studies on travel behaviour include objective characteristics instead of subjective factors. After all, objective characteristics of the individual, the social environment and the spatial environment might facilitate or constrain travel behaviour (for a review, see Ewing and Cervero, 2001; van Wee, 2002). For example, car use will be higher for individuals with a driving license, for households owning several cars and in suburban neighbourhoods. Therefore, the central box is also influenced by objective characteristics at each level of the conceptual model (see Figure 2.1).

2.5 Discussion: conceptual and modelling implications

Key-variables in research on the link between the built environment and travel behaviour generally refer to three components: (i) a spatial component, (ii) a socio-economic component, and (iii) a personality component. Theories in transport geography justify the incorporation of a spatial component (and even a spatiotemporal component) and a socio-economic component, whereas theories in social psychology validate the incorporation of a personality component. Our conceptual model of travel behaviour explicitly combines the three components. Various concepts and findings from the reviewed theories are included within our conceptual model of travel behaviour which is visualized in Figure 2.1.

Firstly, we consider travel behaviour as derived from short-term activity decisions, medium-term location decisions and long-term lifestyle decisions. This decision hierarchy is inspired by principles of the activity-based approach and lifestyle theory. By considering the derived nature of travel behaviour, behavioural insights in travel patterns are obtained which were previously lacking in the frequently used trip-based models.

Secondly, behavioural decisions are regarded as the result of an assessment between reasoned and unreasoned influences. Following the Theory of Repeated Behaviour (Ronis *et al.*, 1989) initial behaviour depends more on reasoned influences, whereas unreasoned influences will determine repeated behaviour to a greater extent. In fact, studies such as Bamberg *et al*. (2003) and Verplanken *et al*. (1994, 1998) confirmed a trade-off between travel attitudes and travel habits. Although we are aware of a link between reasoned and unreasoned influences, it is not represented in Figure 2.1. This is only because the conceptual model focuses on explaining individual daily travel behaviour, and not on the trade-off between reasoned and unreasoned influences. We also argue that these reasoned and unreasoned influences on their turn are affected by the individual's lifestyle. This is partly based on Ganzeboom (1988) who presumed that lifestyles influence preferences. We also consider the link between lifestyles and unreasoned influences. After all, it is possible that certain lifestyles are associated with more unreasoned behaviour than other lifestyles. For example, an adventurous lifestyle permits less well-reasoned behaviour and more unreasoned behaviour than a family-oriented lifestyle.

The conceptual model as described above focuses on travel behaviour of the individual. However, the individual belongs to a social network of family, friends and colleagues and lives within a particular neighbourhood which can affect the individual's behaviour. So finally, the model as a whole should be placed within (i) an individual level, (ii) the social environment, and (iii) the spatial environment. Empirical studies generally use objective variables that refer to characteristics of each level or environment. For example, the spatial environment is defined in terms of density, diversity and design. These objective variables are however perceived and evaluated by individuals with specific lifestyles so that studies such as Schwanen and Mokhtarian (2005a), van Wee *et al*. (2002) and Koppelman and Pas (1980) also used more subjective variables. Nevertheless, almost none of these studies questions whether perceptions correspond to the objective reality. For example, a neighbourhood is objectively evaluated as pedestrian friendly (e.g., low motorized traffic levels, availability of sidewalks), but an individual with a specific lifestyle might still consider this neighbourhood as unsafe (Handy, 1996). Therefore, it would be interesting to assess objective variables with more subjective variables.

The dotted arrows in Figure 2.1 refer to feedback mechanisms: individuals can learn from previous experiences. Consequently, lifestyles, habits, perceptions, attitudes and preferences are not fixed in time.

Putting the conceptual model into practice involves collecting appropriate data and using a suitable modelling technique. Depending on the research focus, different modelling approaches can be undertaken. Our conceptual model includes numerous relationships, resulting in direct and indirect effects on travel behaviour. This kind of interdependency can be analyzed using *structural equation models* (SEM) (e.g., Bagley and Mokhtarian, 2002; Simma and

Axhausen, 2003; Van Acker *et al*., 2007). A second kind of interdependencies results from a nested data structure: individuals are nested within households, and households within neighbourhoods. This nested data structure is best analyzed using a *multilevel analysis*. Multilevel analysis can be combined with a SEM so that both kinds of interdependencies are accounted for and the complexity of travel behaviour is better understood (e.g., Chung *et al*., 2004; Kim *et al*., 2004).

A (multilevel) SEM is represented by a series of simultaneously estimated equations. This implies that all components of the conceptual model in Figure 2.1 are concurrently and continually considered. However, we also argued that components such as attitudes evolve over time and that decisions on various time scales influence each other. In order to study the dynamics between several components of the conceptual model, a *sequential approach* such as event history analysis seems more appropriate (e.g., Verhoeven *et al*., 2005; Scheiner, 2006; Beige and Axhausen, 2008). This approach needs a longitudinal perspective, for example by conducting a panel survey or a retrospective survey.

We expect that an analysis of the relationships outlined in our conceptual model by one of the suggested approaches will enrich the research debate on travel behaviour with constructive insights.

2.6 Conclusion

For several decades researchers try to measure the influence of the built environment on travel behaviour. Empirical studies use three kinds of variables referring to a spatial component (e.g., density, diversity, and design), a socio-economic component (e.g., age, gender, education, income) and a personality component (e.g., lifestyle, attitudes). However, these studies lack a theoretical justification of why travel behaviour should be influenced by these three components after all. Such theoretical justification can, however, be found when theories from transport geography are combined with theories in social psychology and lifestyle theory.

Theories in transport geography justify the influence of factors external to the individual on travel behaviour. In other words, it describes the context in which travel behaviour is performed. More specifically, time geography stresses a spatiotemporal component of travel and the activity-based approach considers travel behaviour as derived from activity patterns.

The influence of factors internal to the individual is validated by theories in social psychology. These theories describe the influence of internal processes including reasoned influences such as perceptions, attitudes and preferences, and unreasoned influences such as habits.

In our conceptual model, we combine both theoretical fields: daily travel behaviour is embedded in a decision hierarchy and these behavioural decisions are the result of an assessment of reasoned and unreasoned influences. Moreover, individual decision-making and behaviour should be considered within a social environment and spatial environment. Those environments include processes and characteristics external to the individual that can influence individual behaviour.

Putting the conceptual model into practice involves collecting appropriate data and using a suitable modelling technique. Depending on the type of research data (cross-sectional versus longitudinal data) and the research focus (e.g., disentangling the complexity between various components of the conceptual model versus analyzing the evolution over time of these components), (multilevel) SEM and event history analysis seem to be appropriate and interesting modelling techniques. Empirical studies that combine the relationships of our conceptual model could make a major contribution to the research debate on travel behaviour.

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"Laat ons de dingen vergeten en
slechts letten op het verband ertussen."

Georges Braque (1882-1963)

3. THE EFFECTS OF THE LAND USE SYSTEM ON TRAVEL BEHAVIOUR
A STRUCTURAL EQUATION MODELLING APPROACH

Van Acker, V., Witlox, F., van Wee, B. (2007) The effects of the land use system on travel behavior: A structural equation modeling approach. Transportation Planning and Technology, 30, pp. 331-353.

Abstract Notwithstanding the extensive research that exists on the strength of the relationship between land use and travel behaviour, a consensus has not yet been reached. One possible explanation may be the existence of a wide range of influencing variables. Previous research assumed that the explanatory variables were not influencing each other, thus ignoring the indirect effects on travel behavior. Clearly, handling a wide range of explanatory variables and multiple directions of influence requires more sophisticated research techniques. Structural equation modelling (SEM) seems to be useful here. Although SEM is a research technique dating from the 1970s, applications involving travel behaviour from the perspective of land use remain scarce. Furthermore, evidence is mainly based on US data. Therefore, this paper adds some new evidence from a European perspective to the research debate. Our preliminary analysis indicates that socio-economic characteristics influence travel behaviour to a greater extent than land use. Furthermore, indirect effects remain important to understand the complexity of travel behaviour.

3.1 Introduction

The impact of land use on travel behaviour has been the subject of many studies. It is unsurprising that living in a high-density and mixed-use neighborhood is associated with fewer motorized vehicle trips, smaller travel distances, and shorter travel times. Knowledge of the travel consequences of land use has certainly increased, but to date, there is no consensus on the strength of this relationship. Confounding results are obtained because of different research designs, as well as a variety of geographical contexts in which studies are performed.

Furthermore, several studies try to answer the question: what influences travel behaviour the most — spatial characteristics of the residential environment or socio-economic and demographic differences among respondents? Some studies (e.g., Newman and Kenworthy, 1989, 1999; Ewing *et al.*, 1994; Frank and Pivo, 1994; Cervero and Kockelman, 1997; Meurs and Haaijer, 2001) indicated that various aspects of land use are linked with travel behaviour, while others (e.g., Boarnet and Sarmiento, 1996; Kitamura *et al.*, 1997; Bagley and Mokhtarian, 2002; Schwanen, 2002) found that socio—economic differences among respondents are of greater interest than spatial differences.

The purpose of this paper is to obtain a better insight into the relative influence of spatial variables, and socio-economic and demographic variables on travel behaviour. Therefore, we constructed a structural equation model (SEM). Although SEM has been applied in travel behaviour research since the 1980s (for a review, see Golob, 2003), applications from a land use perspective remain scarce, and are limited to a North-American context.

The remainder of this paper is structured as follows. First, a brief literature review is presented. Emphasis is placed on the discussion of what types of explanatory variables are used and the geographical context of the studies. Then, the methodological framework of SEM is outlined. The analysis illustrates the use of this technique and tries to measure the relative influence of land use, and socio-economic and demographic characteristics. Finally, conclusions and opportunities for further research are described.

3.2 Literature review

A brief literature review is presented of the land use effects on travel behaviour; however, the impact of transport on land use (location decisions of firms and households) is not considered. Three topics are considered: type of explanatory variables, the methodological framework, and the geographical context. We are aware that other topics may be of interest (e.g. sample size and the geographical scale at which land use characteristics are collected — ranging from the metropolitan area to the small-scaled neighborhood). However, the three topics mentioned previously are of greater importance in explaining why no consensus has been reached on the relative influence of land use, and socio-economic and demographic characteristics. (For a more comprehensive review, see Badoe and Miller, 2000; Crane, 2000; Ewing and Cervero, 2001 for the US; Stead and Marshall, 2002 and van Wee, 2002 for Europe).

3.2.1 Explanatory variables

In spite of the extended body of literature on the impact of land use on travel behaviour, a three-fold distinction with respect to variables that influence travel behaviour can be found (Naess, 2003; Van Acker and Witlox, 2005a, b). These dimensions are based on the type of variables included: (i) the spatial dimension, (ii) the socio-economic dimension, and (iii) the personality dimension.

Initially, only land use variables were taken into account (see *3.2.1.1 Spatial dimension*), but nowadays socio-economic and demographic variables are also incorporated (see *3.2.1.2 Socio-economic dimension*). Still, within 'homogeneous groups' (i.e. respondents that are considered more or less identical — van Wee, 2002) there may be attitudes, lifestyles, perceptions and preferences which also have an impact on land use and/or travel behaviour (see *3.2.1.3 Personality dimension*).

3.2.1.1 Spatial dimension

The activity system approach offers a framework within which daily activity and travel can be analyzed. Living, working, shopping, and recreation are spatially separated activities, inducing the need to travel. Consequently, travel demand does not derive its utility from the trip itself, but rather from the need to reach locations where activities take place. For that reason, the configuration of activities — i.e. the land use pattern, characterized by density, diversity, and design among others — is likely to influence travel behaviour (for an explanation on how land use influences travel behaviour, see Handy, 1992; Cervero and Seskin, 1995). Theoretical justification lies, therefore, in traditional utility-based theories of urban travel demand.

The effects of density on travel demand have long been acknowledged (e.g. Levinson and Wynn, 1963) and remain well-studied. Higher densities are believed to result in less car use, more public transport usage, and more walking and cycling (Frank and Pivo, 1994; Cervero and Kockelman, 1997; Kitamura *et al.*, 1997; Rajamani *et al.*, 2003; Dargay and Hanly, 2004; Schwanen *et al.*, 2004). In high-density areas, public transport can be organized more efficiently, and public transport systems consist of more routes and a higher frequency of services. Car users, on the other hand, face more congestion. Due to lower car use, transportation-related energy consumption per capita is lower in high density areas (Newman and Kenworthy, 1989, 1999). Furthermore, travel distance is negatively associated with density (Stead, 2001; Schwanen, 2002; Schwanen *et al.*, 2004). Thus far, research on the effects of density on travel time has obtained ambiguous results. Ewing *et al.*(1994) and Schwanen (2002) argued that higher densities result in shorter travel times. However, when density is defined more specifically, e.g. employment density by employment sector, different results may be obtained. Frank and Pivo (1994) found that increasing industrial employment densities result in shorter travel times, whereas increasing commercial employment densities and residential densities result in the opposite. This indicates that congestion levels exist around residential and office zones, whereas clustering of manufacturers may permit commuting benefits.

Several measures have been developed to estimate diversity and its influence on travel behaviour — among others, a jobs/housing ratio (Ewing *et al.*, 1994; Boarnet and Sarmiento, 1996), an entropy index to quantify the degree of balance across various land use types (Frank and Pivo, 1994; Kockelman, 1997; Rajamani *et al.*, 2003), or a dissimilarity index to indicate the degree to which different land uses lie within one another's surrounding (Kockelman, 1997). The effects of more diversity on travel behaviour are comparable to the effects of higher densities. More diversity is associated with less car use, more public transport usage, and more walking and cycling (Frank and Pivo, 1994; Cervero and Kockelman, 1997; Kockelman, 1997; Rajamani *et al.*, 2003). Furthermore, travel distance (Kockelman, 1997) and travel times (Ewing *et al.*, 1994) are negatively associated with diversity. Moreover, high-diversity neighborhoods are associated with less trip chaining (Ewing *et al.*, 1994).

Design can be characterized by a general classification of neighborhoods with a standard suburban neighborhood and a neo-traditional neighborhood as extremes (Friedman *et al.*, 1994; McNally and Kulkarni, 1997; Gorham, 2002). Standard suburban neighborhoods are characterized by low densities, limited diversity, and a car-orientated design. As a consequence, these neighborhoods are associated with higher total household trip rates and higher car rates. However, design can also be characterized more specifically by site design, and dwelling and street characteristics. Research results indicate that a pedestrian-orientated design is characterized by, among others, small block sizes, a complete sidewalk system (Hess *et al.*, 1999), the absence of cul-de-sacs (Rajamani *et al.*, 2003), and limited residential parking (Stead, 2001). These characteristics discourage car use and encourage slow modes, such as walking and cycling (Cervero and Kockelman, 1997). However, travel distances remain short (Stead, 2001). Meurs and Haaijer (2001) remarked that, although characteristics of the dwelling, street, and neighborhood, may influence modal choice, this is only true for shopping and social or recreational purposes. Working trips can be less influenced by design characteristics.

Other spatial characteristics influencing travel behaviour include, among others, urban size, polycentrism, and accessibility.

- Spatially large cities are associated with more public transport usage and less walking and cycling. This indicates that environmentally friendly transport modes are competing more with each other than with the private car within large metropolitan areas (Schwanen, 2002). Furthermore, longer commuting distances (Schwanen, 2002), and longer commuting times (Gordon *et al.*, 1998; Schwanen, 2002) may be expected.
- Polycentric and dispersed metropolitan areas are found to facilitate commuting trips (Gordon *et al.*, 1989), resulting in longer commuting distances and times by car (Schwanen *et al.*, 2004).
- Poor accessibility is compensated by linking trips in multipurpose tours (Ewing *et al.*, 1994). Residents with higher accessibility by a given mode are found to travel more by this mode, especially for non-work trips (Rajamani *et al.*, 2003). Higher accessibility results in reduced travel distances and reduced numbers of trips per tour, but in an increased average number of tours (Krizek, 2003).

3.2.1.2 Socio-economic dimension

As mentioned previously, daily travel is derived from the activities in which one wants to participate. One of the basic elements of this activity system is the group whose spatial-temporal activities are being considered, defined as the 'actors'. Chapin (1974) suggested three sets of actors: (i) firms, (ii) institutions, and (iii) individuals. The focus here is on individuals and their characteristics. Age, gender, household size, income, level of education, employment status, and mobility constraints are commonly used variables. These socio-economic and demographic variables are sometimes combined to define, e.g. household type.

Evidence on the effect of age on travel behaviour suggest that car ownership is lower among young (aged below 35 years) and older people (aged above 65 years) (Dargay and Hanly, 2004). Consequently, car use is lower among older people, whereas they walk more often and public transport usage is greater (Dargay and Hanly, 2004; Schwanen *et al.*, 2004). Moreover, if older persons travel by car, they travel shorter distances (Boarnet and Sarmiento, 1996; Stead, 2001; Schwanen *et al.*, 2004). Older people not only travel because they want to participate in activities. Travel itself may have socializing opportunities. Ride-sharing for non-work trips has, therefore, been found to be highest among older people (Rajamani *et al.*, 2003).

Although there are exceptions (e.g., Kockelman, 1997), car use is generally found to be lower among women then men. On the other hand, women travel more often by public transport, by bicycle or on foot (Simma and Axhausen, 2000; Schwanen *et al.*, 2002, 2004). As women are more reliant on slow modes, they cannot travel such long distances as their male counterparts (Stead, 2001). This difference may be explained by, among others, their lower wages and the fact that women obtain different types of jobs to men (Madden, 1981; Hanson and Pratt, 1995). However, because women remain responsible for most household maintenance tasks, car use by women may be higher for non-work trips. Consequently, longer distances for non-work trips by car can be found (Boarnet and Sarmiento, 1996). Schwanen *et al.* (2002) found that the effect of gender depends on household type. Gender differences were found to be largest in two-worker families. Women in two-worker families are more likely to commute by car than men. As these women combine working with household maintenance tasks, they face high levels of time pressure. Consequently, commuting by car is more efficient and flexible (e.g. children can be brought to school on the way to work, shopping activities can be combined within a home- work trip, etc.).

Household size is positively associated with car ownership (Dargay and Hanly, 2004). Because of intra-household decisions related to the activities of several household members, it may be appropriate to own more cars. Consequently, car use is higher, and use of public transport and walking are lower within large households (Rajamani *et al.*, 2003; Dargay and Hanly, 2004). As these households are more car dependent, they can travel longer distances as well (Kockelman, 1997; Simma and Axhausen, 2000). Comparable results have been obtained with respect to the number of employed persons in the household (Cervero and Kockelman, 1997; Simma and Axhausen, 2000; Krizek, 2003).

The effect of the presence of children on travel behaviour is comparable to the effect of employed persons. Car ownership is higher among households with children. As noted previously, households that own a car will use it more often. Consequently, car use is lower and use of public transport is higher among singles and couples (Boarnet and Sarmiento, 1996; Dieleman *et al.*, 2002; Schwanen *et al.*, 2002; Dargay and Hanly, 2004). As singles and couples do not have child care responsibilities, travel distances and times may be longer for work as well as for non-work trips (Boarnet and Sarmiento, 1996; Stead, 2001; Dieleman *et al.*, 2002; Schwanen *et al.*, 2002).

Educational level, employment status, and income may be interwoven. Highly educated workers are more involved in jobs with a higher occupational status, which results in higher incomes. Consequently, studies of the effects of educational level, employment status or income on travel behaviour can result in comparable findings. For example, higher car use, longer travel distances and travel times can be found across highly educated people, employed people, and high- income groups (Boarnet and Sarmiento, 1996; Kockelman, 1997; Stead, 2001; Schwanen *et al.*, 2002; Krizek, 2003; Dargay and Hanly, 2004). These people often obtain jobs with a high occupation status that are concentrated in high-density office parks. As a result, highly-educated people and high-income groups are more involved in long-distance commuting. Moreover, these office parks are often located near train stations. Consequently, the use of public transport for commuting, and especially train use, is found to be higher among these people (Dieleman *et al.*, 2002; Schwanen *et al.*, 2002). Previous findings can be refined when modal choice and travel motives are taken into account. Commuting distance and time are found to be longer for commuting by fast modes (car and public transport), but not by slow modes (walking and cycling) (Dieleman *et al.*, 2002; Schwanen *et al.*, 2002). Similar results have been found for non-work travel (Boarnet and Sarmiento, 1996; Dieleman *et al.*, 2002).

Car ownership can be analyzed as an endogenous variable which is explained by various socio-economic variables. Highly educated people are found to own more cars (Dargay and Hanly, 2004). Due to relationships between education and income, car ownership is higher across high-income groups as well (Kockelman, 1997). On the other hand, car ownership can be considered as an exogenous variable, explaining travel behaviour. As car ownership is related to income, car use will be higher across high-income groups (Frank and Pivo, 1994; Boarnet and Sarmiento, 1996; Kockelman, 1997; McNally and Kulkarni, 1997; Dieleman *et al.*, 2002; Schwanen *et al.*, 2002, 2004; Rajamani *et al.*, 2003).

3.2.1.3 Personality dimension

Handy (1996) was among the first to mention the importance of perceptions and attitudes towards land use. Her research in Austin, Texas, revealed that individual motivations and limitations are central to the decision to walk. Land use is rather a secondary factor in pedestrian choices, although results suggested that it becomes more important if the walking trip has a destination. Kitamura *et al.* (1997) extended the traditional analysis with information about lifestyles. An assessment of the relative contribution of land use, socio-economic and lifestyle characteristics revealed that each variable type adds some explanatory power to the models. However, lifestyle variables explained the highest proportion of the variation in the data for the San Francisco Bay Area. This conclusion has been confirmed by Bagley and Mokhtarian (2002). Their research included lifestyle characteristics and information about attitudes towards travel. Attitudes and lifestyle were found to have a greater impact on travel demand than land use characteristics. Van Wee *et al.* (2002) discussed the preferences for travel modes, especially car and public transportation, in

Utrecht, the Netherlands. Preferences for modes added explanatory power to models for travel behaviour, which already include land use, personal and household characteristics.

Whereas most studies point to a higher significance of attitudes, lifestyles and preferences compared to land use and socio-economic variables, Schwanen and Mokhtarian (2003, 2005a, b) and Naess (2005) concluded the reverse. Schwanen and Mokhtarian (2003, 2005a, b) used data for the San Francisco Bay Area and focused on the concept of residential neighborhood type dissonance, or mismatch between preferred and actual type of residential location. If the travel behaviour of the mismatched individuals differs from the matched residents of the actual neighborhoods, then this suggests that land use is of greater importance than socio-economic and demographic characteristics. The contrary is true when their travel behaviour is found to be different from matched residents of the preferred neighborhoods. The impact of dissonance on travel behaviour is studied in three separate papers. Non-commute trip frequencies (Schwanen and Mokhtarian, 2003), commute mode choice (Schwanen and Mokhtarian, 2005a), and mode-specific travel distances for all purposes (Schwanen and Mokhtarian, 2005b), were compared between matched and mismatched urban and suburban residents. Physical land use structure had, however, a stronger influence than preferences towards land use. Similar results were obtained by Naess (2005). Residential location within the metropolitan area of Copenhagen, Denmark, was found to affect travel behaviour, especially travel volume and modal choice, even after controlling for socio-economic and attitudinal variables.

3.2.1.4 A spatial, socio-economic or personality dimension?

A limited number of research studies concluded that land use variables remained important after controlling for socio-economic differences among respondents. Kockelman (1997) found that accessibility, land use mix and land use balance were more relevant than socio-economic characteristics, especially for travel distance and modal choice in the San Francisco Bay Area. Gorham (2002) used more general land use variables in terms of neighborhood types. Similarities in travel behaviour were found between respondents in equivalent neighborhood types in Stockholm, Sweden, and the San Francisco Bay Area. Dargay and Hanly (2004) and Zhang (2004) supported the importance of land use variables in modal choice. Zhang (2004) compared modal choice in Boston and Hong Kong, and Dargay and Hanly (2004) reported on data from the UK. Whereas previous studies reported on all travel motives, Rajamani *et al.* (2003) investigated only non-working travel. They found that diversity and accessibility remained important in decisions regarding walking or cycling in Portland, USA.

However, the greater part of research studies indicated that socio-economic variables are more important than land use variables. Schwanen *et al*. (2004) reported on modal choice, travel time by car, and travel distance by car for work trips in the Netherlands. They found more variation in travel behaviour among individual workers within a residential zone than the variation between such geographical units. Working remained a well-studied travel motive, but other non-work motives were distinguished as well. Boarnet and Sarmiento (1996) examined non-work travel in general for Southern California. Compared to socio-economic variables, density and diversity were found to be not significant as a group, even rarely significant individually. Modal choice for work and shopping trips were examined by Frank and Pivo (1994) and Simma and Axhausen (2003). Their conclusions are somewhat different. According to Frank and Pivo (1994), density remained important for modal choice in the Puget Sound Area, USA. However, the influence of diversity decreases while controlling for socio-economic variation. Simma and Axhausen (2003) reported on Austrian research, and found a much greater importance of socio-economic characteristics than land use variables. Other researchers, mainly from the Netherlands, reported on travel for working, shopping and leisure activities. Dieleman *et al.* (2002) found an equal influence of land use and socio-economics for modal choice, although travel distance seemed to be more influenced by socio-economic variables. The latter was also found in relation to travel time (Schwanen *et al*., 2002). According to Meurs and Haaijer (2001), modal choice for shopping and leisure activities is determined by land use variables to a greater extent, whereas socio-economic variables are of greater interest for work trips. This indicates that the relative importance of land use and socio-economic variables may be dependent on travel motive.

Since the mid-1990s, attention has been paid to the traveler's personality as well. Characteristics such as lifestyles, perceptions and attitudes towards land use and travel were accounted for. Research on this third dimension of travel behaviour seems to add significant explanatory power to previous models. The greater part of the research concludes that attitudes, lifestyles, perceptions and preferences towards land use and transportation are important explanatory variables (Handy, 1996; Kitamura, 1997; Bagley and Mokhtarian, 2002; van Wee, 2002). Nevertheless, this type of research is still not fully developed because of a lack of data.

3.2.2 Geographical context

Most evidence is based on data stemming from the US. Only recently, the research debate has been enriched with European evidence. As all these studies are performed in various geographical settings, conclusions about the relative importance of land use in determining travel patterns may differ.

Important differences exist in urbanization patterns between North- American and European cities. European cities have a historic city center, sometimes dating from the Middle Ages. Their narrow and winding streets discourage intensive car use, unlike the grid-like street pattern of North-American cities. As a result, Schwanen *et al.* (2002) pointed out that differences in car use between city-center and suburban residents may be even more pronounced in European cities. Moreover, the spatial scale of cities in Europe is smaller than North-American cities. Combined with a spatial planning tradition that favors compact developments, European cities are more suitable for walking and cycling. Differences in culturally defined norms and values may influence travel behaviour as well. For instance, Americans may be more inclined to move house in response to employment changes than Europeans (Schwanen, 2002; Schwanen *et al*., 2004). Transatlantic research remains, however, scarce (see, e.g. Newman and Kenworthy, 1989, 1999; Kenworthy and Laube, 1999; Giuliano and Dargay, 2006). On the other hand, travel behaviour may differ across European countries as well due to various urbanization patterns, spatial planning systems, and cultural factors.

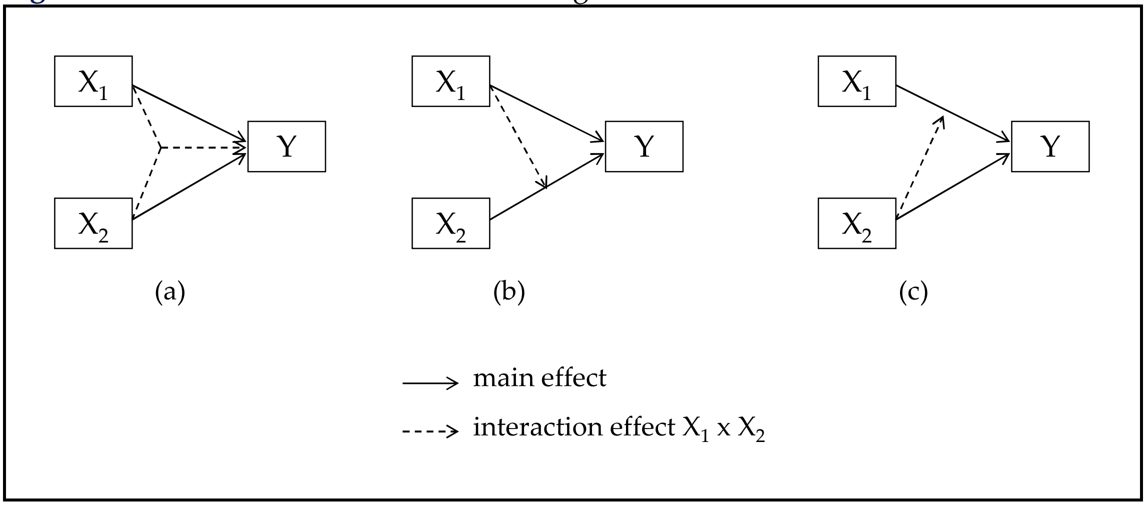
The influence of urbanization patterns on commuting has been analyzed by Schwanen (2002). Important differences were found with respect to modal split, commuting distance and time. Urban size and the distribution of employment and population, referring to urban structure, were strongly associated with commuting time and modal split. Furthermore, commuting distance was found to be strongly and negatively associated with population density. Martens *et al.* (2002) reviewed various spatial planning systems cities use in order to obtain more sustainable travel patterns. They distinguished two main strategies: the monocentric and polycentric planning. Simma and Axhausen (2001) compared modal choice in Switzerland, Germany and the UK. Through the ownership of cars and season tickets, travelers are assumed to commit themselves to a particular travel behaviour. Car availability was found to determine other variables, but relationships remain complex.

3.3 Structural equation modelling

Structural equation modelling (SEM) is a research technique dating, in its current form, from the 1970s. Most applications have been in psychology, sociology, the biological sciences, educational research, political science and marketing research. SEM is a confirmatory method guided by prior theories about the structures to be modeled.

The main advantages of SEM (e.g. compared to regression analysis) are among others: (i) modelling of mediating variables and the distinction between total, direct and indirect effects, (ii) incorporation of unobserved variables with multiple indicators, and (iii) correcting for measurement error in all observed variables (Raykov and Marcoulides, 2000; Byrne, 2001; Golob, 2003; Kline, 2005).

Figure 3.1 Interaction effect and its meaning

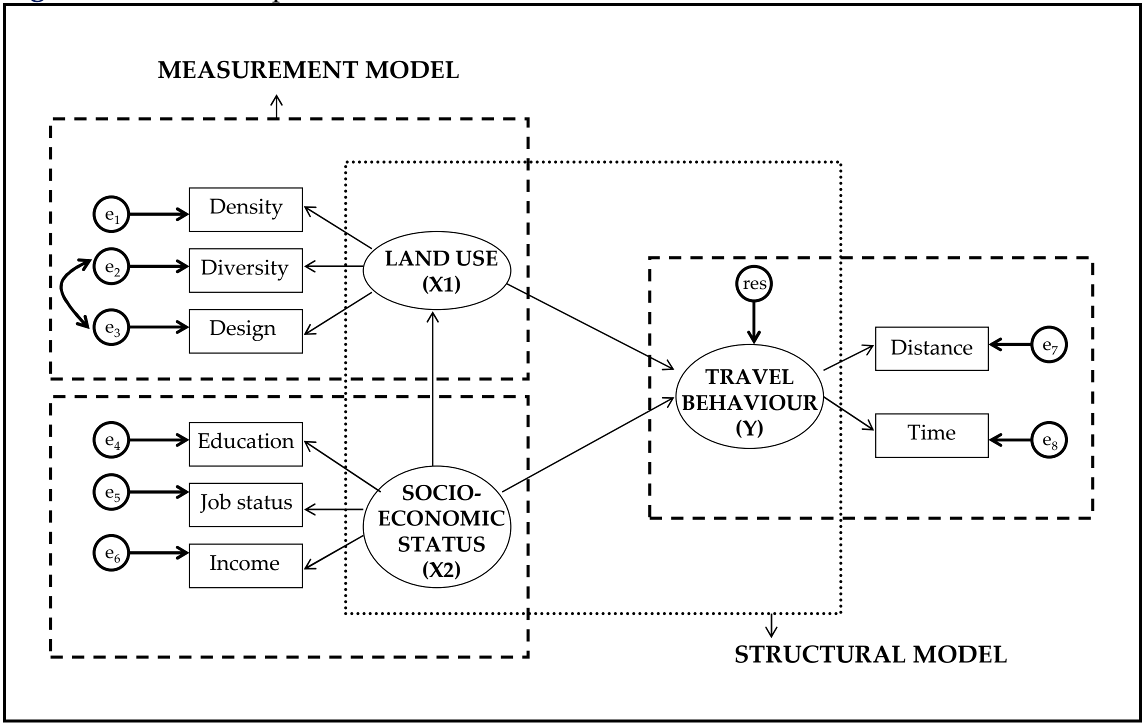


As in traditionally-used regression analysis, SEM captures relationships between independent and dependent variables. Independent and dependent variables are called exogenous and endogenous variables, respectively. Furthermore, SEM can also be used to measure the causal influences of independent variables upon one another, which is not possible with regression analysis, although interaction effects can be modeled between two independent variables, X_1 and X_2. These interaction effects are computed as the product of the independent variables (X_1 x X_2), but its meaning depends on the hypotheses and the knowledge of the researcher. The independent variables can have a mutual effect on the dependent variable (Figure 3.1a) or one independent variable can influence the effect of the other independent variable on the dependent variable (Figure 3.1b, c). SEM can model these relationships more specifically. In this way, SEM makes a distinction between direct, indirect and total effects. This fact is considered very useful in order to obtain better insights into the complex nature of travel behaviour.

Direct effects are the effects that go directly from one variable to another variable. Each direct effect corresponds to an arrow in a path (flow) diagram. For example, Figure 3.2 represents three direct effects: from land use to travel behaviour, from socio-economic status to travel behaviour, and from socio-economic status to land use. Indirect effects occur between two variables that are mediated by one or more intervening variables, such as the relationship between socio-economic status and travel behaviour through land use. The combination of direct and indirect effects determines the total effect of the independent variable on a dependent variable. We need to stress that the arrows between the construct and its indicators do not correspond to direct effects. For example, income is not explained by socio-economic status, but it contributes to the construct socio-economic status.

Whereas a single equation is used in regression analysis, SEM can be composed of up to three sets of simultaneous equations: (i) a measurement (sub)model for the endogenous variables, (ii) a measurement (sub)model for the exogenous variables, and (iii) a structural (sub)model, all of which are estimated simultaneously. This full model is known as 'SEM with latent variables' (Figure 3.2). Latent variables (or factors) are constructs which cannot be observed directly. Thus, latent variables must be defined in terms of underlying variables which are believed to represent the latent variable. These underlying and observable variables are called indicators or manifest variables. The measurement model, therefore, defines the relationships between a latent variable and its indicators. The structural model represents the relationships between exogenous and endogenous variables. Figure 3.2 represents a structural model between three latent variables. Each latent variable is defined by its measurement model. Measurement models are defined for two exogenous variables (land use and socio- economic) and one endogenous variable (travel behaviour). This full model is seldom applied. Generally, several measurement models are dropped. A 'SEM with observed variables' consists only of a structural model without any measurement model. No measurement models are needed if all exogenous and endogenous variables are manifest variables. Many standard statistical procedures can be viewed as special cases of SEM. A measurement model alone equals confirmatory factor analysis. Ordinary regression is the special case of SEM with one observed endogenous variable and multiple observed exogenous variables. In general, a SEM can have any number of endogenous and exogenous variables (Golob, 2003).

Figure 3.2 An example of a SEM with latent variables



Furthermore, SEM makes a distinction between measurement errors (e_1 to e_8) and residual error (res). Measurement error represents error associated with observed variables, thus reflecting the adequacy in measuring the related underlying factor. Error associated with the prediction of endogenous factors from exogenous factors is known as residual error. Residual error equals the error term in regression analysis, in which it is the difference between the observed and estimated values of the dependent variable. Regression analysis, however, ignores potential measurement error in all the explanatory variables. As a result, regression estimates might be misleading.

3.4 SEM: An Example

As noted before, SEM is considered a useful technique because it can deal with several directions of influence between variables. However, evidence in the field of travel behaviour research remains scarce, and is mainly based on US data (e.g., Bagley and Mokhtarian, 2002). In order to illustrate the use of SEM in travel behaviour research, and to enrich this research debate with European evidence, a preliminary analysis based on Flemish data has been carried out.

3.4.1 Data

The 2000 —2001 Flemish Regional Travel Survey (Onderzoek VerplaatsingsGedrag; OVG Vlaanderen) is used to address the research questions posed above. Initiated in 1994 —1995, the OVG is carried out every five years. In every survey, about 2,500 household are asked to participate. Approximately 5,500 individuals fill in a two-day consecutive travel diary, consisting of a household and a personal questionnaire (Zwerts and Nuyts, 2004). The household questionnaire was designed to capture characteristics of the residential environment (e.g., densely built environment) and socio-economic characteristics of the household (e.g., car ownership, household income). Every member of the household, aged above six years, is asked to complete a personal questionnaire in which personal socio-economic characteristics (e.g., age, gender) and every trip undertaken is reported. This resulted in 39,712 trips reported in the 2000-2001 OVG Vlaanderen.

In this preliminary analysis, we used data from 5,696 respondents. Furthermore, additional variables had to be recoded or constructed, in particular land use characteristics. As the travel survey includes only a limited amount of land use variables (e.g., residential environment, distance to public transport), a variable is created based on the categorization of the municipality according to the land use policy in Flanders (Ruimtelijk Structuurplan Vlaanderen; RSV). This variable is considered to be a proxy for differences in density, diversity and design. We are aware that the limited information on land use and the categorical nature of the data may cause problems. Despite these disadvantages, we used this sample to illustrate the use of SEM in travel behaviour research from a land use perspective.

The analysis is performed using the software package AMOS 5, which generally does not support ordinal data. However, several references justify the analysis of ordinal data as if these data were continuous. In particular, large sample analyses with ordinal data consisting of more than five categories are considered feasible (Bollen and Barb, 1981; Johnson and Creech, 1983). Nevertheless, some variables depart from the norm. Therefore, the asymptotically distribution free estimation method has been used, which does not assume normality. The sample was constructed in such a way that no missing data appeared. This enabled us to calculate modification indices in AMOS. These indices allow us to examine all potential modifications in a single analysis, and suggest modifications that will likely result in lower χ_2 values (Arbuckle and Wothke, 1999). Furthermore, outliers are removed so that the final sample includes information on the travel behaviour of 3,905 respondents. Table 3.1 summarizes the variables used in the analysis.

Table 3.1 Summary of variables included in the analysis

Travel behaviour				
	Minimum	**Maximum**	**Average**	**Standard deviation**
Distance (km)	0.2	885.0	44.1	62.2
Time (min)	2.0	650.0	72.5	66.6
Number of trips	1	10	3.7	2.0
Social status				
	Minimum	**Maximum**	**Average**	**Standard deviation**
Number of cars	0	4	1.5	0.7
	Frequency			
Education	12.4% none, 10.2% PE, 22.2% SE, L, 28.3% SE, H, 26.8% HE			
Household income (BEF)	1.1% 0-30.000, 34.3% 30.001-75.000, 46.9% 75.001-125.000, 15.7% 125.001-200.000, 2.0% +200.000			
Job status	13.4% pensioner/disabled, 6.7% housewife/man, 22.9% student, 2.5% work seeking, 15.2% blue collar, 34.6% white collar, 4.7% self-employed			
Full-/Part-time employed	45.5% none, 11.1% part-time, 43.4% full-time			
Household responsibility				
	Minimum	**Maximum**	**Average**	**Standard deviation**
Age	6	84	37.5	17.9
Number of household members	1	8	3.3	1.3
Number of –6 year olds	0	4	0.2	0.5
	Frequency			
Gender	51.7% male, 48.3% female			
Marital status	65.3% married/cohabitating, 34.7% single			
Land use				
	Frequency			
Categorisation by RSV	32.4% OUT_RUR, 7.7% OUT_SUB, 16.7% OUT_SC, 14.1% OUT_RC, 10.7% IN_RUR, 7.3% IN_SUB, 5.1% IN_SC, 5.9% IN_LS			
Residential environment	5.2% rural, 49.5% nor rural, nor urban, 45.3% urban			
Distance to public transport (m)	2.2% +5000, 5.5% 2000-4999, 12.8% 1000-1999, 25.1% 500-999, 27% 250-499, 27.5% 0-249			

Note: 'Education': PE = primary education; SE, L = secondary education, lower; SE, H = secondary education, higher; HE = higher education.
'Categorisation by RSV': IN / OUT = municipality within/outside the Flemish triangle between Antwerp, Brussels and Ghent; LS = large city; RC = regional city; SC = small city; SUB = suburban; RUR= rural.

This analysis tries to determine which travel behaviour is most influenced. Is it the residential environment or the socio-economic characteristics of the individual? In contrast with other studies, latent variables or constructs will be created that measure the joint effect of all spatial or all socio-economic characteristics. Other studies focus on the effect of a specific characteristic. In order to do so, a two-step approach has been undertaken (Anderson and Gerbing, 1988; Raykov and Marcoulides, 2000; McDonald and Ho, 2002). First, various measurement models are estimated by a confirmative factor analysis (CFA). In doing so, the latent variables 'land use', 'social status', 'household responsibility' and 'travel behaviour', are constructed. Second, a structural regression model (SRM) has been constructed in order to estimate relationships between the latent variables defined in the first step.

3.4.2 Confirmative factor analysis

In general terms, factor analysis is an approach to detect latent variables by using observable and measurable indicators. Factor analysis can have an explorative or a confirmative nature. The analysis is explorative if we want to determine how many and which constructs (factors) are needed to explain the relationships between the observed indicators. The analysis is confirmative if a model of the relationships among the indicators already exists. In other words, a CFA is used as a corroboration of what we already know (Raykov and Marcoulides, 2000).

In our example, a pre-existing model is set up based on the literature review. As a result, a CFA is performed in order to verify whether the observed variables (Table 3.1) correctly measure the underlying constructs 'land use', 'social status', 'household responsibility' and 'travel behaviour'. Various socio-economic and demographic characteristics of the individual and its household can be grouped along these two dimensions: social status of the individual and the individual's responsibility within the household (Hanson and Hanson, 1981).

The properties of normality, unidimensionality, convergence validity, reliability and discriminant validity must be fulfilled before the constructs can be considered trustworthy. Unidimensionality denotes the fact that only a single underlying construct is involved in the set of observed variables. Convergence validity refers to the degree of confirmation between two indicators of the same construct. AMOS does not provide any reliability measure and, therefore, it must be computed by hand. Reliability can be evaluated by the composite reliability and the variance extracted. Discriminant validity is fulfilled when two constructs are not correlated (Wijnen *et al.*, 2002).

However, problems occur for the constructs 'land use' and 'house- hold responsibility'. This can be due to the limited spatial information available for the construct 'land use', and the interaction with 'social status' for the construct 'household responsibility' (R_2 = 0.549). Even though, these constructs are considered in the further analysis. Otherwise, important information, such as gender and residential environment, would be missing. Although the constructs must be interpreted carefully, the overall fit of the model is reasonably good (CFI = 0.899, TLI = 0.877, RMSEA = 0.108).

3.4.3 Structural regression model

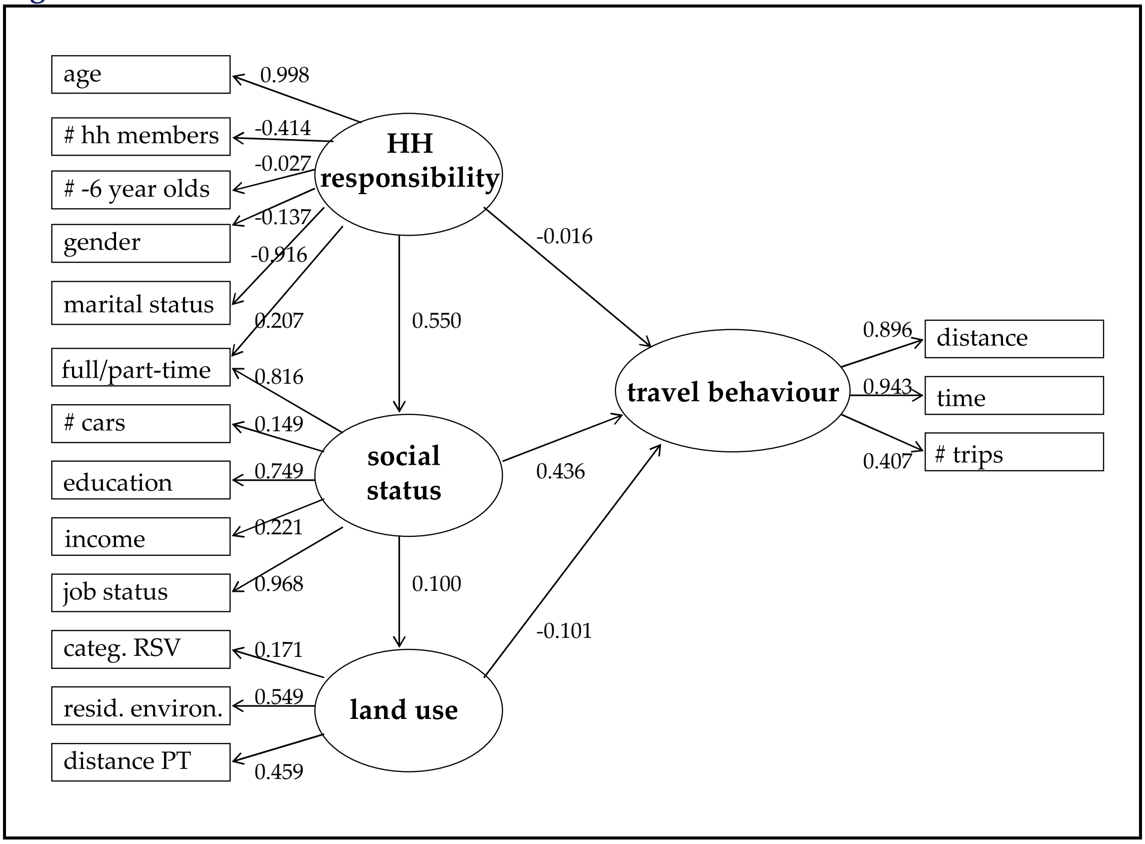
In the CFA, no specific directional relationships were assumed among the constructs. This can be carried out in a SRM, in which some of the latent variables are regressed on others. Thus, after assessing the constructs in the CFA, SRM can be used to test explanatory relationships (Raykov and Marcoulides, 2000).

Based on conceptual reasoning and evidence from the literature review, a system of four equations is developed to represent travel behaviour. Moreover, modification indices in AMOS point out that relationships exist between 'household responsibility' and 'social status', and between 'social status' and 'land use'. The latter indicates that residential choices are influenced by the respondent's social status. As a result, 'social status' will also influence travel behaviour indirectly.

1. Travel behaviour = f (land use, social status, household responsibility, travel distance, travel time, number of trips) + r_1
2. Household responsibility = f (age, number of household members, number of —6 years olds, marital status, full-/part-time employed) + r_2
3. Social status = f (household responsibility, number of cars, education, household income, job status, full-/part-time employed) + r_3
4. Land use = f (social status, residential environment, categorization by RSV, distance to public transport) + r_4

The final model and its standardized estimates are represented in Figure 3.3. Fit indices points to a reasonably good quality of the overall model (TLI = 0.878, CFI = 0.899, RMSEA = 0.108). Arrows in Figure 3.3 symbolize direct effects between two constructs or between a construct and its indicators. For example, the entries -0.016, 0.436 and -0.101 are standardized regression weights of, respectively, household responsibility, social status and land use in relationship with travel behaviour.

Figure 3.3 Standardized estimates



Travel behaviour is mainly influenced by social status: respondents with a higher social status will travel longer distances, longer times and more trips per day. Travel behaviour is less complex among individuals with less household responsibilities, and respondents living in urban environments.

As previously mentioned, direct effects occur between constructs explaining travel behaviour: from ‘household responsibility’ to ‘social status’ (0.550), and from ‘social status’ to ‘land use’ (0.100). Respondents with more household responsibilities (adults, married or cohabitating, full-time employed, small households without children) obtain a higher social status (higher education, full-time employed, high job status, high income, more cars). The effect of ‘social status’ on ‘land use’ is remarkable: respondents with a higher social status live in more urban environments. We assume that this is a consequence of the positive relationship between social status and household responsibility, and especially of age and the absence of children. However, examining direct effects only can be misleading. Due to interrelationships among constructs, indirect effects occur which may be quite strong and different from direct effects. For example, the indirect effect of household responsibility on travel behaviour ((0.550 x 0.436) + (0.550 x 0.100 x -0.101) = 0.234) is larger than its direct effect (-0.016). The indirect effect of social status (0.100 x -0.101 = -0.010) is rather small. Moreover, indirect effects of both constructs have the opposite sign of their direct effects, leading to different conclusions. Therefore, total effects must be interpreted instead of direct effects only.

The total effect of one variable on a second variable is the sum of the direct effect and all indirect effects from the first variable acting through intermediating variables on the second variable. Total effects are represented in Table 3.2. An important question in the research debate is the relative effect of land use and socio-economic characteristics on travel behaviour. Table 3.2 indicates a greater importance of socio-economic characteristics compared to land use. Travel behaviour is mainly influenced by the respondent's social status (0.426). A higher social status (full-time employed, greater car ownership, higher education, high income and job status) is associated with more trips, longer travel distances and times. Although it has limited direct effect, household responsibilities remain important as well (0.219). This is caused by the interaction between social status and land use. The effect of land use, on the other hand, is restricted.

Table 3.2 Standardized total effects

	Travel behaviour		
	Direct effect	**Indirect effect**	**Total effect**
Household responsibility	-0.016	0.234	0.219
Social status	0.436	-0.010	0.426
Land use	-0.101	-	-0.101

Note: - = no relationship defined

3.5 Conclusions

Although a large body of literature exists on the impact of land use on travel behaviour, conclusions are not decisive. Results differ depending on the type of explanatory variables and methodology used. Our literature review revealed three dimensions in this type of travel behaviour research: (i) a spatial dimension, (ii) a socio-economic dimension, and (iii) a personality dimension. Whereas the spatial and socio-economic dimensions are well-studied, research on the personality dimension of travel behaviour (attitudes, preferences) remains scarce, mainly because of a lack of appropriate data. The few studies on attitudes, perceptions and preferences towards land use and travel have been conducted mainly in the US. However, it remains important to obtain information from other countries and cultures.

As more types of variables need to be included, research techniques must be able to deal with more potential relationships among these variables.

Traditionally used techniques, such as regression analysis, can measure only the direct effects between the independent variables (land use, socio-economic characteristics) and the dependent variable (travel behaviour). But, the complexity of travel behaviour may be the result of interdependencies among the independent variables, causing indirect effects on travel behaviour. Emphasis has, however, not been placed on such indirect effects. This is considered an important shortcoming in the debate so far. As SEM can model the influences of independent variables upon dependent variables and influences in-between independent variables, this research technique may be considered helpful in further travel behaviour research. In this way, a distinction can be made between the direct effects and indirect effects of the independent variables upon the dependent variable.

An initial analysis based on Flemish travel data illustrated the use of SEM in travel behaviour research. A two-step approach was under- taken to measure the relative influence of land use and socio-economic characteristics on travel behaviour. Travel behaviour was mainly influenced by the respondent's social status: a high social status was associated with a more complex travel behaviour. Travel behaviour was affected, especially indirectly, by the individual's role within the household. The effect of land use was limited.

The analysis is considered a starting point for further investigation. This initial analysis drew attention to the importance of indirect effects. As these effects were collected at the construct level, no information is available on the effects of a specific variable. Therefore, more research is needed on the interrelationships between specific variables. Travel behaviour has been considered in general terms, such as daily travel distance and number of trips per day. These general aspects of travel behaviour can be broken down by modal choice or travel motive and, thus, be defined more specifically. Furthermore, limited land use data have been used so far, and this on a categorical scale. Software packages, other than AMOS (e.g. LISREL and M-plus), are more suitable to analyze categorical data. Also, to date, no information on attitudes, perceptions and preferences towards land use and travel is available in Flanders/Belgium. The use of more detailed and continuous land use data and attitudinal data is required in order to improve the exploration of the complexity of travel behaviour.

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"De reis van duizend mijl moet met een enkele stap beginnen."

Lao Tse (sixth century BC)

4. CAR OWNERSHIP AS A MEDIATING VARIABLE IN CAR TRAVEL BEHAVIOUR RESEARCH

USING A STRUCTURAL EQUATION MODELLING APPROACH TO IDENTIFY ITS DUAL RELATIONSHIP

Van Acker, V., Witlox, F. (2010) Car ownership as a mediating variable in car travel behaviour research using a structural equation modelling approach to identify its dual relationship. Journal of Transport Geography, 18, pp. 65-74.

Abstract Car ownership is generally considered an important variable in car travel behaviour research, but its specific role is often not well understood. Certain empirical studies consider car ownership as the dependent variable explained by the built environment, whereas other studies deem it to be one of the independent variables explaining car travel behaviour. This paper takes note of the dual influence car ownership has in explaining car travel behaviour by assuming that car ownership mediates the relationship between the built environment and car use. The relationship is estimated using a structural equation model since it accounts for mediating variables. This approach confirms the intermediary nature of car ownership.

4.1 Introduction

Like in most countries, the overall amount of travel in Belgium has increased substantially. Within 10 years time, total travel distance by car has increased by a quarter: from 60 billion vehicle-kms in 1990 to 75 billion vehicle-kms in 2000 (http://www.mobilit.fgov.be/). Because travel is associated with negative externalities such as congestion and pollution, policymakers try to control and manage travel patterns. Illustrative are the New Urbanism movement in the United States and the Compact City Policy in Europe, that aim at reducing car use and travel distances through urban planning. The basic idea is that high-density and mixed-use neighbourhoods are believed to be associated with shorter trips and more non-motorized trips; hence, indicating a clear existing relationship between the built environment and travel behaviour.

So far, many studies exist that try to determine the relationship between the built environment and travel behaviour. Within this research debate, car ownership is considered as mediating the relationship between the built environment and travel behaviour. A theoretical justification for this is given by Ben-Akiva and Atherton (1977). They embedded the built environment, car ownership and travel behaviour in a hierarchy of choices. Car ownership is considered to be a medium-term decision, which is influenced by long-term decisions such as place of employment and residential locational choice. The spatial characteristics of these locations, such as the availability of public transport, constrain or facilitate car ownership. Car ownership, in turn, affects short-term decisions such as daily car use of individuals and households.

However, most empirical studies do not consider car ownership as a mediating variable. Car ownership is mainly used as an exogenous variable, in addition to spatial and socio-economic variables, to explain travel behaviour (e.g., Bagley and Mokhtarian, 2002; Dieleman *et al*., 2002; Schwanen *et al*., 2002; Krizek, 2003). On the other hand, some studies consider car ownership as an endogenous variable and try to explain it based on various spatial and socio-economic variables (e.g., Dargay, 2002; Giuliano and Dargay, 2006; Bhat and Guo, 2007; Cao *et al*., 2007a). Only a limited amount of studies combines both research approaches and considers car ownership as mediating the relationship between the built environment and travel behaviour (e.g., Schimek, 1996; Simma and Axhausen, 2003; Cao *et al*., 2007b; Scheiner and Holz-Rau, 2007). Travel behaviour is, then, directly determined by car ownership and the built environment, and car ownership itself is also influenced by the built environment. This results in an indirect effect of the built environment on travel behaviour through the mediating variable car ownership. Although car ownership is considered as a mediating variable, none of these studies really discussed the consequences of ignoring this. Therefore, this paper will highlight the consequences by comparing the results of a structural equation model with car ownership as a mediating variable with the results of a structural equation model without this.

The aim of this paper is to contribute to our understanding of the role of car ownership as a mediating variable, and specifically in relation to daily car use. The paper is structured as follows. Section 4.2 presents a brief literature review on the relationship between the built environment and (car) travel behaviour. In particular, attention is paid to the role and importance car ownership plays in explaining this relationship. Section 4.3 describes a suitable methodological technique that is able to deal with the ambiguous role of car ownership. Here structural equation modelling is advanced. A structural equation model (SEM) can simultaneously handle relationships between several exogenous and endogenous variables and, as a consequence, it is able to model mediating variables. The analysis (Section 4.5) is preceded by a discussion of the used dataset, which is explained in Section 4.4. Finally, in Section 4.6, our most important findings are summarized and discussed.

4.2 Literature review

There are many studies that focus on the relationship between the built environment and (car) travel behaviour. As a consequence, an enormous variety of variables have been taken into consideration. This section briefly summarizes some of the relevant literature on car ownership and (car) travel behaviour (for more comprehensive reviews, see, e.g., Stead and Marshall, 2001; Handy, 2005; Van Acker and Witlox, 2005).

4.2.1 The built environment and travel behaviour

The effects of *spatial density* on travel demand have long been acknowledged (e.g., Levinson and Wynn, 1963) and remain well-studied and understood. Higher spatial densities are associated with lower car ownership and more public transport use, less car use, and more walking and cycling. After all, in high-density areas public transport is organized more efficiently (more routes, higher frequency of services) and higher densities are also associated with higher levels of congestion (Schwanen *et al.*, 2004). Also, in dense areas people tend to travel shorter distances and they spend less time travelling on average (Cervero and Kockelman, 1997; Kitamura *et al.*, 1997; Stead, 2001; Dargay and Hanly, 2004; Schwanen *et al.*, 2004; Hammadou *et al.*, 2008).

A second issue is *spatial diversity*. Several indicators have been developed to measure diversity: among others, a jobs/housing ratio (Ewing *et al.*, 1994; Boarnet and Sarmiento, 1998), an entropy index to quantify the degree of balance across various land use types (Frank and Pivo, 1994; Kockelman, 1997) or a (dis)similarity index to indicate the degree to which different land uses lie within a person's surrounding (Kockelman, 1997). The effects of more diversity on car ownership and (car) travel behaviour are comparable to the effects of higher densities.

A third dimension is *spatial design.* It can be characterized by a general classification of neighbourhoods with a standard suburban neighbourhood and a neo-traditional neighbourhood as extremes (McNally and Kulkarni, 1997; Gorham, 2002). Standard suburban neighbourhoods are characterized by low densities, limited diversity, and a car-orientated design. These neighbourhoods are associated with more cars per capita and more car use. Spatial design however also relates to site design, and dwelling and street characteristics. Neighbourhoods characterized by small block sizes, a complete sidewalk system, the absence of cul-de-sacs and limited residential parking tend to encourage walking and cycling (Cervero and Kockleman, 1997; Hess *et al.*, 1999; Stead, 2001). Meurs and Haaijer (2001) noted that, although characteristics of the dwelling, street, and neighbourhood may influence modal choice, this is only true for shopping and social or recreational purposes. Working trips are less likely to be influenced by spatial design characteristics.

Accessibility is a fourth important characteristic of the built environment which generally refers to the ability "to reach activities or locations by means of a (combination of) travel mode(s)" (Geurs and van Wee, 2004). Most studies pointed out that accessibility is negatively associated with car ownership (e.g., Kockelman, 1997; Simma and Axhausen, 2003; Chen *et al*., 2008; Gao *et al*., 2008). Rajamani *et al*. (2003) found that higher accessibility by a given mode is likely to result in higher usage of that mode. For example, households living in neighbourhoods that are easily accessible by public transport tend to make more trips by public transport (Kitamura *et al*., 1997). Similarly, individuals that have several facilities and services such as a shops, banks, schools and doctors within walking distance of their residence undertake more walk trips and less car trips (Simma and Axhausen, 2003). However, some confounding results exist related to the influence of accessibility by car on car use. Some studies (e.g., Rajamani *et al*., 2003) found that better accessibility by car results in more car use, whereas other studies state the opposite (e.g., Kockelman, 1997). Despite high levels of car accessibility, Kockelman (1997) argued that less car use might still occur since higher accessibility is generally associated with higher land prices, less convenient parking options and more roadway congestion.

4.2.2 Socio-economic and demographic differences in travel behaviour

Empirical studies focusing on the relationship between the built environment and travel behaviour should also control their results for various socio-economic and demographic characteristics of the individual and the household. *Age* is an important variable. Car ownership and car use tend to be lower among older persons (aged above 65 years). Moreover, if older persons travel by car, they are likely to travel shorter distances. Note also that older persons not only travel because they want to participate in activities, the travelling itself can have certain socializing opportunities. Ride-sharing for non-work trips is, therefore, found to increase by age (Boarnet and Sarmiento, 1998; Stead, 2001; Dargay and Hanly, 2004; Schwanen *et al*., 2004).

Gender is another important variable. The difference in travel behaviour between women and men depend on trip purpose. Other findings can be formulated whether work travel or non-work travel is analyzed. Women are inclined to commute more often by public transport, by bike or on foot, whereas car use tends to be higher among men for work trips. Moreover, commuting distances and times appear to be shorter for women (Schwanen *et al*., 2002, 2004; Stead, 2001). This gender difference is partly explained by the fact that women earn lower wages, and fulfil other types of jobs (Madden, 1981; Hanson and Pratt, 1988). Because women remain primarily responsible for most household maintenance tasks, some studies (e.g., Boarnet and Sarmiento, 1998) specify that women use a car more often and travel longer distances for non-work trips. However, other studies (e.g., Schwanen *et al*., 2002) found the opposite: women spend less time on car travel for shopping purposes than men do. This indicates that women are more likely to travel to shops within walking or cycling distance from their residence.

Educational level, *employment* status, and *income* are related variables, thus resulting in comparable findings. Hence, highly educated persons often obtain more specialized jobs which are generally concentrated in high-density or central business district office parks. As a result, higher educated are more involved in long-distance commuting and their car use is higher (Kockelman, 1997; McNally and Kulkarni, 1997; Boarnet and Sarmiento, 1998; Stead, 2001; Dieleman *et al*., 2002; Schwanen *et al*., 2002, 2004; Krizek, 2003; Dargay and Hanly, 2004). However, the use of public transport, especially train use, might also be higher if these high-density or central business centre office parks are located nearby a railway station.

Household size is positively associated with car ownership. Because of intra-household decisions related to the activities of several household members, the need to own more than one car increases within larger households. Households that own several cars are likely to use their cars more often. Furthermore, because of their possibly stronger car dependency, members of larger households tend to travel longer distances (Kockelman, 1997; Dargay and Hanly, 2004). Comparable results can be found with respect to the number of employed persons in the household (Cervero and Kockelman, 1997; Krizek, 2003) and, to some degree, to the presence of children. Since they do not have to spend time on child care responsibilities, singles and childless couples tend to obtain longer total daily travel times (Boarnet and Sarmiento, 1998; Stead, 2001; Dieleman *et al*., 2002; Schwanen *et al*., 2002; Dargay and Hanly, 2004).

Several studies use *car ownership* as an independent variable in order to explain travel behaviour. Car use seems on average higher among households owning several cars than among household without a car (Dieleman *et al*., 2002). Moreover, owning a car enables people to travel longer distances compared to people that must rely on slower modes such as public transport, walking and biking (Bagley and Mokhtarian, 2002; Schwanen *et al*., 2002; Krizek, 2003). On the other hand, car ownership in itself is influenced by other socio-economic variables, especially income. Car ownership is generally higher among high-income groups (Kockelman, 1997; Dargay and Hanly, 2004; Soltani, 2005; Whelan, 2007).

4.2.3 The built environment or the individual and its household?

There seems to be a lot of literature confirming the relationship between the built environment and travel behaviour. Kockelman (1997) stressed that, after demographic characteristics were controlled for, the built environment still proved to have an important influence on travel behaviour. Similar conclusions have been made by, e.g., Dargay and Hanly (2004) and Zhang (2004). Meurs and Haaijer (2001) refined these findings. According to their analyses the built environment has a significant influence on non-work travel, whereas work travel is almost entirely determined by personal characteristics. Dieleman *et al.* (2002) found an equal influence of the built environment and personal characteristics. On the other hand, several studies point out that the built environment has only a moderate effect on travel behaviour (e.g., Cervero and Kockelman, 1997; Stead, 2001; Simma and Axhausen, 2003; Schwanen *et al.*, 2004).

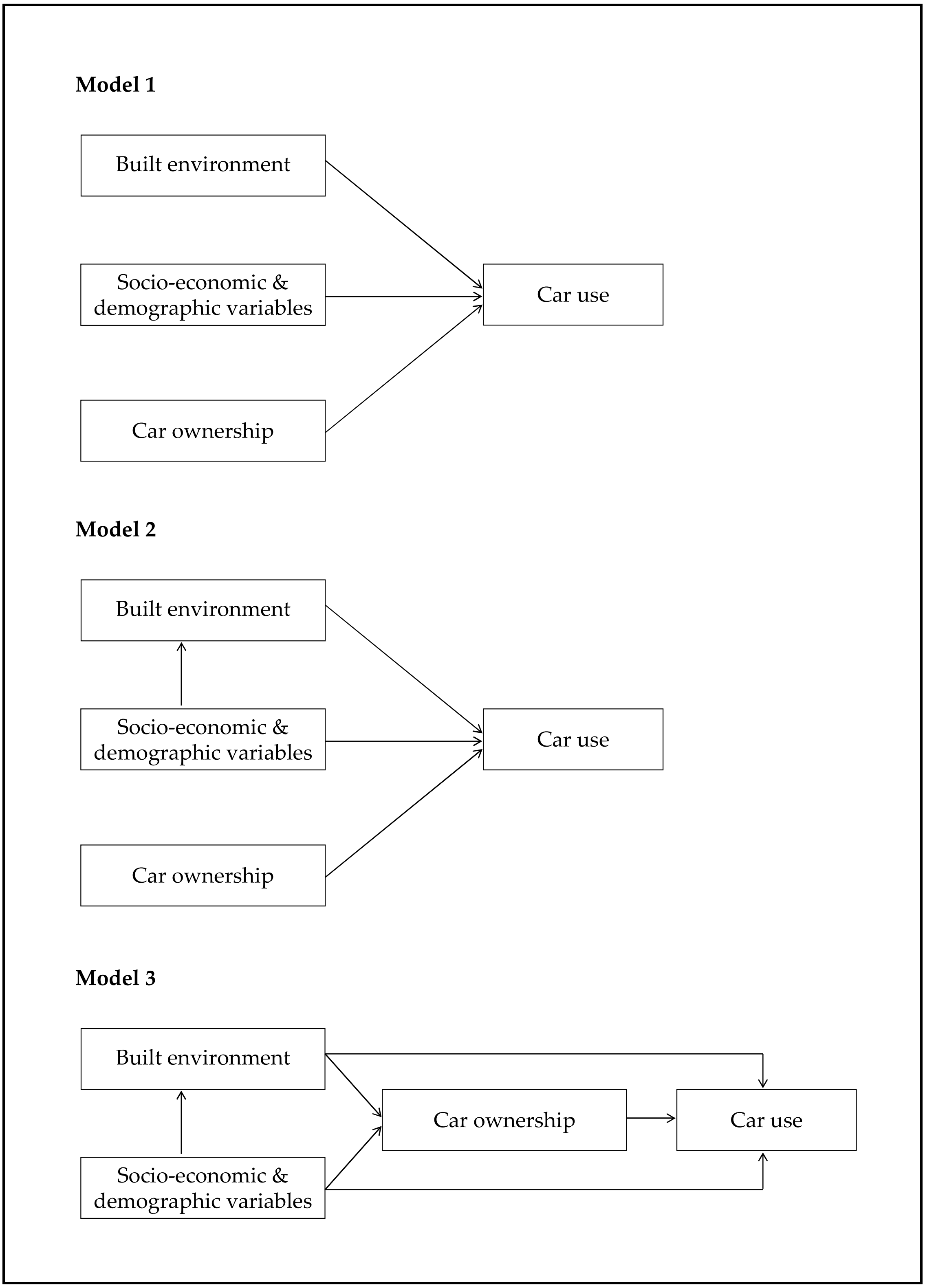
Moreover, there is a fundamental question of causation in any of the previously mentioned studies (Kockelman, 1997; Handy *et al.*, 2005). Based on these studies, it seems that in certain circumstances the built environment may have a statistically significant influence on travel behaviour. However, statistical results can mask underlying linkages that are more important and of which the built environment characteristics are only a proxy. For example, most recently, there is a growing body of literature on the relationship between the built environment and personal characteristics (e.g., Bagley and Mokhtarian, 2002; Cao *et al*., 2006; Bhat and Guo, 2007; Pinjari *et al.*, 2007). This research question refers to the issue of residential self-selection: people might self-select themselves into different residential neighbourhoods. Or in other words, people may choose their residential neighbourhood according to their personal attitudes and preferences. For example, people's residential location decision might be based on their travel preferences, so that they are able to travel according to these preferences. Consequently, the connection between the built environment and travel behaviour is more a matter of personal attitudes and preferences. Moreover, this suggests that the influence of the built environment can not be exogenously determined from these personal characteristics. This is confirmed by Bagley and Mokhtarian (2002) and Cao *et al.* (2006): i.e. after controlling for residential self-selection, the built environment was found to have little effect on travel behaviour. However, Bhat and Guo (2007) and Pinjari *et al.* (2007) state the opposite.

4.2.4 Conceptual model

Based on the previous literature review, several possible effects can be postulated between the built environment and travel behaviour. Figure 4.1 represents these model structures with increasing degree of complexity. The models can be applied to all aspects of travel behaviour, but our analysis is limited to mode choice and car use in particular.

The first model shown in Figure 4.1 resembles a frequently used approach in research on the relationship between the built environment and travel behaviour. In this model, travel behaviour is directly influenced by the built environment, various socio-economic and demographic variables, and car ownership. Model 1 considers car ownership as a variable explaining travel behaviour, but it does not consider car ownership as a mediating variable. Consequently, this model does not result in indirect effects of the built environment and socio-economic and demographic variables on travel behaviour. Since it does not include any relationships between the explanatory variables, this first model can be analyzed by means of a regression analysis. By assuming a relationship from personal characteristics to the built environment, the second model partly accounts for the issue of residential self-selection[1]. As a result, indirect effects of personal characteristics on travel behaviour will occur. Finally, in the third model we seek to reveal the importance of car ownership as a mediating variable while partly controlling for residential self-selection. In doing so, indirect effects of the built environment on travel behaviour occur as well. Mediating variables occur in models 2 and 3, and thus structural equation models must be estimated. Since all models are hierarchically nested in each other, we can compare the models' goodness-of-fit indices. Doing so, we are able to determine the improvement of each model compared to the previous one. Consequently, we can verify the intermediary effect of car ownership on travel behaviour, while partly controlling for residential self-selection.

Figure 4.1 Conceptual models describing the relationships between the built environment and travel behaviour



4.3 Methodology of structural equation modelling

The brief literature review highlights the complex relationship between the built environment and travel behaviour. Several variables must be accounted for and, moreover, these variables can influence each other as well. For example, car ownership can act as a mediating variable between the built environment and travel behaviour. Consequently, car ownership is the outcome variable (or dependent variable) in one set of relationships and at the same time it is a predictor (or explanatory variable) of travel behaviour. Structural equation modelling seems a suitable methodological technique since it can deal with such complex relationships.

Structural equation modelling is a research technique dating from the 1970s. Most applications have been in economics, psychology, sociology, the biological sciences, educational research, political science and marketing research. It is only recently that a structural equation model (SEM) has been applied to understand the relationship between the built environment and (car) travel behaviour (e.g., Bagley and Mokhtarian, 2002; Chung *et al.*, 2004; Cao *et al.*, 2007b; Van Acker *et al.*, 2007).

Structural equation modelling can be considered as a combination of factor analysis and regression analysis. The factor analysis aspect in a SEM refers to the modelling of indirectly observed (or latent) variables of which the values are based on underlying manifest variables (or indicators) which are believed to represent the latent variable. The measurement model, therefore, defines the relationships between a latent variable and its indicators. However, since all variables in our data source are directly observed (manifest variables), this paper is solely based on the regression analysis aspect of SEM. Therefore, our results are based on the estimation of a series of simultaneously estimated structural (i.e. regression) equations. Because a variable can be an explanatory variable in one equation but a dependent variable in another equation, we differentiate between 'endogenous' variables and 'exogenous' variables. Exogenous variables are not caused by any other variable in the model. Instead, exogenous variables influence other variables. In a graphical representation of a SEM, no paths (symbolized by arrows) will point towards exogenous variables and paths will only depart from exogenous variables towards other variables. Endogenous variables are influenced by exogenous variables, either directly or indirectly through other endogenous variables (Raykov and Marcoulides, 2000; Byrne, 2001; Kline, 2005). The relationships between exogenous and endogenous variables are represented by the structural model and are defined by the matrices (Hayduk, 1987; Oud and Folmer, 2008):

$$\boldsymbol{\eta} = \mathbf{B}\,\boldsymbol{\eta} + \boldsymbol{\Gamma}\,\boldsymbol{\xi} + \boldsymbol{\zeta} \qquad [4.1]$$

with $\boldsymbol{\eta}$ = L x 1 matrix of endogenous variables
$\boldsymbol{\xi}$ = K x 1 matrix of exogenous variables
B = L x L matrix of coefficients of the endogenous variables
$\boldsymbol{\Gamma}$ = K x K matrix of coefficients of the exogenous variables
$\boldsymbol{\zeta}$ = L x 1 matrix of residuals of the endogenous variables

The estimation of a SEM is (usually) based on matching the observed covariances among $\boldsymbol{\eta}$ and $\boldsymbol{\xi}$ with the model-based covariances. In this paper, we used the software package M-plus 4.21 because of its ability to model categorical endogenous variables.

4.4 Research design

4.4.1 Study area

For the purpose of addressing the research question how car ownership acts as a mediating variable in the relationship between the built environment and car use, data from the 2000-2001 Ghent Travel Behaviour Survey (Onderzoek Verplaatsingsgedrag (OVG) Gent) were used. The study area comprises the urban region of Ghent which consists of the city of Ghent itself, a medium-sized city in Flanders, Belgium, and the surrounding urbanized villages of Evergem, De Pinte, Destelbergen, Melle and Merelbeke. In 2000, the total population in this study area was about 315,166 inhabitants and the overall population density was 960.8 inhabitants/km². This is much higher than the average population density in Flanders (439.3 inhabitants/km²) and Belgium (335.4 inhabitant/km²).

4.4.2 Data source and study sample

The Ghent Travel Behaviour Survey is part of a series of travel surveys in different urban regions in Belgium. Since 1994-1995, the OVG survey is carried out every five years. In every survey, about 2,500 households are asked to participate. The survey yields data on the travel behaviour of approximately 5,500 persons, including children over the age of six. In addition to information on personal and household characteristics, all household members have to complete a trip diary for two consecutive days. This resulted in 39,712 trips reported in the 2000-2001 Ghent Travel Behaviour Survey. However, trips on the second day are reported less correctly (Zwerts and Nuyts, 2001; Witlox, 2007) and, thus, omitted in further analyses. Given that our focus is on the role of car ownership in explaining the relationship between the built environment and car use, the analysis is based on all trips of persons aged 18 years and older. These persons are considered to undertake trips relatively independently. Moreover, the legal age of obtaining a driving licence is 18 years in Belgium. Therefore, persons aged 18 or older have a potentially larger choice set of travel modes than younger persons. We also limited out analysis to short- and medium-distance trips (N = 12,672 trips), since 95% of all trips are undertaken over a distance of up to 60 km. In doing so, we avoid the disturbance of our results by the characteristics of long-distance trips.

4.4.3 Key variables

Variables used in the analysis include characteristics of the built environment, personal and household characteristics and aspects of car travel behaviour (see Table 4.1). Built environment characteristics only refer to density, diversity and accessibility; design aspects could not be included in the analysis due to a lack of suitable data.

The built environment is characterized by (i) built-up index, (ii) land use diversity, (iii) distance to the nearest railway station, (iv) distance to the CBD of Ghent, and (v) accessibility by car. Information on these characteristics is only available for the residence, where most trips depart from. Such information is, however, not always available for the various trip destination locations. The built-up index equals the percentage of built-up surface at the census tract level. It can be considered as a proxy for built-up density. It is derived from the land use database of the Agency of Spatial Information Flanders which offers a categorization between built-up surfaces and open surfaces. Land use diversity quantifies the degree of balance across residences, services and commerce, recreation and tourism, and regional and local industry. Information on these land use types is obtained from regional zoning plans and recalculated at the census tract level in ArcGIS 9.2 according to the equation (Bhat and Gossen, 2004):

$$\text{Land use diversity} = 1-\left(\frac{\left|\frac{r}{T}-\frac{1}{5}\right|+\left|\frac{c}{T}-\frac{1}{5}\right|+\left|\frac{t}{T}-\frac{1}{5}\right|+\left|\frac{i}{T}-\frac{1}{5}\right|+\left|\frac{o}{T}-\frac{1}{5}\right|}{\frac{8}{5}}\right) \qquad [4.2]$$

with r = km² in residences
c = km² in services and commerce
t = km² in recreation and tourism
i = km² in regional and local industry
o = km² in other land use types
$T = r + c + t + i + o$

A value of 0 means the land use pattern is exclusively determined by a single land use, whereas a value of 1 indicates a perfect mixing of different land uses. Distance to the nearest railway station is calculated in ArcGIS 9.2 as the shortest path by car along the road network between the residence and the nearest railway station. Distance to the CBD of Ghent is similarly defined. Accessibility by car is defined as the number of people that can be reached by car within 15 minutes[2]. For each residence, accessibility is calculated using the regional travel demand forecasting model Multimodal Model Flanders. It is basically the sum of the number of people of every census tract in the region, weighted by the travel time from the residence to these census tracts. Travel time is calculated in ArcGIS 9.2 as the fastest path by car along the road network. We restricted this travel time to 15 minutes in order to detect differences in local accessibility. After all, our study area has a limited geographical scale so that differences in accessibility are more important on a local level (e.g., within 15 minutes) than a regional level (e.g., within 60 minutes).

Personal characteristics include age, possession of a driving licence (0 = yes, 1 = no), marital status (0 = married/cohabiting, 1 = single) and full-time employment (0 = not full-time employed, 1 = full-time employed). Household characteristics include monthly household income (three classes) and car ownership (number of cars per household). Car use is defined as a binary variable. If a trip is undertaken by car (as a car driver or as a passenger) on the survey day, this variable obtains a value of 1. As a result, car use is a categorical endogenous variable in our analysis. This is no restriction to our analysis since we use the software package M-plus 4.21. As mentioned before, one of the features of this software package is the ability to model categorical endogenous variables.

Almost 12% of all households in our sample do not own a car. Table 4.1 illustrates that these households have lower incomes compared to households with several cars. Moreover, Table 4.1 suggests that households with no cars generally reside in densely built neighbourhoods closer to the city centre of Ghent. Surprisingly, these neighbourhoods are not characterized by more land use diversity. Instead, our data suggest that households with several cars live in more diverse neighbourhoods. We suspect that diversity is also associated with higher real estate prices, and rather attract households with higher incomes, and thus more cars.

Table 4.1 Summary of variables included in the analysis

	no cars *N* = 261 households	**1 car** *N* = 1,277 households	**2 or more cars** *N* = 674 households
Built environment			
built up index	0.75 (0.207)	0.66 (0.246)	0.52 (0.251)
land use diversity	0.15 (0.116)	0.17 (0.114)	0.19 (0.112)
distance to railway station (km)	5.02 (2.338)	6.02 (2.619)	7.53 (2.720)
distance to CBD (km)	3.28 (2.547)	4.25 (3.242)	5.69 (3.574)
accessibility by car, 15 min. (# inh.)	94,331 (15,173.8)	94,811 (18,454.0)	92,301 (20,581.0)
Socio-economic and demographic characteristics			
age	53.69 (17.495)	49.43 (15.160)	43.56 (12.190)
driving licence	57.7% no, 42.3% yes	11.5% no, 88.5% yes	2.8% no, 97.2% yes
marital status	32.6% married/ cohabiting 67.4% single	75.0% married/ cohabiting 25.0% single	83.0% married/ cohabiting 17.0% single
monthly household income	91.6% 0-1,859 € 7.7% 1,860-3,099 € 0.8% +3,100 €	58.9% 0-1,859 € 36.0% 1,860-3,099 € 5.1% +3,100 €	14.7% 0-1,859 € 33.4% 1,860-3,099 € 35.7% +3,100 €
full-time employed	64.1% no, 9.8% yes	36.8% no, 63.2% yes	23.4% no, 76.6% yes
Travel behaviour characteristics			
car use	90.2% no, 9.8% yes	36.8% no, 63.2% yes	23.4% no, 76.6% yes

Note: Standard deviations are mentioned between parentheses. Non-significant built environment characteristics and other socio-economic and demographic characteristics are not reported in Table 4.1.

4.5 A SEM for car use

Having specified the research design and the potential different roles car ownership plays in explaining car use (see Figure 4.1) we now turn our attention to the modelling results.

4.5.1 Model specification issues

As in other multivariate techniques, maximum likelihood (ML) method is a generally used estimating procedure in SEM. A basic assumption of this ML-estimator is the multivariate normal distribution of all continuous endogenous variables in the model (Kline, 2005, p. 112). However, in reality this assumption is not always fulfilled. Our models include several not-normally distributed variables and, moreover, our final outcome variable car use is categorical. An alternative estimator in such circumstances is a mean- and variance-adjusted weighted least square parameter estimator (WLSMV) which we used instead. WLSMV is a robust estimator yielding robust standard errors that does not require extensive computations and does not require enormously lager sample sizes. In addition to robust estimation, a robust mean-adjusted and mean- and variance-adjusted chi-square can be given (Muthén, 1983; Satorra, 1992; Yu and Bentler, 2000).

We have to note that the modelling process consists of two phases. During the first phase, all variables mentioned in Table 4.1 are included in the models. However, only those variables that significantly influence car ownership and car use are retained in the second modelling phase during which the final models are estimated. Insignificant influences were constrained to be zero.

We also controlled our analysis for the effect of outliers. Commonly used measures to detect outliers are the Mahalanobis distance or the Loglikelihood. However, we could not calculate these measures: the Mahalanobis distance is only available for continuous endogenous variables and the Loglikelihood assumes maximum likelihood estimators. However, M-plus can also calculate Cook's D (Cook, 1977, 1979) and a loglikelihood distance influence measure adjusted for weighted least squares estimators (Cook and Weisberg, 1982) for each observation. These outlier scores were plotted against the scores for car ownership and car use, which are key variables in the model. Doing so, we were able to determine 41 outliers. We removed five outliers at a time and observed the changes in goodness-of-fit indices of the model and individual parameter estimates. Comparable to other studies (e.g., Gao *et al.*, 2008), we found that the χ^2 statistic generally increased after each step of removing outliers. This indicates a worse-fitting model since the χ^2 statistic is the product of the sample size minus one (*N-1*) and the minimized fit function (F_{min}) (Byrne, 2001, p. 78; Kline, 2005, p. 135). A larger χ^2 statistic with a smaller sample size indicates an increase of F_{min}, or in other words a greater discrepancy between the observed covariance matrix and the model-based covariance matrix. Moreover, the means and variances of all variables for the reduced sample are close to the ones of the original sample. After all, 41 outliers on an original sample size of 12,672 observations seem negligible. These findings supported the decision to retain as much information as possible. The results reported in section 4.5.3 are based on all 12,672 observations.

4.5.2 Model fit indices

A widely used index to determine model fit is the χ^2-statistic which measures the discrepancy between the observed and model-based covariance matrices. However, χ^2 values increase with sample size and, thus, models based on large sample sizes might be rejected based on their χ^2 value even though small differences exist between the observed and model-based covariance matrices. Nevertheless, it is reported in Table 4.2 since χ^2 is the basis for other model fit indices (Byrne, 2001; Kline, 2005). Moreover, a dozen of alternative model fit indices are described in the SEM literature in contrast to other multivariate techniques such as linear regression.

Table 4.2 reports some alternative model fit indices from several different index families. Model fit of the three models generally improves with increasing complexity of the models. However, only the third model obtains a good fit. Only the WRMR-value indicates that the model still can be improved. However, based on the findings of the literature review and the modification indices calculated by M-plus, we could not improve our third model in a theoretically sound way. We suspect that other variables such as attitudes and lifestyles must be accounted for and could improve the modelling results. However, our data source does not contain that kind of information. Therefore, we decided to retain model 3 in its present form.

The model fit of each model separately indicates that model 3 is an improvement over model 2 and model 1. This is also confirmed by a χ^2 difference. The models are hierarchically nested into each other so that comparing the χ^2 values is possible. The χ^2 difference test suggests that model 2 is an improvement over model 1 ($\chi^2\Delta$ = 9,676.238, df = 8, p = 0.000), and model 3 over model 2 ($\chi^2\Delta$ = 6,459.387, df = 7, p = 0.000). Or in other words, defining car ownership as a mediating variable while partly controlling for residential self-selection adds explanatory power to the models. Model 3 is, therefore, retained for further discussion.

Table 4.2 Comparison of some model fit indices for the three models

Model fit indices	Formula	Description	Cut-off value	Model-based value		
				Model 1	Model 2	Model 3
χ^2 (df)	$(N\text{-}1)\ F_{min}$	Measuring the discrepancy between the observed and model-based covariance matrices. χ^2 dependents on sample size. Smaller values indicate better model fit.	$p > 0.05$	13,530.427 (24) $p = 0.000$	4,196.113 (16) $p = 0.000$	521.171 (13) $p = 0.000$
Error-of-approximation-based indices						
RMSEA (Root Mean Square Error of Approximation)	$\delta = \max(\chi^2 - df, 0)$ $RMSEA = \sqrt{\frac{\delta}{df(N-1)}}$	Measuring the amount of error of approximation per model degree of freedom, while controlling for sample size. Smaller values indicate better model fit.	< 0.05	0.21	0.14	0.05
Residual-based fit indices						
WRMR (Weighted Root Mean Square Residual)	$\sqrt{\frac{\sum_r^e (s_r - \hat{\sigma}_r)/v_r}{e}}$ where e is the number of sample statistics, s_r and $\hat{\sigma}_r$ are elements of the sample statistics and model-estimated vectors, respectively, v_r is an estimate of the asymptotic variance of s_r	Measuring the weighted average differences between the observed and estimated variances and covariances.	< 1.00	21.58	11.18	3.89
Measures of comparative fit to a baseline model						
CFI (Comparative Fit Index)	$1 - \frac{\delta_M}{\delta_B}$	Assessing the improvement of the hypothesized model M compared to the independence model B with unrelated variables.	> 0.90	0.07	0.71	0.97
TLI (Tucker-Lewis Index)	$\frac{\frac{\chi_B^2}{df_B} - \frac{\chi_M^2}{df_M}}{\frac{\chi_B^2}{df_B} - 1}$	Assessing the improvement of the hypothesized model M compared to the independence model B with unrelated variables.	> 0.90	-0.05	0.51	0.93

Note: Based on Hu and Bentler (1999), Yu (1999), Byrne (2001) and Kline (2005).

4.5.3 Direct, indirect and total effects

Prior to discussing the results of model 3, we determine the consequences of ignoring car ownership as a mediating variable by comparing the results of model 1, model 2 and model 3. Table 4.3 reports unstandardized as well as standardized total effects. Unstandardized total effects point out the direction and the significance of the relationship between the built environment, and car ownership and car use, whereas standardized total effects illustrate the strength of this relationship.

Table 4.3 Comparison of total effects on car use of the three models (significant at $\alpha = 0.05$)

	Model 1	Model 2	Model 3
Built environment characteristics			
built up index	-0.781 (-0.173)	-0.611 (-0.134)	-0.699 (-0.155)
land use diversity	-	-	-0.023 (-0.005)
distance to railway station	-	0.517 (0.091)	0.192 (0.034)
distance to CBD	-	-	0.077 (0.013)
accessibility by car, 15 min.	-	0.391 (0.065)	0.153 (0.026)
Socio-economic and demographic characteristics			
age	-0.360 (-0.065)	-0.361 (-0.064)	-0.356 (-0.064)
no driving licence	-1.008 (-0.277)	-1.010 (-0.274)	-0.996 (-0.272)
marital status, single	-0.285 (-0.112)	-0.286 (-0.110)	-0.282 (-0.110)
household income, 0-1,859 € (ref. cat.)			
household income, 1,860-3,099 €	-	0.089 (0.039)	0.159 (0.071)
household income, + 3,100 €	-	0.154 (0.053)	0.376 (0.129)
full-time employed	0.062 (0.028)	0.062 (0.028)	0.061 (0.027)
car ownership	2.968 (0.234)	2.974 (0.231)	2.350 (0.224)

Note: - = no significant effect defined, unstandardized coefficients are mentioned without parentheses, standardized coefficients are mentioned between parentheses

According to our findings, ignoring the effects of residential self-selection and/or car ownership as a mediating variable might result in a misspecification of the effects of the built environment. While partly controlling for the effects of residential self-selection model 2 did not consider car ownership as a mediating variable. Two built environment characteristics, the distance between the residence and the nearest railway station as well as car accessibility, obtain larger unstandardized total effects. Moreover, their standardized total effects are somewhat larger than in model 3, indicating a more important influence compared to other variables. Ignoring car ownership as a mediating variable can also lead to non-significant effects of the built environment. The significant effects in model 3 of land use diversity and distance between the residence and the CBD of Ghent disappear in model 2. Only the built-up index seems to maintain a similar effect. This is also the case in the first model which does not account for residential self-selection and car ownership as a mediating variable. All built environment characteristics, except the built-up index, have an insignificant effect on car use in model 1. The effect of car ownership itself on car use might also be somewhat overestimated if results of model 1 and model 2 are compared to model 3. These findings confirm that, while controlling for residential self-selection, car ownership should be considered as a mediating variable to correctly determine the effects of the built environment on travel behaviour.

Subsequent to determining model fit, the significance of every single parameter in model 3 is tested. We controlled our results for the issue of residential self-selection by estimating the effect of income on the built environment characteristics (see Table 4.4). Based on our data, higher incomes are associated with living in less densely built and more diverse neighbourhoods. These neighbourhoods have good car accessibility, but are also located further away from the CBD of Ghent and the nearest railway station. Doing so, the results are partly controlled for residential self-selection.

Table 4.4 Direct, indirect and total effects on car ownership and car use (significant at $\alpha = 0.05$)

	BUILT UP INDEX (R^2 = 1.8%)		
	Direct effect	**Indirect effect**	**Total effect**
household income, 0-1,859 € (ref. cat.)			
household income, 1,860-3,099 €	-0.039 (-0.077)	-	-0.039 (-0.077)
household income, + 3,100 €	-0.095 (-0.148)	-	-0.095 (-0.148)
	LAND USE DIVERSITY (R^2 = 0.4%)		
	Direct effect	**Indirect effect**	**Total effect**
household income, 0-1,859 € (ref. cat.)			
household income, 1,860-3,099 €	0.016 (0.034)	-	0.016 (0.034)
household income, + 3,100 €	0.040 (0.066)	-	0.040 (0.066)
	DISTANCE TO RAILWAY STATION (R^2 = 0.1%)		
	Direct effect	**Indirect effect**	**Total effect**
household income, 0-1,859 € (ref. cat.)			
household income, 1,860-3,099 €	0.011 (0.027)	-	0.011 (0.027)
household income, + 3,100 €	0.013 (0.025)	-	0.013 (0.025)
	DISTANCE TO CBD (R^2 = 0.9%)		
	Direct effect	**Indirect effect**	**Total effect**
household income, 0-1,859 € (ref. cat.)			
household income, 1,860-3,099 €	0.024 (0.062)	-	0.024 (0.062)
household income, + 3,100 €	0.050 (0.102)	-	0.050 (0.102)
	ACCESSIBILITY BY CAR, 15 MIN. (R^2 = 0.1%)		
	Direct effect	**Indirect effect**	**Total effect**
household income, 0-1,859 € (ref. cat.)			
household income, 1,860-3,099 €	-	-	-
household income, + 3,100 €	0.017 (0.034)	-	0.017 (0.034)

Note: - = no significant effect defined, unstandardized coefficients are mentioned without parentheses, standardized coefficients are mentioned between parentheses

Table 4.4 Direct, indirect and total effects on car ownership and car use (significant at $\alpha = 0.05$) *continued*

	CAR OWNERSHIP (R^2 = 37.3%)		
	Direct effect	**Indirect effect**	**Total effect**
Built environment characteristics			
built up index	-0.038 (-0.088)	-	-0.038 (-0.088)
land use diversity	-0.010 (-0.022)	-	-0.010 (-0.022)
distance to railway station	0.082 (0.151)	-	0.082 (0.151)
distance to CBD	0.033 (0.058)	-	0.033 (0.058)
accessibility by car, 15 min.	0.065 (0.115)	-	0.065 (0.115)
Socio-economic and demographic characteristics			
age	-0.026 (-0.049)	-	-0.026 (-0.049)
no driving licence	-0.076 (-0.219)	-	-0.076 (-0.219)
marital status, single	-0.020 (-0.080)	-	-0.020 (-0.080)
household income, 0-1,859 € (ref. cat.)			
household income, 1,860-3,099 €	0.055 (0.255)	0.003 (0.014)	0.055 (0.269)
household income, + 3,100 €	0.128 (0.463)	0.007 (0.025)	0.128 (0.488)
	CAR USE (R^2 = 20.1%)		
	Direct effect	**Indirect effect**	**Total effect**
Built environment characteristics			
built up index	-0.610 (-0.135)	-0.089 (-0.020)	-0.699 (-0.155)
land use diversity	-	-0.023 (-0.005)	-0.023 (-0.005)
distance to railway station	-	0.192 (0.034)	0.192 (0.034)
distance to CBD	-	0.077 (0.013)	0.077 (0.013)
accessibility by car, 15 min.	-	0.153 (0.026)	0.153 (0.026)
Socio-economic and demographic characteristics			
age	-0.294 (-0.053)	-0.062 (-0.011)	-0.356 (-0.064)
no driving licence	-0.817 (-0.223)	-0.180 (-0.049)	-0.996 (-0.272)
marital status, single	-0.236 (-0.092)	-0.046 (-0.018)	-0.282 (-0.110)
household income, 0-1,859 € (ref. cat.)			
household income, 1,860-3,099 €	-	0.159 (0.071)	0.159 (0.071)
household income, + 3,100 €	-	0.376 (0.129)	0.376 (0.129)
full-time employed	0.061 (0.027)	-	0.061 (0.027)
car ownership	2.350 (0.224)	-	2.350 (0.224)

Note: - = no significant effect defined, unstandardized coefficients are mentioned without parentheses, standardized coefficients are mentioned between parentheses

Table 4.4 reports the direct, indirect and total effects on car ownership and car use. According to the unstandardized total effects, car ownership is lower among people living in densely built and diverse neighbourhoods as expected. The same seems to hold for distance to the nearest railway station and distance to the CBD of Ghent. On the other hand, residing in neighbourhoods with good car accessibility might encourage car ownership. This indicates that the built environment can have the presumed effect on car ownership. All socio-economic and demographic variables have the expected effect on car ownership. Car ownership is positively related to household income, and it is negatively related to age, not owning a driving licence and being single. Nevertheless, other variables, such as full-time employment, gender, education and the presence of young children, are not significant and, therefore, not reported in Table 4.4.

Comparable conclusions can be drawn for car use. Unstandardized total effects indicate that people living in a highly built and mixed use neighbourhood are less likely to use a car on the survey day. Both spatial aspects have the expected and significant effect on car use. Moreover, based on our data car use is also likely to be lower among people residing in neighbourhoods close to a railway station and the CBD of Ghent. However, car use is likely to be higher in neighbourhoods with good car accessibility. Car use is positively related to monthly household income, being full-time employed and car ownership. On the other hand, our results suggest that older people and people not owning a driving licence or being single are less likely to use a car on the survey day. It is important to base these conclusions on the total effects. Total effects are the sum of direct and indirect effects. Whereas other studies sometimes find opposing direct and indirect effects (e.g., Gao *et al.*, 2008; Van Acker and Witlox, 2010), all variables with a direct as well as an indirect influence have synergistic effects resulting in even larger total effects. However, focusing on direct effects only would lead to inconsistent conclusions in some cases. For example, our data suggests that most built environment characteristics are not significantly associated with car use if one should only focus on direct effects. However, car use is likely to be influenced by the built environment but mainly in an indirect way through the interaction with car ownership. This finding could give us the impression that car ownership is only a substitution of the built environment. However, the built-up index has a significant direct effect on car use. This suggests that car ownership replaces the influence of some but not all built environment characteristics. Another example relates to the influence of income on car use. It is believed that middle and high income families can afford to own (several) cars and to travel more by car. However, the direct effect of monthly household income on car use is not significant. It is only through the indirect effect, caused by the interaction between car ownership and car use, that the total effect is significant. This indicates that car mobility of high income groups is not necessarily caused by their higher incomes but rather by their higher car ownership.

Based on the standardized total effects (reported between parentheses in Table 4.4), variables can be distinguished that determine car ownership and car use to a large extent. It seems that car ownership is mainly influenced by monthly household income and owning a driving licence. However, our data also suggests an important influence of the built environment on car ownership, especially car accessibility and the distance between the residence and the nearest railway station. The effect of the built environment is, however, less pronounced for car use than for car ownership. Only the built-up index has a considerable effect on car use, other socio-economic and demographic variables such as owning a driving licence are more important. The standardized direct effect also suggests a clear relationship between car ownership and car use. Hence, our analysis points out that the effect of the built environment on car use primarily exists through the mediating variable car ownership.

4.6 Conclusion

So far, empirical studies on travel behaviour consider car ownership either as an aspect of travel behaviour that has to be explained or as a variable that explains other aspects of travel behaviour (e.g., car use, travel distance, etc.). This paper aimed at combining both approaches and deducing the meaning of car ownership as a mediating variable.

Since car ownership is considered as an explanatory and a dependent variable at the same time, statistical techniques such as regression analysis are no longer suitable. Structural equation modelling is a more advanced modelling technique that can be used to disentangle the complexity of travel behaviour. Within this paper, a structural equation model (SEM) is used to estimate the relationships between the built environment, car ownership and car use.

SEM is a confirmatory method; hence, the modelling process has to be guided by a conceptual model and hypotheses. By comparing the overall fit of three models, we found that car ownership likely mediates the relationship between the built environment and car use. The interpretation of the modelling results also confirmed car ownership as a mediating variable. For example, some studies (e.g., Kockelman, 1997; Schwanen *et al.*, 2002; Dargay and Hanly, 2004) assume a direct effect of income on car use. However, with our definition of car use as a binary variable in mind, our analysis indicated that the income effect on car use probably exists only through car ownership. Thus, car use seems to be influenced only indirectly by income. Nevertheless, direct effects of income remain possible on other aspects of travel behaviour. For example, higher incomes probably do significantly contribute to higher distances travelled. Moreover, ignoring car ownership as a mediating variable is likely to result in a misspecification of the effects of the built environment: the effect of some built environment characteristics on car use might be overestimated. This indicates that car ownership should be considered as a mediating variable in order to correctly determine the usefulness of urban planning policies which intend to discourage car use.

Comparing our findings with modelling results from other studies on the relationship between the built environment and travel behaviour points out that our model explain a relatively large proportion of variance in car use (R^2 = 20.1%)[3]. However, it also indicates that other variables must be taken into account to fully understand car travel behaviour. Some studies (e.g., Bagley and Mokhtarian, 2002; Schwanen and Mokhtarian, 2005a, b; Van Acker *et al.*, 2010) suggest that socio-psychological characteristics, such as lifestyle, perceptions, attitudes and preferences, may add explanatory power.

Our analysis does however offer some insights which support the importance of the built environment. Unlike the findings of other studies (e.g. Dieleman *et al.*, 2002; Simma and Axhausen, 2003; Schwanen *et al.*, 2004), we found that lower car ownership and less car use is associated with living in high density and mixed use neighbourhoods which have poor car accessibility and are located close to the CBD of Ghent or a railway station. Although the unstandardized model results point out a desired effect of the built environment on car use, the standardized results indicate that this relationship is weak. Other variables, especially car ownership, influence car use to a greater extent. This suggests that urban planning policies should not only focus on influencing car use directly by measures of increasing density and diversity, but also on indirect measures through car ownership. Once people own a car, they tend to use it more often. Besides making cars directly more expensive to own and operate, i.e. through registration fees, gasoline taxes and road pricing, our results suggest that urban planning policies can apply measures of increasing density and diversity in order to discourage car ownership (Boussauw and Witlox, 2009). In this way, urban planning policies are likely to influence car travel behaviour.

Notes

1. Model 2 in Figure 4.1 partly accounts for residential self-selection since it only does so with respect to observed personal variables. Mokhtarian and Cao (2008) mention two sources from which residential self-selection occur: personal characteristics and attitudes. Since our data source does not include information on attitudes, we can only consider a relationship between personal characteristics and the built environment.
2. We are aware that accessibility is more than just having access to people. Access to facilities such as jobs and shops is important as well. However, we do not focus on a specific travel motive such as working or shopping. Consequently, we could limit our accessibility measure to having access to people and use this measure as a proxy for accessibility in general.
3. We have to note that with a dichotomous outcome variable, the reported explained proportion of variance is actually the variance in the underlying continuous latent variable for which the binary car use variable is the

observed manifestation, and not the variance in the observed car use variable itself.

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"Wees niet bang langzaam te gaan,
wees alleen bang stil te staan."

Chinese proverb

5. COMMUTING TRIPS WITHIN TOURS

HOW IS COMMUTING RELATED TO LAND USE?

Van Acker, V., Witlox, F. (2010) Commuting trips within tours: How is commuting related to land use? Transportation (under review).

Abstract Studies that model the affects of land use on commuting generally use a trip-based approach or a more aggregated individual-based approach: i.e. commuting behaviour is conceptualized in terms of modal choice, commuting distance and commuting time per single trip or in terms of daily commuting distance or time. However, people try to schedule activities in a daily pattern and, thus, consider tours instead of trips. Some studies acknowledge this fact by estimating the effect of tour complexity on commuting behaviour. However, our results suggest that ignoring tour complexity as an explanatory variable does not result in the misspecification of the effect of other explanatory variables such as land use characteristics. Moreover, our findings suggest that trip-related decisions should be considered simultaneously with tour-related decisions. Car use and commuting times significantly differ between commuting trips within work-only tours and commuting trips within more complex tours. A multiple group structural equation model (SEM) confirmed that the relationship between land use and commuting behaviour differs between work-only tours and more complex tours. The effect of land use characteristics at home is stronger for commuting trips in work-only tours, whereas commuting trips in more complex tours are mainly influenced by land use characteristics at work. However, this only holds for car use. This clearly illustrates that trips should be considered within tours in order to correctly understand the effect of land use scenarios such as densifying on commuting behaviour. Moreover, the use of multiple group SEM enabled us to address the issue of the complex nature of commuting behaviour. Due to interactions between various explanatory variables, land use patterns do not always have the presumed effect on commuting behaviour. This suggests that land use policy can successfully influence commuting behaviour, only if it simultaneously accounts for the land use effects on car availability, car use, commuting distance and commuting time.

5.1 Introduction

In Belgium, like in most other European countries, the influence of land use patterns on commuting remains an important issue for planners, urban policy makers and transport researchers. This important concern is fed by the notable increase in daily commuting distances and times. In 2001 a commuter travelled on average 19 kilometres and spend on average 29 minutes on the journey to work (one-way trip to work), which is an increase of 1.8 kilometres (or almost 10%) and 2 minutes (or almost 7%) compared to 1981 (Verhetsel *et al.*, 2007). If this trend continues, transport policy expects that Belgians will commute for about one hour per day in 2010 (Ministerie van de Vlaamse Gemeenschap, 2001). This is confirmed by findings of recent time use research: Belgian commuters travel on average 64 minutes to and from their workplace (Glorieux *et al.*, 2008). Research has indicated that these (slightly) increasing commuting times are mainly due to increasing commuting distances (especially the increase in long-distance commuting), but are also due to higher levels of road congestion and, thus, decreasing commuting speeds (Mérenne *et al.*, 1997; Verhetsel *et al.*, 2007). Other countries face similar situations (e.g., for Canada: Vandersmissen *et al.*, 2003; for the USA: Hsu and Reusher, 2004; for Great-Britain: Dargay and Hanly, 2007; for the Netherlands: Susilo and Maat, 2007).

In order to find a solution to these growing transportation problems in general, and commuting problems in particular, urban planners and transport policy makers have tried to integrate land use planning and transportation planning. Because most travel is derived from the activities a person wants to participate in, a change of location of these activities and a change of the design characteristics of these locations will alter travel patterns. Therefore, an integrated land use and transportation policy would allow us to better alleviate today's transportation problems. Illustrative of this approach are the New Urbanism movement in the United States (e.g., Greenwald, 2003; Handy, 2005) and the Compact City Policy in Europe (e.g., Schwanen *et al.*, 2004; Maat *et al.*, 2005). Both policies aim at modifying travel behaviour through land use planning. The basic idea is that high-density and mixed-use neighbourhoods are believed to be associated with shorter trips and more non-motorized trips; hence, indicating a clear relationship between land use and travel behaviour.

Although numerous studies have tried to measure and explain the strength of this relationship (for a review, see, e.g. Badoe and Miller, 2000; Crane, 2000; Ewing and Cervero, 2001 for the USA; Stead and Marshall, 2001; van Wee, 2002 for Europe), there is little consensus to be found in the conclusions of these studies. Some studies (e.g., Cervero and Kockelman, 1997; Meurs and Haiijer, 2001) indicate that various land use characteristics are linked with travel behaviour, while others (e.g., Bagley and Mokhtarian, 2002; Schwanen, 2002) state the opposite. These conflicting results might be caused by, among others, different research designs (e.g., cross-sectional versus longitudinal) and the usage of a variety of geographical scales (e.g., neighbourhoods versus larger metropolitan areas), contexts (e.g., Western cities versus rapidly evolving cities), and conceptual and theoretical models (e.g., models with causal relations versus correlation models). Moreover, empirical studies often use a trip-based approach (e.g., Rajamani *et al.*, 2003; Guo *et al.*, 2007) or a more aggregated individual-based approach (e.g., Buliung and Kanaroglou, 2006; Giuliano and Dargay, 2006): i.e. travel behaviour is conceptualized in terms of modal choice, travel distance or travel time per trip or these aspects are aggregated into summary measures such as daily travel distance and daily travel time. However, activity-based studies point to some disadvantages of such an approach. People do not make separate decisions considering only trips, but they try to schedule activities in a daily pattern and, thus, think about tours instead of trips (Jones *et al.*, 1990; Bhat and Koppelman, 1999; McNally, 2000; Primerano *et al.*, 2008). Consequently, trip characteristics might depend on tour characteristics. To our knowledge, tour characteristics such as tour frequency and tour complexity are in most empirical studies considered as dependent variables that are explained by land use patterns (e.g., Krizek, 2003; Limanond and Niemeier, 2004; Maat and Timmermans, 2006). Only a few studies consider tour-related characteristics simultaneously with trip-related characteristics. For example, Frank *et al.* (2008) and Srinivasan (2002) analyzed how land use influences modal choices for trips in different tour types. This paper also focuses on trips *within* tours by comparing modal choice, more specifically car use, between work-only tours (i.e. home-work-home) and more complex tours (i.e. tours in which commuting trips are combined with other trips such as shopping or leisure trips). Moreover, we statistically test the differential influence of land use on modal choices between tour types.

The remainder of the paper is organized as follows. Section 5.2 provides a brief literature review of the relationship between land use and commuting behaviour. The methodological framework of multiple group structural equation modelling is outlined in Section 5.3. This is followed by Section 5.4 in which the dataset and the applied research design are described. Section 5.5 describes the model results and, finally, in Section 5.6, some major conclusions are drawn.

5.2 Land use and commuting

The effect of land use on commuting behaviour has been the subject of many studies. For most people, living and working are two spatially separated activities that necessitate some form of commuting. Changes in the spatial configuration of these activities are likely to influence commuting behaviour (Handy, 1992; Cervero and Seskin, 1995). Important and frequently mentioned land use characteristics include density, diversity and design (Cervero and Kockelman, 1997) and accessibility (Geurs and van Wee, 2004).

Many studies found density to be negatively associated with car ownership, car use, commuting distances and commuting times. Various density measures exist: Levinson and Kumar (1997) used population density; Frank and Pivo (1994) calculated population and employment density, and Susilo and Maat (2007) calculated the effects of residential density and transport network density. For example, using Metropolitan Adelaide travel data, Soltani (2005) found that as density increases, the likelihood of owning more cars decreases. On average, an increase in density of 100 persons per hectare is associated with a 4-6% decrease in car ownership. Similar results have been found by Schwanen *et al.* (2002), but with respect to commuting modal choice and commuting distance. Based on the 1998 Netherlands National Travel Survey, Schwanen *et al.* (2002) stated that an increase in density of 100 residences per square kilometre is likely to result in 10% less commuting by car. Moreover, an increase in job density at the residence by 100 jobs per square kilometre is associated with shorter commuting distances (-2%). However, other studies such as Crane (2000) and Handy (1996) questioned the impact of density on commuting behaviour. They emphasized that density might be merely a proxy for other land use characteristics that are correlated with density. Moreover, the influence of density on tour complexity (i.e., the number of stops per tour) is not well-understood. Some studies (e.g., Strathman *et al.*, 1994; Maat and Timmerman, 2006) suggest that higher densities are associated with more complex tours and less simple tours (out and back), whereas other studies find the opposite which indicates that trips might be chained into complex tours in order to compensate for locational deficiencies (e.g., Noland and Thomas, 2007).

Another important aspect of land use is diversity. Higher diversities are believed to result in lower car ownership levels, lower car use, shorter commuting distances and shorter commuting times. As with density, diversity can be measured in several ways. For example, Potoglou and Kanaroglou (2008) calculated an entropy index and a mixed density index. The entropy index referred to the mixing of several land use types such as residential, commercial and industrial within walking distance (500m) of the residence. The mixed density index was a combination of residential density and employment density and can be considered as a proxy of the jobs-housing balance (Ewing *et al.*, 1994; Peng, 1997). Using the CIBER-CARS survey (Hamilton, Canada), their results indicated that diversity negatively influences car ownership, especially the probability of a household to own two or more cars. Frank and Pivo (1994) also used an entropy index, but in relationship with modal choice for work trips. Based on travel data of the Puget Sound Area (USA), land use mixing was found to be significantly related to less car use and more walking and transit usage. Cervero (1996) investigated how the presence of retail shops within residential neighbourhoods influences commuting behaviour. The presence of nearby commercial land-uses was found to be associated with lower car ownership levels and more non-motorized commuting, as well as with shorter commuting distances.

A third land use characteristic is design. Meurs and Haaijer (2001) included in their analysis of travel patterns in the Netherlands design characteristics of the dwelling (e.g., house type, presence of a garden, presence of garage) as well as of the street (e.g., traffic calming measures, pedestrian priority area). However, these characteristics did not have much effect on modal choice for commuting trips. Based on travel data of the San Francisco Bay Area, Cervero and Kockelman (1997) obtained similar results. In contrast to non-work trips, work trips were not significantly influenced by residential design characteristics.

Accessibility is a fourth important land use characteristic. Accessibility has become a frequently used concept, but its meaning always refers to the ability "to reach activities or locations by means of a (combination of) travel mode(s)" (Geurs and van Wee, 2004). This definition already indicates that accessibility is related to other land use characteristics, especially to density. Higher densities increase the likelihood to have several opportunities within reach, and thus density might be associated with accessibility. Consequently, some studies suggest that the impact of density is mediated through accessibility variables (e.g., Miller and Ibrahim, 1998; Badoe and Miller, 2000). Most studies agree on the effects of accessibility on commuting behaviour. For example, based on a sample from the Sacramento County (USA), Gao *et al.* (2008) found that households living in residential locations with higher job accessibility are likely to own fewer cars. Kitamura *et al.* (1997) found for five neighbourhoods in San Francisco that better accessibility levels by public transport result in more trips by public transport. Several studies also point out that accessibility is negatively associated with commuting times (e.g., Ewing *et al.*, 1994; Shen, 2000; Susilo and Maat, 2007) and tour complexity (e.g., Krizek, 2003; Limanond and Niemeier, 2004)

Although there seems to be a lot of literature confirming the relationship between land use and transport, the empirical evidence is somewhat contradictory and inconclusive. For example, Schwanen *et al.* (2002) pointed out that commuting time was influenced by personal and household characteristics to a greater extent than by land use characteristics. Similar conclusions related to modal choice for commuting and commuting distances were obtained by Dieleman *et al.* (2002) and to tour complexity by Cao *et al.* (2008).

Many studies have examined the impact of land use on commuting behaviour. The greater part of these studies only includes land use characteristics of the residence since this is the origin of most trips. However, a limited amount of studies also include land use characteristics of the destination. These studies provide interesting insights in commuting behaviour since land use characteristics of the destination might play a different role than residential land use characteristics. For example, Chen *et al.* (2008) studied modal choice decisions for commuting trips in the New York Metropolitan Region. They found that car use is discouraged by higher employment densities at work, in contrast to density measures at home which did not obtain a significant effect. Similar results were obtained by Ewing and Cervero (2001), Chatman (2003) and Shiftan and Barlach (2002).

Previously cited studies collect land use variables at a variety of spatial scales, ranging from micro scaled zones such as census tracts (e.g., Chen *et al.*, 2008; Gao *et al.*, 2008; Van Acker and Witlox, 2010) to macro scaled zones such as the municipality or larger metropolitan areas (e.g., Dieleman *et al.*, 2002; Simma and Axhausen, 2003; Susilo and Maat, 2007). However, the effects of different zonal sizes and the partitioning scheme of these zones are combined to form the so-called modifiable areal unit problem (MAUP) (Openshaw and Taylor, 1979; Unwin, 1996). Research has shown that the estimated relationships between land use patterns and travel patterns might be sensitive to MAUP effects (e.g., Zhang and Kukadia, 2005). This paper, however, does not focus on the MAUP, but nevertheless we should be aware that this could affect our results and findings.

Also, most recently, there is a growing interest in the issue of residential self-selection (e.g., Bagley and Mokhtarian, 2002; Cao *et al.*, 2006; Bhat and Guo, 2007; Pinjari *et al.*, 2007). This issue refers to the potential problem that people might self-select themselves into different residential neighbourhoods. In other words, people's residential location decision might be based on their travel preferences, so that they are able to travel according to these preferences. Consequently, the connection between land use and travel behaviour is more a matter of residential location choice. After controlling for residential self-selection, Bagley and Mokhtarian (2002) and Cao *et al.* (2006) found little effect of land use on travel behaviour, whereas Bhat and Guo (2007) and Pinjari *et al.* (2007) found the opposite.

Figure 5.1 Land use and commuting behaviour

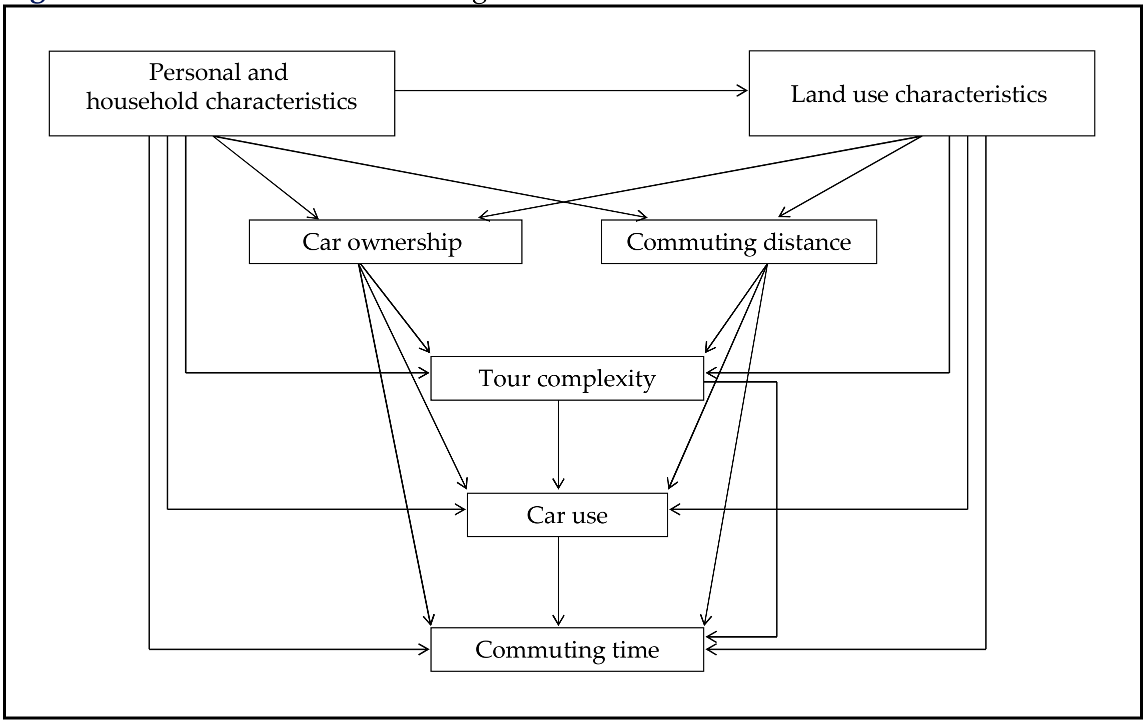


Figure 5.1 summarizes the previously described relationships between land use, personal and household characteristics and commuting behaviour. It includes all relationships that will be estimated and discussed in Section 5.5.

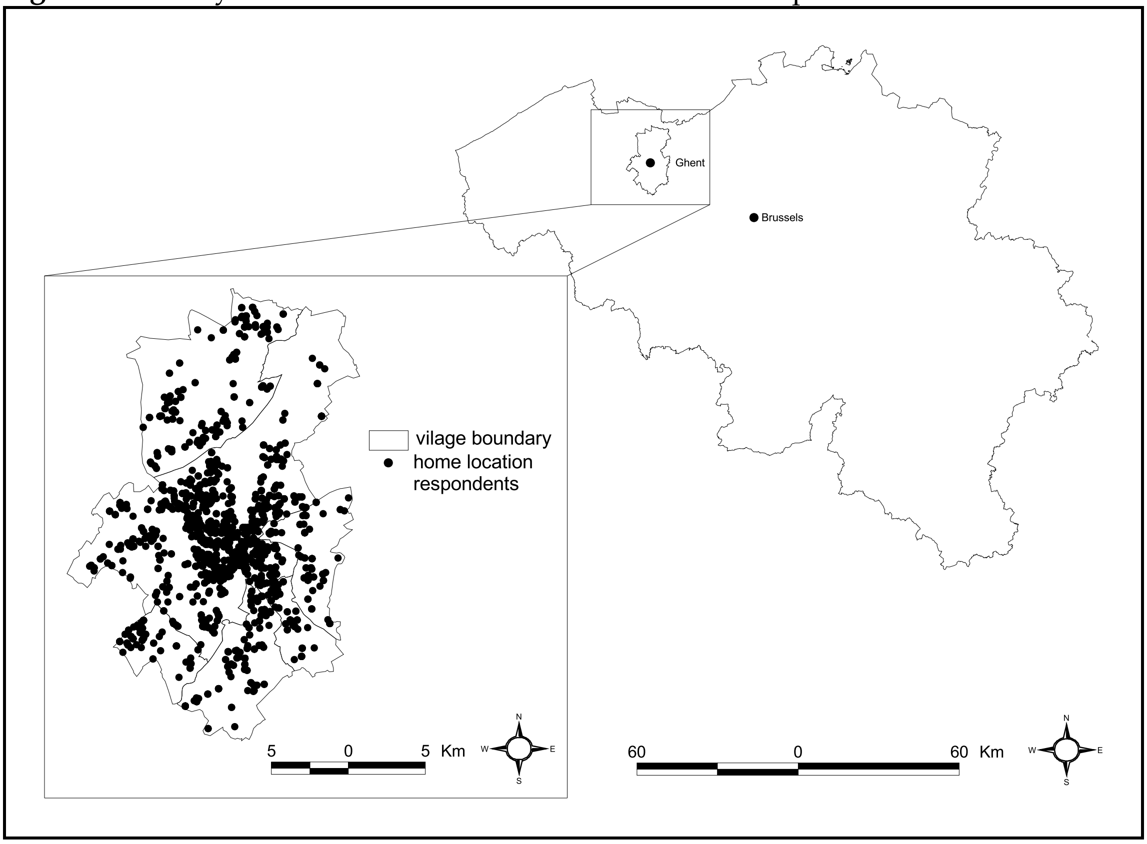
Relationships might also exist between several aspects of commuting behaviour. Whereas most empirical studies focus on the effect of land use on a specific aspect of commuting behaviour, it might also be useful to consider several aspects of commuting behaviour simultaneously. For example, some studies indicated that car ownership mediates the relationship between land use and modal choice (e.g., Schimek, 1996; Simma and Axhausen, 2003; Chen *et al.*, 2008; Van Acker and Witlox, 2010). Similar to Schwanen *et al.* (2002) and Susilo and Maat (2007), we suppose that modal choice is influenced by commuting distance, and commuting time is influenced by both commuting distance and modal choice. In most cases, workers always commute to the same workplace and, thus, commuting distance is unchangeable and might become a factor on which the modal choice is based. Longer commuting distances will favour the decision to commute by car (e.g., Cervero, 1996; Bhat, 1997; Cervero and Kockelman, 1997). Aside from the disturbing influence of congestion, commuting time is related to the velocity of the chosen travel mode and commuting distance. The car is a faster travel mode than public transport, walking or biking, and will result in shorter commuting times. Being all else equal, shorter commuting times can also be the result of short commuting distances. Our analysis will clarify this aspect. Another example of interrelations among commuting behaviour aspects relates to tour complexity.

Tour complexity can be considered as influenced by car ownership and commuting distance, whereas tour complexity on its turn influences modal choices. Studies suggest that the tendency to undertake complex or simple tours varies systematically with car ownership and commuting distance (e.g., Krizek, 2003; Maat and Timmerman, 2006) and that the participation in complex tours increases the propensity to use the car (e.g., Hensher and Reyes, 2000; Ye *et al.*, 2007; Chen *et al.*, 2008).

5.3 Research design

5.3.1 Study area

Figure 5.2 Study area and home locations of the selected respondents



Our analysis is based on data from the 2000-2001 Ghent Travel Behaviour Survey (Onderzoek Verplaatsingsgedrag (OVG) Gent). Figure 5.2 shows the study area of this survey, as well as the residential locations of the selected respondents. The study area comprises the urban region of Ghent which consists of the city of Ghent itself, a medium-sized city in Flanders, Belgium, and the surrounding urbanized villages of Evergem, De Pinte, Destelbergen, Melle and Merelbeke. In 2000, the total population in this study area was about

315,166 inhabitants and the overall population density was 960.8 inhabitants/km^2.

5.3.2 Data source

The Ghent Travel Behaviour Survey is part of a series of travel surveys in different urban regions in Belgium. In every survey, about 2,500 households were asked to participate. The survey yielded data on the travel behaviour of approximately 5,500 persons, including children over the age of six. In addition to information on personal and household characteristics, all household members had to complete a trip diary for two consecutive days. However, trips on the second day are reported less correctly (Zwerts and Nuyts, 2001; Witlox, 2007) and, thus, omitted in further analyses. This resulted in 15,783 usable trips reported in the 2000-2001 Ghent Travel Behaviour Survey.

5.3.3 Study sample

In view of the aims of this paper, we first classified each trip to the type of tour to which the trip belongs. A tour is defined as a sequence of trips that starts and ends at home. If such a tour only includes trips for working activities, it is defined as a work-only tour (68.5% of all tours). Most work-only tours (88.6%) are very straightforward: one leaves home for work, stays at the workplace and returns in the evening. A small amount of commuters (7.0%) spends, e.g., their lunch break at home and have multiple work-only tours during a single day. A small amount of work-only tours include tours with multiple workplaces (11.4%). Most of these tours combine two stops for working purposes, but some tours might become complicated (e.g., up to ten work stops per tour). A more complex tour combines trips for working activities with trips for non-working activities (31.5% of all tours). For example, children are dropped off at school before going to work or some grocery shopping is done during the lunch break. Second, we excluded the effects of long-distance commuting trips by selecting only trips less than 70 km's. This equals 95% of all commuting trips. Finally, only commuting trips of persons aged 18 years or older were selected (N = 2,174 trips). These persons are considered to undertake trips relatively independently. Moreover, in Belgium, the legal age at which one is allowed to drive is 18 years.

5.3.4 Land use characteristics, personal and household characteristics

Variables used in the analysis include land use characteristics of the residence and the workplace, personal and household characteristics and aspects of commuting behaviour (see Table 5.1). Land use characteristics only refer to density, diversity and accessibility; design aspects could not be included in the analysis due to a lack of suitable data.

Land use patterns of both the residence and the workplace are characterized by (i) job density, (ii) built-up index, (iii) land use mix, (iv) the distance to the nearest bus stop and nearest railway station, (v) the distance to the CBD of Ghent, and (vi) accessibility by car. Job density at the TAZ level is defined as the number of jobs per square km and is obtained from the Multimodal Model Flanders, a regional travel demand forecasting model for 2001 in Flanders, Belgium. The size of TAZ's in this model equals to the size of one or a pair of census tracts. Job density is used here as an indicator for the density dimension; however, for the residence end of the commute trip it has also been used as a measure of the diversity dimension (e.g., Boarnet and Sarmiento, 1998). However, our data suggest that job density at the residence is statistically significant correlated with population density. We preferred to use job density instead of population density, since a job-related measure seems to be more relevant for commuting than an inhabitant-related measure. Consequently, job density seems to be an appropriate indicator for the density dimension in our study. The built-up index at the census tract equals the percentage of built-up surface, and can be considered as a proxy for built-up density. It is derived from the land use database of the Agency of Spatial Information Flanders. The land use diversity index quantifies the degree of balance across residences, services and commerce, recreation and tourism, nature (parks, nature reserves and forests), agriculture, regional industry and local industry. Information on these land use types is obtained from regional zoning plans and recalculated at the census tract level in ArcGIS 9.2 according to the equation (Bhat and Gossen, 2004):

Land use diversity =

$$1-\left[\frac{\left|\frac{r}{T}-\frac{1}{8}\right|+\left|\frac{c}{T}-\frac{1}{8}\right|+\left|\frac{t}{T}-\frac{1}{8}\right|+\left|\frac{n}{T}-\frac{1}{8}\right|+\left|\frac{a}{T}-\frac{1}{8}\right|+\left|\frac{ri}{T}-\frac{1}{8}\right|+\left|\frac{li}{T}-\frac{1}{8}\right|+\left|\frac{o}{T}-\frac{1}{8}\right|}{\frac{14}{8}}\right] \quad [5.1]$$

with r = km² in residences, c = km² in services and commerce, t = km² in recreation and tourism, n = km² in nature, a = km² in agriculture, ri = km² in regional industry, li = km² in local industry, o = km² in other land use types, and T = r + c + t + n + a + ri + li + o.

A value of 0 means that the land use pattern is exclusively determined by a single land use, whereas a value of 1 indicates a perfect mixing of the different land uses. Distance to the nearest bus stop is calculated in ArcGIS 9.2 as the shortest path by car along the road network between the residence or the workplace and the nearest bus stop. Distances to the nearest railway station and the CBD of Ghent are similarly defined. Accessibility by car is calculated using the previously mentioned regional travel demand forecasting model Multimodel Model Flanders. Residential job accessibility by car is expressed by the number of jobs that can be reached by car. It is basically the sum of the number of jobs of every TAZ in the region, weighted by the travel time from the residence to these TAZ's. Travel times are calculated in ArcGIS 9.2 as the fastest path by car along the road network. We restricted this travel time to 15 and 30 minutes in order to detect differences in local and more regional job accessibility. Workplace accessibility by car is defined in a similar way. But since it is more relevant for workplace locations which can encounter competition effects for employees, we express workplace accessibility as the number of employees (and not jobs) available for the workplace. Finally, land use patterns of the workplace are also characterized by the level of parking difficulties. This is actually a subjective variable since respondents were asked to report whether they encountered difficulties parking their car at work (0 = no, 1 = yes).

Personal characteristics include gender (0 = male, 1 = female), age, marital status (0 = married/cohabiting, 1 = single), car needed during work hours (three classes). Household characteristics include household size, number of children aged below 6 years, monthly household income (three classes) and the number of cars per person able to drive. The latter is the ratio between the number of cars and the number of people with a driving license in the household, and is a measure of car availability.

Other personal and household characteristics such as education were not significant in our analysis. Therefore, these variables are not reported in Table 5.1. Commuting behaviour is characterized by tour type, car use, commuting distance, commuting time and tour complexity. Tour type and car use are defined as binary variables (tour type: 0 = work-only tour, 1 = more complex tour, car use: 0 = no car used, 1 = car used). As mentioned previously, a tour is defined as a sequence of trips that starts and ends at home. A work-only tour solely exists of commuting trips, whereas a more complex tour combines commuting trips with non-commuting trips. If the commuting trip within the tour is undertaken by car, the car use variable obtains a value of 1. Consequently, car use refers to the chosen mode for only the commuting trip. Commuting distance and commuting time refer to the travel distance and travel time of the work trip (home-work) within the tour. Finally, tour complexity represents the number of trips in the tour. For example, a home-work-home tour composes of two trips.

Table 5.1 Summary of variables included in the analysis

	Minimum	Maximum	Average	Standard deviation
Land use characteristics at home				
job density (jobs/km²)	0.75	18,176.83	1,135.07	2,354.098
built-up index	1.91	99.37	50.03	27.647
land use mix	0.00	0.56	0.18	0.126
job/housing balance	0.08	38.83	1.21	3.888
distance to bus stop (km)	0.00	2.38	0.29	0.223
distance to railway station (km)	0.21	16.99	5.47	3.724
distance to CBD (km)	0.20	14.21	7.14	3.001
job accessibility, 15 min.	40,604	133,390	92,550.28	20,200.380
job accessibility, 30 min.	131,482	282,641	209,548.58	38,340,688
Land use characteristics at work				
job density (jobs/km²)	3.85	44,777.24	2,734.67	6,053.266
built-up index	0.32	100.00	55.11	29.968
land use mix	0.00	1.00	0.18	0.131
job/housing balance	0.08	2855.00	16.84	167.063
distance to bus stop (km)	0.00	6.96	0.30	0.420
distance to railway station (km)	0.15	19.41	4.21	3.165
distance to CBD (km)	0.12	25.53	5.97	3.533
workplace accessibility, 15 min.	31,652	894,616	141,085.68	115,945.251
workplace accessibility, 30 min.	141,040	1,213,724	413,831.42	171,679.045
Household characteristics				
household size	1	11	2.86	1.299
children -6 years	0	3	0.26	0.606
car availability	0	5.0	0.80	0.390
Personal characteristics				
age	19	71	40.54	10.158
Commuting characteristics				
commuting distance (km.)	0.00	90.00	15.77	20.096
commuting time (min.)	1	90	22.94	18.145
tour complexity (stops per tour)	2	10	2.84	1.349
	Frequency			
Land use characteristics at work				
parking difficulties	79.8% no, 20.2% yes			
Personal characteristics				
gender	57.6% male, 42.4% female			
marital status	72.8% married/cohabiting, 27.2% single			
car needed during work hours	25.4% always, 28.1% often, 46.5% never			
employment	83.4% full-time employed, 16.6% part-time employed			
Household characteristics				
household income	32.4% 0-1859 €, 47.2% 1860-3099 €, 20.4% +3100 €			
Commuting behaviour characteristics				
car use	29.4% no, 70.6% yes			
tour type	68.5% work-only tour, 31.5% more complex tour			

Note: 2,174 trips; 1,627 tours; 1,521 persons; 1,144 households; 217 residential neighbourhoods, 458 workplace neighbourhoods

5.4 Methodological framework

The variables discussed in the previous section will now serve as input for the estimation of a structural equation model (SEM). Structural equation modelling is a suitable methodological technique for handling complex relationships, which exist between land use and commuting behaviour as the brief literature review in Section 5.2 has illustrated.

Structural equation modelling (SEM) is a methodology dating from the 1970s. Whereas most applications have been in economics, psychology and sociology, more sophisticated SEM applications such as latent class modelling or multiple group modelling have only recently been used in transportation studies (for a review, see Golob, 2003).

A SEM is represented by a set of simultaneously estimated equations. In doing so, SEM can handle relationships between several exploratory and predicted variables. This results in one of the main advantages of SEM (e.g., compared to regression analysis): the modelling of mediating variables and, as a consequence, the distinction between total, direct and indirect effects. The fact that a variable can be an exploratory variable in one equation but a predicted variable in another equation, makes it necessary to distinguish between 'endogenous' and 'exogenous' variables rather than between 'dependent' and 'independent' variables. Exogenous variables are not influenced by any other variable. Hence, when graphically representing the SEM, no paths (symbolized by arrows) will point towards these exogenous variables. Contrary to exogenous variables, endogenous variables are influenced by other variables, either directly or indirectly, and thus, paths will point towards endogenous variables in a graphical representation (Raykov and Marcoulides, 2000; Kline, 2005; Van Acker *et al.*, 2007).

The relationships between exogenous and endogenous variables are represented by the structural model and are defined by the matrices (Hayduk, 1987; Oud and Folmer, 2008):

$$\boldsymbol{\eta} = \mathbf{B}\,\boldsymbol{\eta} + \boldsymbol{\Gamma}\,\boldsymbol{\xi} + \boldsymbol{\zeta} \qquad [5.2]$$

with $\boldsymbol{\eta}$ = L x 1 matrix of endogenous variables, $\boldsymbol{\xi}$ = K x 1 matrix of exogenous variables, $\mathbf{B}$ = L x L matrix of coefficients of the endogenous variables, $\boldsymbol{\Gamma}$ = K x K matrix of coefficients of the exogenous variables, and $\boldsymbol{\zeta}$ = L x 1 matrix of residuals of the endogenous variables.

The relationships in Figure 5.1 can be expressed by a set of equations:

$$LU = \beta_{1LU} \times PH + \varepsilon_{LU} \qquad [5.3]$$
$$CO = \beta_{1CO} \times PH + \beta_{2CO} \times LU + \varepsilon_{CO}$$
$$CD = \beta_{1CD} \times PH + \beta_{2CD} \times LU + \varepsilon_{CD}$$
$$TC = \beta_{1TC} \times PH + \beta_{2TC} \times LU + \beta_{3TC} \times CO + \beta_{4TC} \times CD + \varepsilon_{TC}$$
$$CU = \beta_{1CU} \times PH + \beta_{2CU} \times LU + \beta_{3CU} \times CO + \beta_{4CU} \times CD + \beta_{5CU} \times TC + \varepsilon_{CU}$$
$$CT = \beta_{1CT} \times PH + \beta_{2CT} \times LU + \beta_{3CT} \times CO + \beta_{4CT} \times CD + \beta_{5CT} \times TC + \beta_{6CT} \times CU + \varepsilon_{CT}$$

with PH = personal and household characteristics, LU = land use characteristics, CO = car ownership, CD = commuting distance, TC = tour complexity, CU = car use, and CT = commuting time.

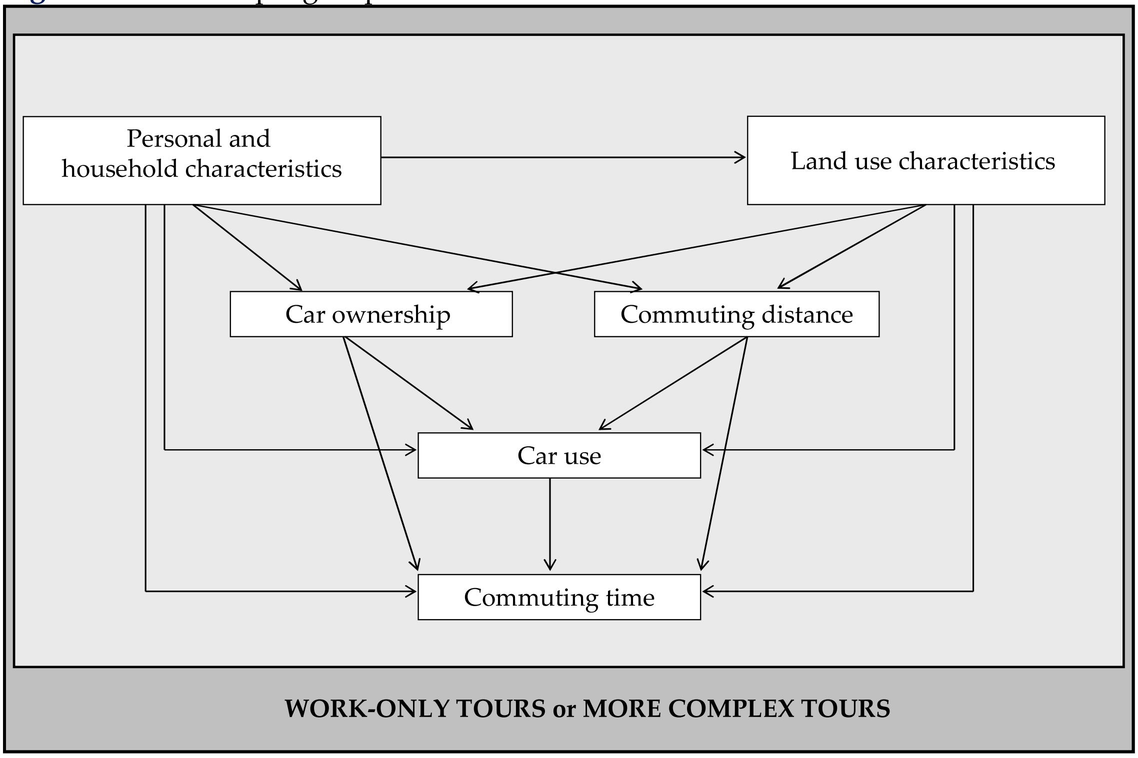
In this paper, we used the software package M-plus 4.21 (Muthén and Muthén, 2006) because it offers more facilities (e.g., the ability to model categorical endogenous variables, and the availability of estimation procedures that account for skewed distributed data) than other SEM software packages. For example, we defined car use as a binary variable and M-plus can model categorical endogenous variables. Moreover, M-plus has several estimation procedures that account for skewed distributed data. Given the fact that car use, commuting distance and commuting time are not normally distributed, the weighted least squares mean and variance adjusted (WLMSV) estimator is used to estimate the model. This estimator accounts for non-normally distributed data (Muthén and Kaplan, 1985; 1992).

The estimation of a SEM is (usually) based on matching the observed covariances among η and ξ with the model-based covariances. The χ^2- statistic measures the discrepancy between these observed and model-based covariance matrices and is a widely used index to evaluate model fit. However, χ^2 values increase with sample size and, thus, models based on large sample sizes might be rejected even though small differences exist between the observed and model-based covariance matrices. Therefore, SEM literature reports various alternative model fit indices which are mostly variations on the χ^2- statistic (for an overview, see Cao *et al.*, 2007; Van Acker and Witlox, 2010). Tables 5.2 and 5.4 in Section 5.5 mention several of these model fit indices. Cut-off criteria for these model fit indices are: χ^2 with p-value > 0.05, Comparative Fit Index (CFI) > 0.90, Tucker-Lewis (TLI) > 0.90, Root Mean Square Error of Approximation (RMSEA) < 0.05, Weighted Root Mean Square Residual (WRMR) < 0.90 (Hu and Bentler, 1999; Yu, 1999; Byrne, 2001; Kline, 2005).

In this paper, we do not only focus on the interrelationships between variables depicted in Figure 5.1 and Equations 5.3. We also want to know whether the relationship between land use and commuting behaviour differs between work-only tours and more complex tours. Or in other words: do the model parameters in Figure 5.1 vary across commuting trips in work-only tours and commuting trips in more complex tours? We assume that commuting trips in work-only tours are more influenced by the land use pattern than commuting trips in more complex tours. In work-only tours, land use characteristics of merely the workplace should favour commuting decisions, and land use characteristics at work should have a very straightforward influence on commuting. In more complex tours, working is combined with other non-working activities and, thus, land use characteristics of more than only the workplace location have to be considered. Commuting decisions will be based on land use characteristics of all stops in this tour, and not only on land use characteristics of the workplace. For example, although the workplace location offers good access by public transport, Vande Walle and Steenberghen (2006) found that a person will not commute by public transport if there is no easy access to public transport at other stops in the tour.

A commonly used approach would be to consider tour complexity as an explanatory variable of commuting behaviour (as illustrated by Figure 5.1). But this approach estimates only the magnitude and the significance of the effect of tour complexity on commuting behaviour. It remains unclear how the effects of land use characteristics on commuting vary *across* different tour types. The latter question could be addressed by performing analyses for each tour type separately, but instead, we advance a *multiple group* SEM. This model performs one single analysis in which parameters are estimated for both groups and hypotheses about both groups are tested *at once*. As illustrated by Figure 5.3, tour complexity is no longer considered as an endogenous variable in the model, but rather as outside the model defining the groups for which the model is tested. This offers two advantages over doing separate analyses (Arbuckle and Wothke, 1999). First, it determines the significance of any difference found between groups. In this way, we can determine whether the relationship between land use and car use for commuting trips really differs between work-only tours and more complex tours and, thus, if trip characteristics are influenced by tour characteristics. Second, if no differences are found between groups, more efficient parameter estimates are obtained by using the pooled sample to estimate them.

Figure 5.3 A multiple group SEM



A multiple group SEM is performed by the specification of one model with cross-group equality constraints and another model without such constraints. In doing so, equal unstandardized estimates between each group are derived for the constrained model and different unstandardized coefficients between each group are estimated for the unconstrained model. The fit of the constrained and the unconstrained model can then be compared. A significantly worse fit of the constrained model indicates that parameters are not equal across groups (Kline, 2005). In this analysis, we first constrained all parameters to be equal across commuting trips within work-only tours (= group 1) and commuting trips in more complex tours (= group 2). Second, we unconstrained the parameters of car use only. Contrary to car use, we assume that car ownership and commuting distance are not affected by the characteristics of the tour. The decisions to own a car and to commute over a specific distance are long-term decisions and happen at a very different level than the daily decision to perform a simple or complex tour (Salomon and Ben-Akiva, 1983; Van Acker *et al.*, 2010). Therefore, the parameters of car ownership and commuting distance were still constrained across both tour types.

5.5 Results

In what follows we discuss several aspects of the relationship between land use and commuting, modelled by a multiple group SEM. In all models, we controlled the results for the issue of residential self-selection by estimating the effect of income, household size and the presence of children aged below 6 years on the land use characteristics at home. Doing so, the results are (partly) controlled for residential self-selection.

Tables 5.2, 5.4 and 5.5 all report unstandardized coefficients as well as standardized coefficients of the model parameters. Unstandardized coefficients point out the direction and the significance of the relationship between land use and commuting behaviour, whereas standardized coefficients illustrate the strength of this relationship.

5.5.1 Tour complexity as an endogenous variable or not?

A first question that has to be addressed is whether tour complexity should be considered as an endogenous variable (as depicted in Figure 5.1) or as a variable outside the model that defines tour type (as depicted in Figure 5.3). Based on model fit, there are no reasons to favour the SEM with or without tour complexity. Both models have reasonably good model fit. However, Table 5.2 points out that neglecting tour complexity as an endogenous variable does not result in a misspecification of the land use effects on commuting. The magnitude and the significance levels of the coefficients of most model parameters are comparable for both models. Moreover, taken tour complexity into account does not result in larger values of explained variances. Consequently, it seems reasonable considering the less complicated model without tour complexity as an endogenous variable for further analyses.

Table 5.2 Comparison of total effects of two models with or without tour complexity

	MODEL WITH TOUR COMPLEXITY					**MODEL WITHOUT TOUR COMPLEXITY**			
χ² (df) p	208.242 (89) 0.000					179.286 (80) 0.000			
CFI	0.941					0.951			
TLI	0.928					0.939			
RMSEA	0.038					0.036			
WRMR	1.279					1.248			
	Commuting distance	**Car availability**	**Tour complexity**	**Car use**	**Commuting time**	**Commuting distance**	**Car availability**	**Car use**	**Commuting time**
Land use characteristics at home									
job density	-	-0.559* (-0.147)	-0.167* (-0.010)	-4.574* (-0.326)	0.017 (0.010)	-	-0.566* (-0.150)	-4.583* (-0.327)	0.003 (0.002)
land use mix	-	-	-	-0.164* (-0.042)	0.005* (0.011)	-	-	-0.164* (-0.042)	0.005* (0.011)
distance to bus stop	0.168* (0.076)	0.288* (0.062)	-0.067 (-0.003)	0.461* (0.027)	0.123* (0.060)	0.170* (0.077)	0.294* (0.064)	0.470* (0.028)	0.123* (0.060)
distance to railway station	-	0.177* (0.087)	-1.216* (-0.136)	-	-	-	0.171* (0.084)	0.118* (0.016)	-0.004* (-0.004)
job accessibility, 30 min.	-	0.129* (0.081)	-	-	-	-	0.129* (0.081)	0.089* (0.015)	-0.003* (-0.004)
Land use characteristics at work									
built-up index	-	-	0.475* (0.075)	-	-0.076* (-0.120)	-	-	-	-0.079* (-0.124)
distance to railway station	0.309* (0.214)		-0.279* (-0.021)	0.482* (0.043)	0.237* (0.178)	0.312* (0.216)	-	0.490* (0.044)	0.238* (0.179)
distance to CBD	-	-	-	-	-0.205* (-0.153)	-	-	-	-0.205* (-0.153)
workplace accessibility, 15 min.	1.127* (0.425)	-	1.591* (0.066)	1.758* (0.086)	0.847* (0.347)	1.121* (0.423)	-	1.757* (0.086)	0.855* (0.349)
workplace accessibility, 30 min.	-	-	-1.638* (-0.133)	-	-	-	-	-	-
jobs/housing balance	-	-	-	-	0.005* (0.063)	-	-	-	0.005* (0.063)
parking difficulties	-	-0.150* (-0.156)	-0.045* (-0.011)	-0.958* (-0.269)	-0.007 (-0.017)	-	-0.152* (-0.158)	-0.959* (-0.270)	-0.007 (-0.017)

Note: * = significant at $\alpha = 0.05$, ** = significant at $\alpha = 0.10$, standardized total effects shown in parentheses, - = no effect defined

Table 5.2 Comparison of total effects of two models with or without tour complexity *continued*

	MODEL WITH TOUR COMPLEXITY					MODEL WITHOUT TOUR COMPLEXITY			
	Commuting distance	**Car availability**	**Tour complexity**	**Car use**	**Commuting time**	**Commuting distance**	**Car availability**	**Car use**	**Commuting time**
Household characteristics									
household size	-	-0.023**	-0.034*	0.050*	0.001	-	-0.024*	0.049*	0.001
		(-0.078)	(-0.026)	(0.046)	(0.005)		(-0.081)	(0.045)	(0.005)
children -6 years	-	0.065*	0.236*	0.045*	-0.003*	-	0.065*	0.045*	-0.001*
		(0.109)	(0.091)	(0.020)	(-0.011)		(0.110)	(0.021)	(-0.005)
income, 0 - 1,845 € (ref.)									
income, 1,860 - 3,099 €	0.031**	0.021*	0.249*	0.173*	0.022*	0.030**	0.021*	0.173*	0.023**
	(0.088)	(0.028)	(0.076	(0.063)	(0.066)	(0.085)	(0.028)	(0.063)	(0.069)
income, + 3,100 €	0.031**	0.100*	0.458*	0.117*	0.018	0.029**	0.100*	0.115*	0.020
	(0.076)	(0.119)	(0.124	(0.038)	(0.049)	(0.072)	(0.120)	(0.037)	(0.054)
car availability	-	-	0.298*	0.689*	-0.023*	-	-	0.693*	-0.022*
			(0.068	(0.187)	(-0.051)			(0.187)	(-0.048)
Personal characteristics									
age	-	0.182*	-1.660*	0.125*	0.007	-	0.188*	0.130*	0.054**
		(0.090)	(-0.189)	(0.017)	(0.007)		(0.094)	(0.018)	(0.061)
gender, female	-0.023**	-	0.021	-0.036**	-0.018**	-0.024**	-	-0.037**	-0.018*
	(-0.062)		(0.006)	(-0.013)	(-0.052)	(0.065)		(-0.013)	(-0.053)
marital status, single	-	0.110*	0.033*	0.076*	-0.002*	-	0.107*	0.074*	-0.002*
		(0.128)	(0.009)	(0.024)	(-0.007)		(0.125)	(0.023)	(-0.006)
employment, part-time	-	0.054**	0.016	0.037**	-0.001	-	0.053*	0.037**	-0.004
		(0.054)	(0.004)	(0.010)	(-0.003)		(0.053)	(0.010)	(-0.003)
car work, never (ref.)									
car work, often	-	0.062**	0.019	0.528*	-0.016*	-	0.058**	0.527*	-0.016*
		(0.078)	(0.005)	(0.180)	(-0.046)		(0.073)	(0.179)	(-0.046)
car work, always	-	0.224*	0.067*	1.406*	-0.043*	-	0.207*	1.403*	-0.044*
		(0.261)	(0.018)	(0.443)	(-0.113)		(0.241)	(0.442)	(-0.114)

Note: * = significant at $\alpha = 0.05$, ** = significant at $\alpha = 0.10$, standardized total effects shown in parentheses, - = no effect defined

Table 5.2 Comparison of total effects of two models with or without tour complexity *continued*

	MODEL WITH TOUR COMPLEXITY					MODEL WITHOUT TOUR COMPLEXITY			
	Commuting distance	**Car availability**	**Tour complexity**	**Car use**	**Commuting time**	**Commuting distance**	**Car availability**	**Car use**	**Commuting time**
Commuting behaviour characteristics									
commuting distance	-	-	-0.904* (-0.099)	1.560* (0.203)	0.808* (0.876)	-	-	1.567* (0.204)	0.811* (0.878)
tour complexity	-	-	-	-	-0.006* (-0.061)	-	-	-	-
car use	-	-	-	-	-0.030* (-0.252)	-	-	-	-0.031* (-0.258)
R^2	***24.7%***	***16.9***	***10.8%***	***47.5%***	***73.8%***	***24.6%***	***16.2%***	***47.5%***	***73.3%***

Note: * = significant at α = 0.05, ** = significant at α = 0.10, standardized total effects shown in parentheses, - = no effect defined

5.5.2 Differences between work-only tours and more complex tours

Previous section confirmed that not accounting for tour complexity does not introduce biases in the coefficients for variables in other equations of the SEM. Consequently, our data suggest that tour complexity can be considered as a variable outside the model that defines tour type. A second part in our analysis is the estimation of a multiple group SEM. Contrary to a basic SEM (such as described in the previous section) which reports the effect of tour complexity and land use separately from each other, a multiple group SEM also illustrates the 'combined' effect of tour complexity and land use on commuting behaviour. That is to say, in our study, the multiple group SEM points out how the coefficients of the land use variables differ between simple work-only tours and more complex tours. This difference is important since it is likely that land use effects on commuting behaviour might be different for various tour types. A multiple group SEM will, thus, depict which land use scenarios are likely to influence commuting behaviour for specific tour types.

5.5.2.1 Descriptive analysis

Prior to discussing the results of a multiple group SEM, the differences in commuting behaviour between work-only tours and more complex tours need to be highlighted first (see Table 5.3). In work-only tours 67% of the commuting trips are undertaken by car, whereas this is somewhat higher in more complex tours (74%). On the other hand, commuting time is slightly longer in work-only tours than in more complex tours. This is logical because of competing time demands: the time someone spends at non-working activities is less time that one has to commute. Although differences are small, the Mann-Whitney U test specifies that these differences in commuting behaviour are indeed significant. Since car use and commuting times are not normally distributed, a non-parametric test, namely the Mann-Whitney U test, must be used instead of an ordinary t-test in order to compare commuting behaviour between work-only tours and more complex tours.

Table 5.3 Differences in commuting behaviour

	Work-only tour	More complex tour	Mann-Whitney U	P
Car use	67%	74%	437,297.00	0.001
Commuting time	21.6 min	18.2 min	432,389.00	0.000

5.5.2.2 Multiple group SEM

A multiple group SEM is assessed that compares the influence of land use on commuting trips between work-only tours and more complex tours. In a first step, a fully constrained model is estimated in which model parameters for both groups (work-only tours and more complex tours) are set equal. This fully constrained model results in a reasonably good model fit according to the values of CFI, TLI and RMSEA. However, the WRMR value is too high. In a second step, an unconstrained model is estimated in which model parameters of car use and commuting time vary between both groups. Model fit indices for this unconstrained model have slightly lower values than for the fully constrained model. However, a χ^2 difference test ($\chi^2 = 90.89$, df = 11, $p = 0.000 < 0.050$) confirmed that model parameters are not equal across work-only tours and more complex tours. Table 5.4 illustrates the consequences of neglecting the tour-based nature of travel. The direction of the relationship between land use and commuting behaviour are similar for the constrained and the unconstrained model. However, the size of the coefficients might differ significantly. For example, neglecting the tour-based nature of travel seems to result in an underestimation of the influence of residential characteristics for commuting trips within work-only tours (or an overestimation for commuting trips within more complex tours). This finding indicates the differential impact of land use measures when individuals travel in simple patterns or in more complex ways. Consequently, it is useful to examine the modelling results of the unconstrained model more into detail (see Section 5.5.2.3).

Table 5.4 Model estimation results (total effect) for car use and commuting time

	CONSTRAINED MODEL		UNCONSTRAINED MODEL			
χ² (df) p	336.883 (137) 0.000		299.915 (133) 0.000			
CFI	0.930		0.942			
TLI	0.921		0.932			
RMSEA	0.051		0.047			
WRMR	1.841		1.732			
			WORK-ONLY TOUR		MORE COMPLEX TOUR	
	Car use	Commuting time	Car use	Commuting time	Car use	Commuting time
Land use characteristics at home						
job density	-4.373*	0.022	-6.412*	0.043	-2.993*	0.014
	(-0.286)	(0.012)	(-0.392)	(0.022)	(-0.248)	(0.011)
land use mix	-0.172*	0.005*	-0.335*	0.013*	-0.056	0.001
	(-0.044)	(0.010)	(-0.081)	(0.026)	(-0.019)	(0.002)
distance to bus	0.268*	0.151*	0.221*	0.189*	0.276*	0.117*
stop	(0.017)	(0.082)	(0.013)	(0.096)	(0.016)	(0.061)
distance to	0.159*	-0.004*	0.179*	-0.007*	0.065	-0.001
railway station	(0.023)	(-0.005)	(0.024)	(-0.008)	(0.009)	(-0.001)
job accessibility,	0.093**	-0.003**	0.105	-0.004	0.038	0.000
30 min.	(0.017)	(-0.004)	(0.018)	(-0.006)	(0.006)	(-0.001)
Land use characteristics at work						
built-up index	-	-0.027	-	-0.049**	-	0.001
		(-0.046)		(-0.078)		(0.003)
distance to	0.495*	0.279*	0.401*	0.342*	0.501*	0.212*
railway station	(0.046)	(0.219)	(0.035)	(0.253)	(0.045)	(0.168)
distance to CBD	-	-0.267*	-	-0.312*	-	-0.191*
		(-0.218)		(-0.239)		(-0.143)
workplace	1.610*	0.908*	1.340*	1.144*	1.673*	0.710*
accessibility, 15	(0.090)	(0.430)	(0.071)	(0.509)	(0.101)	(0.380)
min.						
parking	-0.996*	0.026*	-1.018*	0.038*	-0.913*	0.010**
difficulties	(-0.285)	(0.066)	(-0.283)	(0.090)	(-0.282)	(0.028)
Household characteristics						
household size	0.047*	0.000	0.071*	0.000	0.036*	0.000
	(0.044)	(0.002)	(0.064)	(0.002)	(0.034)	(-0.001)
children -6 years	0.064*	-0.002*	0.081*	-0.003*	0.029**	0.000
	(0.027)	(-0.006)	(0.032)	(-0.010)	(0.015)	(-0.001)
income,						
0 - 1,845 € (ref.)						
income,	0.126*	0.003**	0.190*	0.004	0.093*	0.003
1,860 - 3,099 €	(0.048)	(0.011)	(0.068)	(0.011)	(0.035)	(0.009)
income,	0.083*	0.004*	0.098*	0.005	0.044*	0.005*
+ 3,100 €	(0.026)	(0.012)	(0.029)	(0.011)	(0.015)	(0.014)
car availability	0.883*	-0.024*	1.096*	-0.041*	0.397*	-0.004
	(0.256)	(-0.059)	(0.298)	(-0.095)	(0.104)	(-0.010)

Note: * = significant at $\alpha = 0.05$, ** = significant at $\alpha = 0.10$, standardized total effects shown in parentheses

Table 5.4 Model estimation results (total effect) for car use and commuting time *continued*

	CONSTRAINED MODEL		UNCONSTRAINED MODEL			
			WORK-ONLY TOUR		MORE COMPLEX TOUR	
	Car use	Commuting time	Car use	Commuting time	Car use	Commuting time
Personal characteristics						
age	0.149* (0.021)	-0.004* (-0.005)	0.193* (0.026)	-0.007* (-0.008)	0.070 (0.009)	-0.001 (-0.001)
gender, female	-0.026** (-0.010)	-0.015** (-0.046)	-0.023 (-0.008)	-0.019* (-0.057)	-0.028** (-0.010)	-0.012* (-0.038)
marital status, single	0.057* (0.019)	-0.002* (-0.004)	0.074* (0.023)	-0.003* (-0.007)	0.027 (0.009)	0.000 (-0.001)
car work, never (ref.)						
car work, often	0.600* (0.213)	-0.016* (-0.050)	0.464* (0.156)	-0.017* (-0.049)	0.950* (0.331)	-0.011** (-0.033)
car work, always	1.400* (0.377)	-0.038* (-0.088)	1.457* (0.370)	-0.055* (-0.118)	1.324* (0.458)	-0.015** (-0.046)
Commuting behaviour characteristics						
commuting distance	1.343* (0.170)	0.757* (0.811)	1.123* (0.129)	1.001* (0.968)	1.402* (0.195)	0.611* (0.756)
car use	-	-0.027* (-0.232)		-0.038* (-0.318)		-0.011** (-0.100)

Note: * = significant at α = 0.05, ** = significant at α = 0.10, standardized total effects shown in parentheses, - = no effect defined

5.5.2.3 Direct, indirect and total effects of work-only and more complex tours

Table 5.5 reports the estimation results of the unconstrained model more into detail. Contrary to Tables 5.2 and 5.4, Table 5.5 distinguishes total effects from direct effects.

Following our model results we can state that land use does influence commuting behaviour, but not all aspects of commuting behaviour are influenced in the same way. We found that higher job densities at home and shorter distances between the residence and the nearest bus stop, as well as the nearest railway station, will likely result in lower levels of car availability and lower car use. Commuting behaviour is merely influenced by diversity at home. Our analysis points out that more diversity is associated with car use and commuting time, but only for commuting trips in work-only tours. More diversity seems to result in less car use (β = -0.335), but also in longer commuting times (β = 0.013). The latter is actually due to the interrelationship between land use, car use and commuting time. More diversity results in lower car use, but lower car use does not result in shorter commuting times (β = -0.038). Lower car use means that commuters travel by slower modes such as public transport and biking. The indirect effect of diversity on commuting time through car use (0.013 = -0.335 x -0.038) consequently suggests that more diversity results in longer commuting times. Commuting distances are less influenced by land use characteristics at home: it is only influenced by the distance between the residence and the nearest bus stop.

Beside the influence of land use characteristics at home, we also tested the influence of land use characteristics at work. Our analysis indicates that parking difficulties at the workplace decrease car availability. This might indicate that land use patterns at the workplace might influence the decision on owning a car, an important factor of car availability. Consequently, people might commute by slower travel modes, resulting in lower car use and longer commuting times. Other land use characteristics at work include built-up density, the distance between the workplace and the nearest railway station as well as the CBD of Ghent, and workplace accessibility by car. Higher built-up densities are likely to result in shorter commuting times ($\beta = -0.049$ in work-only tours, not significant in more complex tours). Longer distances between the workplace and the nearest railway station are associated with longer commuting distances ($\beta = 0.357$), more car use ($\beta = 0.401$ in work-only tours, $\beta = 0.501$ in more complex tours) and longer commuting times ($\beta = 0.342$ in work-only tours, $\beta = 0.212$ in more complex tours). Despite more car use commuting times are longer, but in that case longer commuting times are likely the result of the interrelationship between land use, commuting distance and commuting time. Longer distances to the nearest railway station characterize remote workplace locations and, thus, are likely to be associated with longer commuting distances. Longer commuting distances on its turn are related with longer commuting times ($\beta = 0.958$ in work-only tours, 0.595 in more complex tours), resulting in a positive association between distance to the nearest railway station and commuting times after all. On the other hand, our data also suggest that longer distances between the workplace and the CBD of Ghent are negatively associated with commuting time. Workplace accessibility by car has the presumed effect on car use: workplaces with good car accessibility within 15 minutes are likely to encourage car use. However, commuting times are not shortened due to higher car use. This is again the result of the interaction between land use, commuting distance and commuting time.

Table 5.5 Model estimation results of the unconstrained model

	Commuting distance	Car availability	WORK-ONLY TOURS: Car use	WORK-ONLY TOURS: Commuting time	MORE COMPLEX TOURS: Car use	MORE COMPLEX TOURS: Commuting time
Land use characteristics at home						
job density	-	-0.577* (-0.130) *-0.577* (-0.130)*	-6.412* (-0.392) *-5.779* (-0.354)*	0.043 (0.022) *-0.199* (-0.103)*	-2.993* (-0.248) *-2.764* (-0.229)*	0.014 (0.011) *-0.019 (-0.014)*
land use mix	-	-	-0.335* (-0.081) *-0.335* (-0.081)*	0.013* (0.026) -	-0.056 (-0.019) *-0.056 (-0.019)*	0.001 (0.002) -
distance to bus stop	0.197* (0.104) *0.197* (0.104)*	-	0.221* (0.013) -	0.189* (0.096) -	0.276* (0.016) -	0.117* (0.061) -
distance to railway station	-	0.164* (0.081) *0.164* (0.081)*	0.179* (0.024) -	-0.007* (-0.008) -	0.065 (0.009) -	-0.001 (-0.001) -
job accessibility, 30 min.	-	0.096** (0.062) *0.096** (0.062)*	0.105 (0.018) -	-0.004 (-0.006) -	0.038 (0.006) -	0.000 (-0.001) -
Land use characteristics at work						
built-up index	-	-	-	-0.049** (-0.078) *-0.049** (-0.078)*	-	0.001 (0.003) *0.001 (0.003)*
distance to railway station	0.357* (0.273) *0.357* (0.273)*	-	0.401* (0.035) -	0.342* (0.253) -	0.501* (0.045) -	0.212* (0.168) -
distance to CBD	-	-	-	-0.312* (-0.239) *-0.312* (-0.239)*	-	-0.191* (-0.143) *-0.191* (-0.143)*
workplace accessibility, 15 min.	1.193* (0.549) *1.193* (0.549)*	-	1.340* (0.071) -	1.144* (0.509) -	1.673* (0.101) -	0.710* (0.380) -
parking difficulties	-	-0.155* (0.159) *-0.155* (0.159)*	-1.018* (-0.283) -0.848* (-0.236)	0.038* (0.090) -	-0.913* (-0.282) *-0.851* (-0.263)*	0.010** (0.028) -
Household characteristics						
household size	-	-0.015 (-0.048) *-0.026* (-0.085)*	0.071* (0.064) -	0.000 (0.002) -	0.036* (0.034) -	0.000 (-0.001) -
children -6 years	-	0.074* (0.108) *0.077* (0.113)*	0.081* (0.032) -	-0.003* (-0.010) -	0.029** (0.015) -	0.000 (-0.001) -

Note: * = significant at $\alpha = 0.05$, ** = significant at $\alpha = 0.10$, direct effects shown in italics, standardized effects shown in parentheses, - = no effect defined

Table 5.5 Model estimation results of the unconstrained model *continued*

	Commuting distance	Car availability	WORK-ONLY TOURS		MORE COMPLEX TOURS	
			Car use	Commuting time	Car use	Commuting time
Household characteristics						
income, 0 - 1,845 € (ref.)						
income, 1,860 - 3,099 €	0.005* (0.016) -	0.017* (0.022) -	0.190* (0.068) -	0.004 (0.011) -	0.093* (0.035) -	0.003 (0.009) -
income, + 3,100 €	0.008* (0.021) -	0.081* (0.089) _0.073* (0.080)_	0.098* (0.029) -	0.005 (0.011) -	0.044* (0.015) -	0.005* (0.014) -
car availability	-	-	1.096* (0.298) _1.096* (0.298)_	-0.041* (-0.095) -	0.397* (0.104) _0.397* (0.104)_	-0.004 (-0.010) -
Personal characteristics						
age	-	0.176* (0.087) _0.176* (0.087)_	0.193* (0.026) -	-0.007* (-0.008) -	0.070 (0.009) -	-0.001 (-0.001) -
gender, female	-0.020* (-0.062) _-0.020* (-0.062)_	-	-0.023 (-0.008) -	-0.019* (-0.057) -	-0.028** (-0.010) -	-0.012* (-0.038) -
marital status, single	-	0.067* (0.077) _0.067* (0.077)_	0.074* (0.023) -	-0.003* (-0.007) -	0.027 (0.009) -	0.000 (-0.001)
car work, never (ref.)						
car work, often	-	0.091* (0.112) _0.091* (0.112)_	0.464* (0.156) _0.365* (0.122)_	-0.017* (-0.049) -	0.950* (0.331) _0.914* (0.318)_	-0.011** (-0.033) -
car work, always	-	0.231* (0.216) _0.231* (0.216)_	1.457* (0.370) _1.204* (0.306)_	-0.055* (-0.118) -	1.324* (0.458) _1.232* (0.426)_	-0.015** (-0.046) -
Commuting behaviour characteristics						
commuting distance	-	-	1.123* (0.129) _1.123* (0.129)_	0.958* (0.927) _1.001* (0.968)_	1.402* (0.195) _1.402* (0.195)_	0.595* (0.737) _0.611* (0.756)_
car use	-	-	-	-0.038* (-0.318) _-0.038* (-0.318)_	-	-0.011* (-0.100) _-0.011* (-0.100)_

Note: * = significant at $\alpha = 0.05$, ** = significant at $\alpha = 0.10$, direct effects shown in italics, standardized effects shown in parentheses, - = no effect defined

Since we consider trip-related characteristics simultaneously with tour-related characteristics, we can compare the effect of land use on commuting trips across work-only tours and more complex tours. We suggested that commuting trips in more complex tours are less influenced by land use patterns, which is partly confirmed by our model results. Coefficients of land use characteristics at home are generally lower in magnitude and less significant for commuting trips in more complex tours. Moreover, the opposite seems true for land use characteristics at work, but this only holds for car use. Workplace locations that are characterized by shorter distances to the nearest railway station, worse car accessibility and difficult parking situations are associated with lower car use, even if the commuting trip is combined with other non-commuting trips. We assume that these types of workplace locations are also characterized by more diversity. Non-commuting activities might, therefore, be performed nearby the workplace location. In doing so, individuals are not necessitated to commute by car after all. The differential influence of land use is less pronounced for commuting time. Furthermore, the relationship between land use and commuting time is not that strong. Standardized coefficients reveal that commuting time is mainly influenced by commuting distance (B = 0.927 for work-only tours, B = 0.737 for more complex tours).

By estimating a SEM, we are not limited to focus on the relationship between land use and one single aspect of commuting behaviour (e.g., commuting time). Other aspects of commuting behaviour can act as mediating variables. For example, in our model car use mediates the relationship between land use and commuting time. Because of such mediating variables, indirect effects of land use on commuting behaviour occur. Some of these indirect effects have been discussed above and we cannot stress the importance of this finding enough. For example, our analysis supports the view that commuting time can be influenced by land use policies but mainly indirectly. Using a simple regression analysis, researchers might conclude that a relationship exists between land use and commuting time while neglecting the fact that this is particularly an indirect relationship. Higher densities, more diversity and better access to public transport can result in shorter commuting times but only through the interaction with commuting distance. If such land use policies enable commuters to shorten their commuting distances in the first place, lower commuting times become possible. A relationship between land use and commuting exists, but one should be aware of the direct and indirect nature of this relationship.

5.6 Conclusions

With this paper we aimed to contribute to the existing research debate on the relationship between land use and commuting. In all, three important points can be made. First of all, many empirical studies focus on single trips, whereas activity-based studies recognize that people combine trips for different activities into one single tour (Hanson, 2004). This study, therefore, analyzed commuting trips *within* different types of tours. By estimating a multiple group SEM, we found that the effect of land use on commuting was different for work-only tours and more complex tours. The effect of land use on commuting is more pronounced in simple work tours. But this depends on which aspect of commuting behaviour is analyzed. This also suggests that empirical studies should consider trip-related characteristics together with tour-related characteristics.

Second, empirical studies tend to describe land use by spatial characteristics of the residence only since this is an important origin for most trips. Nevertheless, spatial characteristics of the destination are important as well. Since our approach measured the land use effects on commuting, we also included land use characteristics of the workplace. Our analysis confirmed that land use characteristics at work significantly influence car availability, car use, commuting distances and commuting times. This corresponds to the results of the limited number of studies that also include workplace characteristics (e.g., Abreu e Silva *et al.*, 2006; Chen *et al.*, 2008).

The third issue relates to the complex nature of commuting behaviour. A SEM enabled us to disentangle various aspects of commuting behaviour (car use, commuting distance and commuting time) and their relationship with each other as well as with land use. Other studies such as Abreu e Silva and Goulias (2009) also pointed out the utility of SEM in travel behaviour research. Using SEM, their modelling results indicated that the effects of land use on daily travel behaviour were in great part indirectly through the interaction with long-term decisions on commuting distance, car ownership and transit pass ownership. In our analysis, we also found that the effect of land use on commuting might not be as straightforward as initially expected, due to interactions among various travel behaviour aspects. For example, the effects of land use on commuting time could plausibly be in either direction. On the one hand, densely built and mixed-use neighbourhoods are associated with lower car use and, consequently, longer commuting times. On the other hand, these neighbourhoods are also associated with shorter commuting distances and, consequently, shorter commuting times. Our analysis clarified that the first is true for residential land use patterns, whereas the latter seems to hold for land use patterns at the workplace location. For example, residential land use patterns do not seem to have the presumed effect on commuting time: commuting times are longer in residential neighbourhoods with high-densities, mixed-use and easy access to pubic transportation. However, this is due to the indirect effect of land use through car use. Commuting times are not directly lengthened because of density, diversity and access to public transportation, but because of lower car use. This suggests that land use policies that only focus on reducing commuting times could fail because such policies are also likely to result in less car use and, consequently, more use of slower travel modes. The latter is however without doubt also a positive consequence of these land use policies. On the other hand, the opposite holds for workplace locations. Worse car accessibility and short distances between the workplace and the nearest railway station are associated with shorter commuting distances, and thus shorter commuting times as well. Again, these shorter commuting times are simply and solely the result of the interaction with commuting distance. Our data suggest no direct effect of these workplace characteristics on commuting time. However, other workplace characteristics such as density and the distance to the CBD of Ghent directly influence commuting times. All these findings suggest that land use policy can successfully reduce commuting times, but only if it accounts for the land use patterns of the residence as well as the workplace, and for the land use effects on car use and commuting distance at the same time.

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“Indien men een woord veel hoort, weet dan,
dat het begrip ervan verdwenen is.”

Godfried Bomans (1913-1971)

6. REFINING THE LIFESTYLE CONCEPT IN TRAVEL BEHAVIOUR RESEARCH

Van Acker, V., Mokhtarian, P.L., Witlox, F. (2010) Refining the lifestyle concept in travel behaviour research. Transportation Research A (submitted).

Abstract This paper considers the complex relationships between different lifestyles, the built environment, stage in life, car availability and travel behaviour by means of structural equation modelling. The analyses are based on 1,800+ respondents to an Internet survey conducted in 2007 in Flanders, Belgium. Highly-educated respondents are overrepresented in the sample, but different travel patterns can still be found within this homogeneous group. This is (partly) due to lifestyles. While controlling for residential self-selection and mediating variables such as car availability, the results indicate that lifestyles significantly influence modal choice for shopping for fun, family visits and active leisure activities. The built environment also has the expected effect on modal choice: car use is lower among respondents living in neighbourhoods closely located to a local or regional centre, with high density and good local accessibility. The influence of lifestyle on modal choice is, however, not always that strong compared to the influence of other variables. Especially modal choice for shopping for fun (particularly for car and bicycle/walk modes) is more influenced by the built environment than by lifestyles.

6.1 Introduction

Although at times people travel just 'for fun' (e.g., Mokhtarian *et al.*, 2001; Mokhtarian and Salomon, 2001), they mainly travel in order to access desired activities in other locations (or have both intrinsic and utilitarian motivations for a given trip). Hence, travel is generally considered to be a derived demand. After all, activities such as living, working, shopping and recreating are in most cases spatially separated. Therefore, it seems commonsensical that the travel behaviour of individuals and households will alter by changing the location of these activities and the design characteristics of these locations. This suggests a strong relationship between the built environment and travel behaviour. Many studies try to model and measure this relationship while controlling for socio-economic and socio-demographic differences among individuals and households. However, different travel patterns can still be found within similar neighbourhoods or within similar socio-economic population groups. This is (partly) due to the existence of personal lifestyles. The impact of lifestyle has certainly increased. During the last decennia, prosperity increased, resulting in more available possibilities to choose from. Moreover, the social burden to behave uniformly disappeared because of increasing individualization and decreasing social control. These processes resulted in people leading different personal lifestyles (Ferge, 1972; Bootsma *et al.*, 1993). Consequently, taking lifestyles into account in addition to the traditionally used variables in travel modelling provides interesting insights in explaining the connection between the built environment and travel behaviour.

Despite its frequent colloquial use, a distinct lifestyle theory is hard to find. Lifestyle is elaborated pragmatically, rather than theoretically. Especially marketing studies (e.g., Mitchell, 1983) use the concept of lifestyle in order to retrieve market sectors. These studies generally cluster analyze numerous variables. Each cluster is then referred to as another lifestyle. Because a sound theoretical basis is lacking and results are data-dependent, each study 'discovers' new lifestyles. This pragmatic approach is criticized by Sobel (1983) among others. Nevertheless, some theoretical contributions to the lifestyle concept are made by Weber (1972), Bourdieu (1984) and Ganzeboom (1988). They all agree on the communicative character of lifestyles: i.e., the individual elucidates his or her social position through specific patterns of behaviour. However, lifestyles are more than observable patterns of behaviour. According to Ganzeboom (1988), lifestyles also refer to opinions and motivations, including beliefs, interests and attitudes. This may confound our understanding of the lifestyle concept. For that reason, Munters (1992) distinguished lifestyles from lifestyle expressions. He considered lifestyles as the individual's opinions and motivations, or orientations. Mainly work orientation, leisure orientation and household/family orientation define lifestyles (Salomon and Ben-Akiva, 1983; Bootsma *et al.*, 1993). Consequently, lifestyles are internal to the individual and, thus, are unobservable. A lifestyle, then, manifests itself in observable patterns of behaviour, or lifestyle expressions. In this way, observable patterns of behaviour (i.e., lifestyle expressions) are explained by underlying opinions and orientations (i.e., lifestyles). Current travel behaviour surveys can be used to analyze travel behaviour as the derivative of activity behaviour, but these surveys generally lack information on lifestyles. Therefore, we conducted an Internet survey which primarily aimed at identifying how different lifestyles interact with travel behaviour. This paper is part of a series of studies based on this Internet survey. The current paper specifically focuses on the measurement of lifestyles and the incorporation of lifestyles into travel behaviour research.

The paper is structured as follows. Section 6.2 reviews the literature on the relationship between lifestyles, the built environment and travel behaviour. Section 6.3 discusses the Internet survey and the measurement of lifestyles. The methodology of structural equation modelling is summarized in Section 6.4. Results are presented in Section 6.5 and, finally, our major conclusions are drawn in Section 6.6.

6.2 Literature review

Many studies focus on the relation between the built environment and travel behaviour. As a consequence, an enormous variety of variables have been taken into consideration. By summarizing some of the relevant literature, this section discusses several major research questions which are centre stage in the debate on the relation between the built environment and travel behaviour (for more comprehensive reviews, see, e.g., Stead and Marshall, 2001; van Wee, 2002 ; Handy, 2005; Van Acker and Witlox, 2005; Cao *et al.*, 2009).

6.2.1 The built environment and travel behaviour: basic conceptual model

While controlling for socio-economic and socio-demographic variables such as gender, household income and car ownership, empirical studies use various measures to characterize the built environment. Frequently used variables are density, diversity, design and accessibility.

The effects of density on travel demand have long been acknowledged (e.g., Levinson and Wynn, 1963) and remain well-studied and understood. Higher spatial densities are associated with lower car ownership and more public transport use, less car use, and more walking and cycling. After all, in high-density areas public transport is organized more efficiently (more routes, higher frequency of services) and car users face higher levels of road congestion. Also, travel distance and time are negatively associated with increasing spatial density (Cervero and Kockelman, 1997; Kitamura *et al.*, 1997; Stead, 2001; Dargay and Hanly, 2004; Schwanen *et al.*, 2004).

A second variable is diversity. Several indicators have been developed to measure diversity: among others, a jobs/housing ratio (Ewing *et al.*, 1994; Boarnet and Sarmiento, 1998), an entropy index to quantify the degree of balance across various land use types (Frank and Pivo, 1994; Kockelman, 1997) or a (dis)similarity index to indicate the degree to which different land uses lie within a person's surroundings (Kockelman, 1997). The effects of more diversity on car ownership and (car) travel behaviour are comparable to the effects of higher densities.

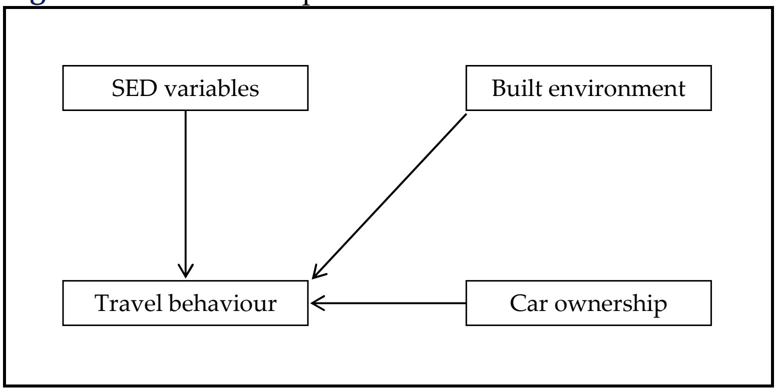
A third dimension is spatial design. Design can be characterized by a general classification of neighbourhoods with a standard suburban neighbourhood and a neo-traditional neighbourhood as extremes (McNally and Kulkarni, 1997; Gorham, 2002). Standard suburban neighbourhoods are characterized by low densities, limited diversity, and a car-orientated design. As a consequence, these neighbourhoods are associated with more cars per capita and more car use. Spatial design however also relates to site design, and dwelling and street characteristics. Neighbourhoods characterized by small block sizes, a complete sidewalk system, the absence of cul-de-sacs and limited residential parking tend to encourage walking and cycling (Cervero and Kockelman, 1997; Hess *et al.*, 1999; Stead, 2001). Meurs and Haaijer (2001) noted that, although characteristics of the dwelling, street, and neighbourhood may influence modal choice, this is only true for shopping and social or recreational purposes. Work trips are less likely to be influenced by spatial design characteristics.

Accessibility is a fourth important characteristic of the built environment which is generally referred to as the ability "to reach activities or locations by means of a (combination of) travel mode(s)" (Geurs and van Wee, 2004). Most studies pointed out that accessibility is negatively associated with car ownership (e.g., Kockelman, 1997; Simma and Axhausen, 2003; Chen *et al.*, 2008; Gao *et al.*, 2008). Rajamani *et al.* (2003) found that higher accessibility by a given mode is likely to result in higher usage of that mode. For example, households living in neighbourhoods that are easily accessible by public transport tend to make more trips by public transport (Kitamura *et al.*, 1997). Similarly, individuals that have several facilities and services such as shops, banks, schools and doctors within walking distance of their residence undertake more walk trips and fewer car trips (Simma and Axhausen, 2003). However, some confounding results exist related to the influence of accessibility by car on car use. Some studies (e.g., Rajamani *et al.*, 2003) found that better accessibility by car results in more car use, whereas other studies (e.g., Kockelman, 1997; Gao *et al.*, 2008) state the opposite (given that greater car accessibility can mean greater accessibility by other modes too, whereas when accessibility is low, car may be the only practical way to travel).

In sum, there seems to be a lot of literature confirming the relationship between the built environment and travel behaviour. Kockelman (1997) stressed that, after demographic characteristics are controlled for, the built environment has an important influence on travel behaviour. Similar conclusions have been made by, e.g., Dargay and Hanly (2004) and Zhang (2004). Meurs and Haaijer (2001) refined these findings. According to their analyses the built environment has a significant influence on non-work travel, whereas work travel is largely or almost entirely determined by personal characteristics. Dieleman *et al.* (2002) found an equal influence of the built environment and personal characteristics. On the other hand, several other studies point out that the built environment has only a moderate effect on travel behaviour (e.g., Cervero and Kockelman, 1997; Stead, 2001; Simma and Axhausen, 2003; Schwanen *et al.*, 2004).

Figure 6.1 visualizes how travel behaviour can be explained using various spatial (built environment) and socio-economic/demographic (SED) variables, and car ownership. Usually some form of regression analysis is then applied to study the relationship between the built environment and travel behaviour. However, some of these explanatory variables might influence each other as well. For example, car ownership can be considered as a mediating variable and results should also be controlled for the effect of residential self-selection.

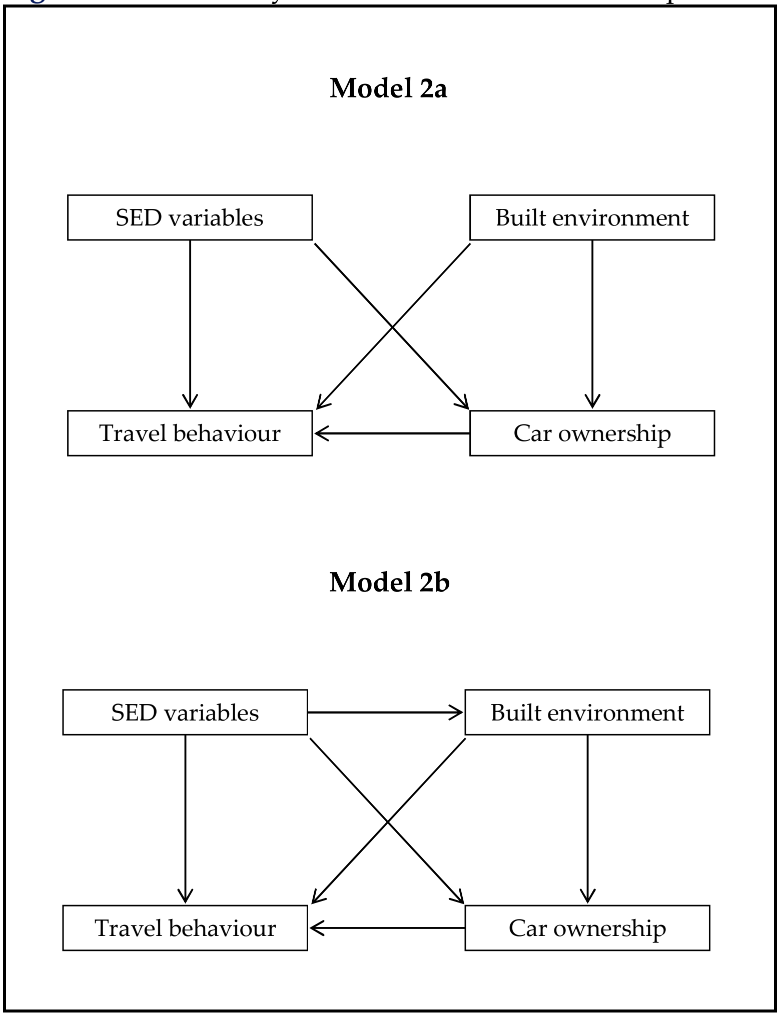
Figure 6.1 Basic conceptual model



6.2.2 The built environment and travel behaviour: necessary extensions

Clearly, the basic conceptual model needs to be extended. Figure 6.2 illustrates some of these necessary extensions. First, several studies use car ownership as an independent variable in order to explain travel behaviour. Car use seems higher among households owning several cars than among households without a car (Dieleman *et al.*, 2002). Moreover, owning a car enables people to travel longer distances compared to people who have to rely on slower transport modes such as public transport, walking and biking (Bagley and Mokhtarian, 2002; Schwanen *et al.*, 2002; Krizek, 2003). On the other hand, car ownership in itself is influenced by other SED variables, especially income. Car ownership is generally higher among high-income groups (Kockelman, 1997; Dargay and Hanly, 2004; Soltani, 2005; Whelan, 2007). Only some studies combine both approaches and consider car ownership as a variable that mediates the relationship between travel behaviour on one hand, and spatial and SED variables on the other hand (Schimek, 1996; Simma and Axhausen, 2003; Cao *et al.*, 2007; Scheiner and Holz-Rau, 2007). This approach is illustrated by Model 2a in Figure 6.2. Recently, Van Acker and Witlox (2010a) pointed out that ignoring car ownership as a mediating variable results in a misspecification of the effects of the built environment. Spatial characteristics such as accessibility and distance to public transport are significantly associated with car ownership. The effect of these characteristics on car use could therefore be overestimated if car ownership is not considered as a mediating variable. An underestimation of the effect of the built environment is also possible. On the other hand, spatial characteristics such as density, diversity and distance to the CBD are more associated with car use than with car ownership.

Figure 6.2 Necessary extensions of the basic conceptual model



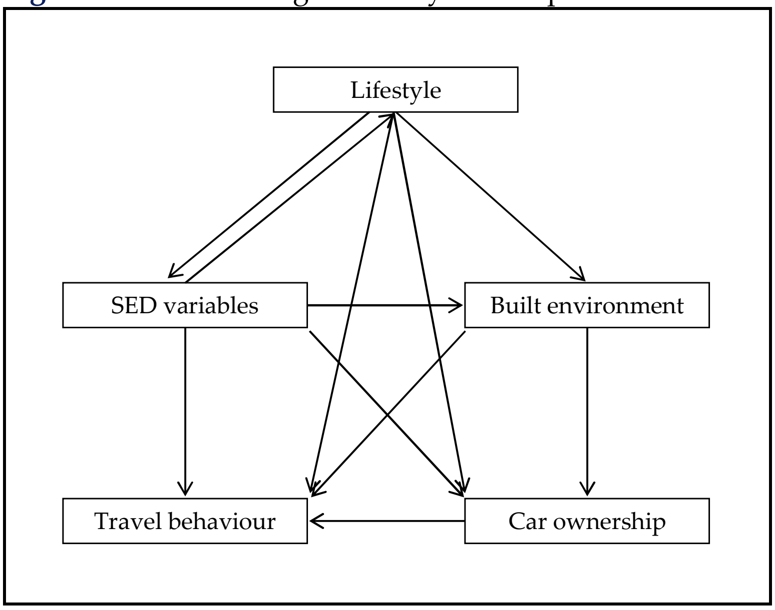
Second, there is also a fundamental question of causation in any of the previously mentioned studies (Kockelman, 1997; Handy *et al.*, 2005). Based on these studies, it seems that in certain circumstances the built environment may have a statistically significant influence on travel behaviour. However, statistical results can mask underlying linkages that are more important and of which the built environment characteristics are only a proxy. For example, most recently, there is a growing body of literature on the relationship between the built environment and personal characteristics (e.g., Bagley and Mokhtarian, 2002; Cao *et al.*, 2006; Bhat and Guo, 2007; Pinjari *et al.*, 2007). This research question refers to the issue of residential self-selection: i.e., different people tend to self-select themselves into different residential neighbourhoods. In other words, people choose their residential neighbourhood according to their personal characteristics (e.g., income), attitudes and preferences. For example, people's residential location decision is based on their travel preferences, so that they are able to travel according to these preferences. Consequently, the relationship between the built environment and travel behaviour is more a matter of personal characteristics, attitudes and preferences. Moreover, this suggests that the influence of the built environment is not exogenous, but rather must be determined in relation to these personal characteristics. This is supported by Bagley and Mokhtarian (2002) and Cao *et al.* (2006): after controlling for residential self-selection, the built environment was found to have little effect on travel behaviour. However, Bhat and Guo (2007) and Pinjari *et al.* (2007) found the opposite. Model 2b in Figure 6.2 considers this issue[1].

6.2.3 Introducing the lifestyle concept

Controlling for the mediating role car ownership plays, and taking care of the issue of residential self-selection, still leaves another important issue to be tackled. Although several studies exist that control their results for SED differences among respondents, Mokhtarian and Cao (2008) and van Wee (2002) note that different travel patterns still occur within homogeneous socio-economic population groups. Hence, individuals with similar socio-economic and socio-demographic backgrounds do not (have to) travel in similar ways. Differences are due to personal lifestyles, among other reasons. Therefore, recently some studies focus on the influence of lifestyles on travel behaviour. This is illustrated by Figure 6.3.

We already mentioned that lifestyles refer to the individual's opinions and orientations toward general themes such as family, work and leisure. However, these orientations are internal to the individual and hard to observe by an outsider. Therefore, most studies focus on lifestyle expressions which are observable patterns of behaviour reflecting someone's lifestyle. Applying factor and cluster analysis to data measuring leisure and mobility orientations that were collected from four neighbourhoods in Cologne, Germany, Lanzendorf (2002) identified seven leisure mobility styles. He found that mobility style significantly explained the decision to travel for various leisure purposes and distance travelled by car, while it was not a significant influence on modal choice. Bagley and Mokhtarian (2002) discussed the influence of lifestyle expressions on travel demand. They used data from a 1993 survey carried out in five neighbourhoods in San Francisco. This survey included among others a list of more than 100 types of activities and interests. Respondents had to indicate what types of subjects they had read last month, how they spent their last weekend and what type of leisure activities they had conducted within the last year. These answers were factor analyzed into eleven lifestyle factors such as culture lover, hobbyist and family-oriented. A more adventurous lifestyle appeared to be associated with longer travel distances by car. Collantes and Mokharian (2007) used data from a different 1998 survey undertaken in the same geographic area as Bagley and Mokhtarian (2002). This survey included among other items, 18 statements on work, family, money, status and time use. These statements were also factor analyzed, with four lifestyle factors emerging: frustrated, status seeker, workaholic and family-oriented. Individuals with a family-oriented lifestyle as well as individuals with a frustrated lifestyle indicated frequently using their car for short-distance trips. A family-oriented lifestyle was also found to be associated with fewer long-distance leisure trips. Furthermore, they found that workaholics travel significantly fewer short-distance as well as long-distance trips for leisure purposes. Previously mentioned studies confirm the influence of lifestyles on travel behaviour. Scheiner (2006) and Scheiner and Holz-Rau (2007) refined these conclusions. They found that travel behaviour is indeed influenced by lifestyles, but SED characteristics of the respondents are more important.

Figure 6.3 Introducing the lifestyle concept



Some empirical studies (e.g., Salomon and Ben-Akiva, 1983; Cooper *et al.*, 2001; Hildebrand, 2003) analyze what they would call lifestyles, but in fact they combine various objective SED characteristics of the individual and the household. Consequently, these studies refer to stage of life or household composition rather than to lifestyles. Although a lifestyle is partly influenced by stage of life or household composition (e.g., high-income groups are able to obtain a more materialistic lifestyle) and a lifestyle in its turn influences SED characteristics (e.g., a family-oriented lifestyle is likely to result in larger household sizes), lifestyle has a different meaning. SED variables must, therefore, be separated from lifestyles (Ganzeboom, 1988; Regtershot, 2002).

Consequently, Figure 6.3 also distinguishes SED variables from lifestyles and considers the dual relationship between lifestyles and SED variables. This is the model we will take as a starting point of our analyses.

6.3 How to measure lifestyles?

Current travel behaviour surveys generally lack information on lifestyles. Therefore, we conducted an Internet survey on lifestyle and mobility between May 2007 and October 2007. In this section, we describe the study background characteristics, the measurement of lifestyles, and the correlations between lifestyles and other key variables.

6.3.1 Study background

The survey was announced among students and staff members of the University of Antwerp and the Faculty of Sciences at Ghent University and an announcement was published in regional information magazines of several villages in the larger urban region of Ghent (Flanders, Belgium). In total, 2,363 persons completed the survey of which 1,878 were retained after data cleaning for further analyses. Despite our efforts to obtain a well-balanced sample, the most striking non-representative characteristic of our survey related to educational level. Highly-educated respondents with a college or university degree are overrepresented in the sample (66.0 %) compared to the average number for Flanders (24.7 %). Moreover, the average age of the respondents is 31 years, which is remarkably younger than the average age in Flanders (41 years). We refer to Van Acker *et al.* (2010) for a more complete overview of sample characteristics.

Note that the combined overrepresentation of highly-educated respondents and young adults is, however, not surprising since most highly-educated people are within this age range. Within this 'homogeneous' group of highly-educated respondents and young adults, research that only accounts for commonly used SED variables cannot explain divergent travel patterns. For example, some studies suggest that car use is higher among highly-educated people (e.g., Kockelman *et al.*, 1997) and analysis results of Schwanen *et al.* (2001) illustrate that from the age of 27 onwards people in the Netherlands travel by car less often than by public transport for leisure trips. Contrary to these studies involving conventional variables, we want to illustrate that within this so-called homogeneous group, different travel patterns still exist and that these differences are due to personal lifestyles.

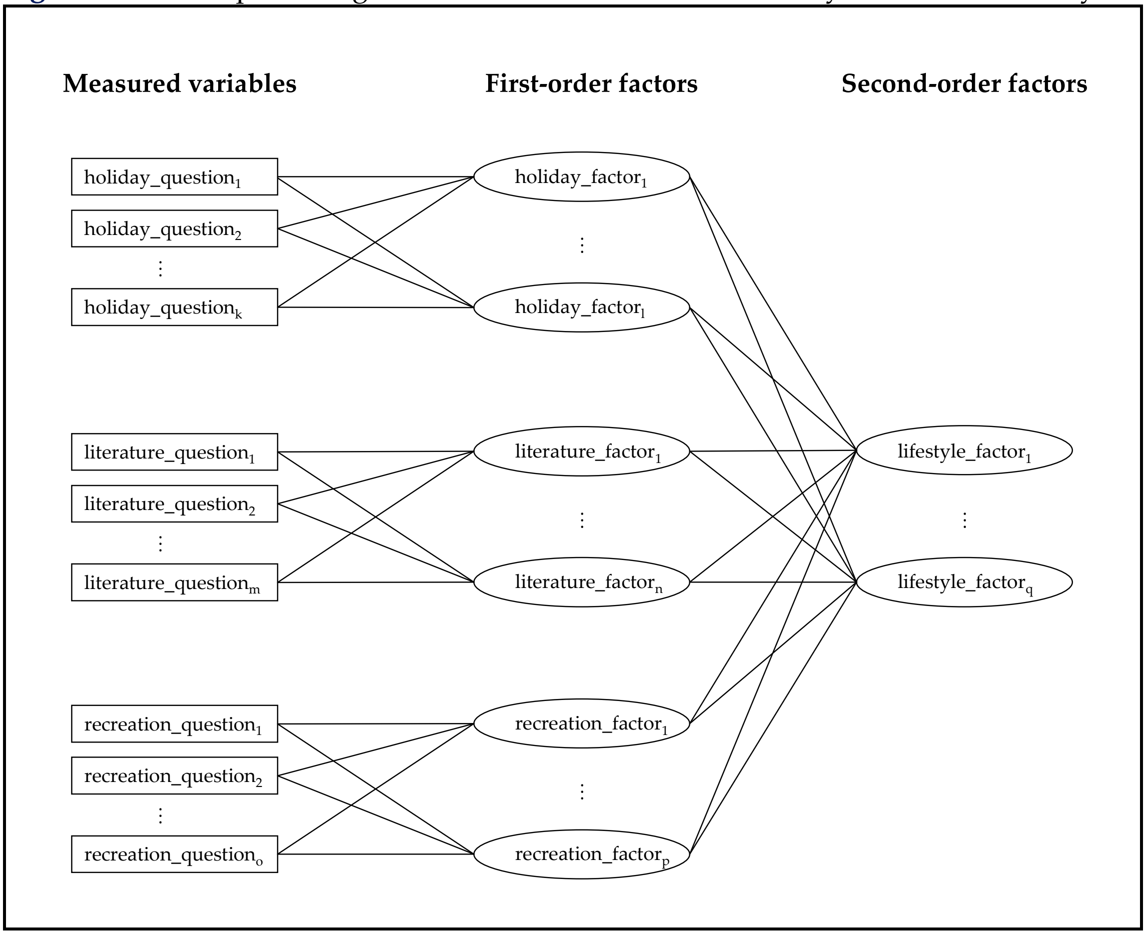
6.3.2 Lifestyle measurement: a second-order factor analysis

In accordance with the definition of lifestyle, the Internet survey contained questions on leisure orientation and on the assessment of the work-family balance. The survey included several questions referring to three aspects of leisure: (i) holidays/travel, (ii) literary interests, and (iii) recreational activities (sports, attending cultural events, recreational activities, hobbies). For example, respondents had to mark what aspects are important on holiday (having 13 possible choices), on what types of subjects they generally read a book or magazine (having 29 possible choices), and what recreational activities they like to do (having 20 possible choices). This resulted in 136 binary variables representing a diverse set of lifestyle activities. These variables are measures of leisure activity and leisure preference (i.e., what types of leisure activity someone participates in), but without an indication of quantity (i.e., how many times someone participates in a specific leisure activity). In this study, we are not addressing the issue of whether an individual is leisure-oriented or not, but rather, given whatever degree of orientation toward leisure someone may have, what types of leisure activities that person prefers. Note also that our questions actually refer to aspects of lifestyle expressions (behaviour) rather than to lifestyles (orientations and attitudes) as such. Nevertheless, as we previously mentioned, lifestyle expressions are often used as indicators of the underlying lifestyles. Consequently, for convenience, we will generically refer to our measures as 'lifestyle' measures.

According to Ganzeboom (1988), lifestyles not only refer to work, family and leisure orientation but these orientations are also influenced by three dimensions, namely an economic dimension, a cultural dimension, and a stage-of-life dimension. Therefore, we constructed the binary variables in such a way that these three dimensions were reflected in the possible choices. For example, important holiday aspects ranged from 'inexpensive holiday' to 'luxury stay' (referring to the economic dimension), literary interests ranged from 'comic books and cartoons' to 'art and architecture' (referring to the cultural dimension), and recreational activities ranged from 'going out to party' to 'visiting family' (referring to the stage-of-life dimension). Furthermore, work-family balance was assessed using 16 five-point agree-disagree Likert-type scale statements related to work, family and friends. However, the latter set of variables was excluded from the analysis since no satisfactory factors were obtained from them.

Factor analysis was, then, used in order to reduce the considerable amount of information found in the observed indicators to a feasible number of lifestyle factors. Although it is generally performed on continuous (or at least ordinal) variables, Rummel (1970) points out that any data whatsoever can be factor analyzed. However, factor-analyzing binary variables must be done with caution. Therefore, we checked the distributions of all binary variables and excluded those variables with too large (or too small) a proportion of responses in any category.

Figure 6.4 Conceptual diagram of the second-order factor analysis model for lifestyles



Because of the large number of candidate variables, it made sense to initially factor-analyze them in groups, rather than all together. However, since several constructs (e.g. family orientation, culture lover) appeared across more than one group, we decided to perform a second-order factor analysis. In general, factor analysis involves the extraction of factors from a correlation matrix or variance-covariance matrix between the variables. These extracted factors are typically rotated, which redistributes the variance contributed by the variables to the factors in such a way that results in a more understandable structure. Rotation procedures can allow for oblique angles between factor dimensions, which results in correlated factors. In that case, the matrix of associations between the factors themselves can be factor analyzed in turn. The factors extracted from this second factor analysis are called 'second-order' factors (Thomas, 1995; Arnau, 1998). Figure 6.4 illustrates how we performed a second-order factor analysis in order to obtain lifestyle factors. In keeping with standard practice, we represent manifest (i.e. directly observed) variables by rectangles, and factors (viewed as latent, or indirectly observed, variables) by ellipses, but note that the scores computed from the first factor analysis are treated as directly observed variables in the second-order analysis.

First, we factor analyzed each leisure aspect (holidays, literary interest and recreational activities) separately, in order to retrieve factors reflecting the three dimensions (economic, cultural and stage of life) that influence lifestyles. In each factor analysis, the number of factors was chosen based on interpretation of the scree plot, eigenvalues larger than one and, especially, interpretability of the factors. Tables 6.1 to 6.3 present the results of these three first-order factor analyses (principal axis factoring, promax rotation) on holidays (36.4% explained variance), literary interests (36.4% variance explained), and recreational activities (23.7% variance explained). The results confirm that the three lifestyle dimensions are included within the extracted factors of each leisure aspect. For example, the economic dimension is reflected in holiday factors such as low-budget-but-active-and-adventurous holidays (low economic score) and frequent traveller with a second home (high economic score). Based on our results, the low economic dimension of the low-budget holiday is indicated by characteristics such as staying at a camping site (and not in a hotel), self-organizing the holiday and important aspects such as inexpensive instead of luxury. Frequent travellers seem to have the budget to spend several (long) holidays in one year and to own a second home. The factor analyses of each leisure aspect also revealed factors that reflect the cultural dimension. Aspects such as culture and staying with local people are important characteristics of the culture-lover holiday factor. The factor representing literary interests of culture and current events readers include history, art and architecture, but also politics and religion. Cultural recreational activities such as visiting a museum or exhibition, attending an opera or musical, going to a concert and acting in a play, characterize the culture lover recreational activities factor. Finally, the stage-of-life dimension is also represented in the factors of each leisure aspect. For example, being a student in higher education is positively correlated with an all-in-one holiday, literary interests in style and trends, and recreational activities such as partying (correlations are respectively 0.152, 0.118 and 0.109), whereas the opposite holds for older families (correlations are respectively -0.055, -0.199 and -0.133). These families rather prefer self-organized and family-oriented holidays (correlation of 0.201) and pro-housing literary interests (correlation of 0.122).

Next, we performed a second-order factor analysis (principal axis factoring, promax rotation, 45.5% variance explained) by using the factor scores from the first analyses as input (see Table 6.4). The number of factors was based on the same rules of thumb as we used in the first-order factor analyses. We found five resulting lifestyle factors. The culture-lover lifestyle is associated with cultural literary interests and cultural holidays. Moreover, culture lovers might also perform cultural activities within a club or association (e.g., theatre acting, playing music in a band or orchestra) since they are socially engaged. A friends-and-trends lifestyle is more oriented toward the social network of friends than one's own family. It is characterized by going out and partying with friends (as opposed to performing traditional family activities such as doing chores and do-it-yourself), and by 'soft' literary interests such as showbiz news and women's magazines. A third lifestyle factor is the home-oriented-but-active-family. It is a family-oriented lifestyle, indicated by the high loadings on the pro-housing and cocooning literary interest factor, and on the self-organized and family-oriented holiday factor. However, this family-oriented lifestyle is not solely focussed on the family and the home. The family orientation is combined with an active lifestyle: respondents are involved in different sports, and holidays are organized by themselves. Active lifestyles can also be combined with a low-budget lifestyle, resulting in a low-budget-and-active/creative lifestyle group. A final lifestyle is a home-oriented-traditional-family lifestyle. Compared to the active family factor, respondents scoring highly on this factor are also home-oriented, but in different ways, focused more on traditional activities (such as doing chores, gardening and attending a parade) and less on outdoor activities. Moreover, literary interests are rather 'soft' and holidays are characterized by an all-in-one package (which is often organized by a tour operator). Consequently, respondents of this lifestyle group seem to be less active outside their home and, thus, are likely to be more home-oriented.

By using an oblique rotation procedure, we allowed the lifestyle factors to be correlated. This is in correspondence with our understanding that lifestyles must not be considered as unambiguous types but rather as a continuum of types (Ganzeboom, 1988; Chaney, 1996). Fortunately, however, the resulting correlations between our lifestyle factors are not too high. A maximum (in magnitude) correlation of -0.265 was found, between the culture-lover lifestyle and the home-oriented-traditional-family lifestyle. Other correlations are generally lower than 0.100. Therefore, the resulting lifestyle factors are still usable as explanatory variables in other analyses.

Table 6.1 First-order pattern matrix for holiday-related factors

	Low-budget, active and adventurous	Frequent traveller with second home	Self-organized, family-oriented	All-in-one	Culture lover	Close to home and unadventurous
What type of accommodation? camping site	0.742					
What type of accommodation? hotel	-0.531				0.240	
Who organizes the holiday? myself	0.486					
What aspects are important? inexpensive, low-budget	0.425		-0.264			0.200
How many holidays lasted one week or longer?		0.818				
How many times did you spend a holiday the last year?		0.766				
What type of accommodation? second home		0.256				
How do you travel? by car			0686			
What type of accommodation? rental house			0.389			
How do you travel? by train	0.275		-0.277			
What aspects are important? sunny				0.582		
What aspects are important? relaxation				0.408		
What aspects are important? good food				0.329		
What aspects are important? sports accommodation				0.307		
What aspects are important? luxury	-0.246					
What type of accommodation? resort, holiday village				0.229		
What aspects are important? culture					0.437	
What type of accommodation? local people					0.387	
How do you travel? by airplane			-0.290		0.341	
What aspects are important? nature	0.248		0.243		0.328	
What aspects are important? familiar places						0.340
What aspects are important? close to home						0.324
What aspects are important? no language problems						0.251
What aspects are important? unfamiliar places, adventure	0.221				0.211	-0.226

Table 6.2 First-order pattern matrix for factors on literary interests

	Home improvement, cocooning	Fantasy world, fiction	Style and trends	Culture and current events	Non-emotional, non-fiction
Literary subjects: housing/decoration	0.581				
Literary subjects: gardening	0.558				
Literary subjects: do-it-yourself	0.481				
Literary subjects: cooking	0.380				
Literary subjects: health	0.338				
Literary subjects: pets	0.259				
Literary subjects: thriller, adventure		0.549			-0.288
Literary subjects: fantasy, SF		0.427			
Literary subjects: horror		0.421			
Literary subjects: detective, crime story		0.400			-0.300
Literary subjects: humor, comedy		0.387	0.233		0.271
Literary subjects: comic book, cartoon		0.356			
Literary subjects: women's magazine			0.582		
Literary subjects: fashion			0.528		
Literary subjects: entertainment, showbiz			0.365		
Literary subjects: science			-0.318		
Literary subjects: environment, nature	0.286		-0.294		
Literary subjects: history				0.612	
Literary subjects: art, architecture				0.522	
Literary subjects: politics, news magazine				0.375	
Literary subjects: religion, spirituality				0.337	
Literary subjects: novel				0.232	-0.391
Literary subjects: computer, ICT					0.331
Literary subjects: sports					0.325
Literary subjects: men's magazine					0.242
Literary subjects: finances, business, trade					0.242

Table 6.3 First-order pattern matrix for factors on recreational activities

	Traditional family activities	Sports	Social nest-builders	Socially engaged	Culture lovers	Party people	Creativity
Hobbies: doing chores, do-it-yourself	0.670						
Hobbies: gardening	0.598		-0.283				
Recreational activities: gardening	0.560		-0.342				
Recreational activities: doing chores, do-it-yourself	0.555						
Cultural activities: flea market	0.323						
Hobbies: constructing and repairing furniture	0.272						
Sports: cycling	0.253						0.213
Cultural activities: parade	0.239						
Cultural activities: commodity exchange	0.214						
Recreational activities: practicing sports		0.853					
Hobbies: practicing sports		0.846					
Sports: jogging, running		0.391					
Sports: soccer		0.271					
Sports: badminton, (table) tennis, squash		0.271					
Recreational activities: going to the movies, cinema			0.537				
Recreational activities: staying at home and relaxing			0.506				
Recreational activities: shopping			0.467				-0.258
Recreational activities: watching TV, movies, DVD			0.464				
Cultural activities: going to the movies, cinema			0.441				
Recreational activities: going out for diner, to restaurant			0.362				-0.250
Recreational activities: listening to the radio, to music			0.342				0.239
Recreational activities: visiting family and friends			0.298				
Recreational activities: inviting family and friends			0.241				
Recreational activities: cooking			0.216				-0.203
Recreational activities: volunteering, club/social life				0.903			
Hobbies: volunteering, club/social life				0.888			
Member of a club				0.240			

Table 6.3 First-order pattern matrix for factors on recreational activities *continued*

	Traditional family activities	Sports	Social nest-builders	Socially engaged	Culture lovers	Party people	Creativity
Cultural activities: museum, exhibition					0.526		
Cultural activities: opera, musical					0.509		
Cultural activities: concert					0.411		0.251
Hobbies: reading					0.385		
Cultural activities: library					0.350		
Cultural activities: ballet, dance performance					0.285		
Sports: walking	0.260				0.278		
Hobbies: playacting					0.258		
Recreational activities: a night out in a disco or at a party						0.896	
Cultural activities: party						0.617	
Cultural activities: disco, club						0.569	
Hobbies: computer, web design							0.376
Hobbies: playing music							0.356
Hobbies: photography							0.244
Recreational activities: cultural and creative activities							0.235

Table 6.4 Second-order pattern matrix for lifestyle factors

	Culture lover	**Friends-and-trends**	**Home-oriented but active family**	**Low-budget and active/creative**	**Home-oriented traditional family**
Leisure: socially engaged	0.843				
Literary interests: culture and current events	0.444				
Holiday: culture lover	0.423				
Literary interest: non-emotional readers	-0.305				
Leisure: party people		0.937			
Leisure: sports			0.741		
Literary interests: home improvement, cocooning			0.628		
Holiday: self-organized, family-oriented			0.253		
Leisure: creative				0.922	
Literary interests: non-emotional, non-fiction				0.289	
Holiday: low-budget, active and adventurous				0.246	
Leisure: traditional family activities		-0.246			0.607
Literary interests: style and trends		0.262			0.598
Holiday: all-in-one					0.444
Holiday: frequent traveller with second home					-0.200

6.3.3 Lifestyles in relation to other key variables

Having described the measurement of lifestyles, we now turn our attention to the other key variables in Figure 6.3 (i.e. SED variables, the built environment, car ownership and travel behaviour). Calculating correlations between these key variables and lifestyles also reveals a number of interesting results (see Table 6.5).

Table 6.5 Correlations between lifestyles and other key variables

	Culture lover	Friends-and-trends	Home-oriented but active family	Low-budget and active/ creative	Home-oriented traditional family
Student living at home	-0.051**	0.113*	-0.224*	0.111*	0.116*
Older family, working adults	0.088*	-0.158*	0.163*	-0.175*	-0.224*
Young family	-0.091*	-0.027	0.069*	-0.064*	0.006
Gender (female)	0.287*	0.061**	0.074*	-0.375*	0.420*
Location relative to local centre	-0.006	0.048**	0.054*	0.054	0.023
Location relative to regional centre	0.007	0.035	-0.020	-0.020	0.094*
Local accessibility	0.015	0.013	-0.059*	-0.059	0.037
Regional accessibility	0.004	-0.043	0.028	0.028	-0.059*
Density	0.164*	0.035	-0.018	-0.018	0.092*
Car availability	-0.046	-0.028	0.169*	-0.141*	-0.081*
Car use, fun shopping	-0.260*	-0.052	0.212*	-0.055	-0.112*
Car use, family visits	-0.057	0.074	0.025	-0.146*	0.076**
Car use, active leisure activities	-0.120*	0.123*	0.066	-0.088**	0.133*
Public transport, fun shopping	0.108*	0.117*	-0.251*	0.067	0.280*
Public transport, family visits	0.144*	0.061	-0.144*	0.065	0.052
Public transport, active leisure activities	0.167*	-0.117	0.020	0.075	0.083
Cycling/walking, fun shopping	0.173*	-0.142*	0.005	0.069	0.047
Cycling/walking, family visits	0.108*	-0.119*	-0.080	0.176*	-0.008
Cycling/walking, active leisure activities	0.076	-0.020	-0.019	0.142*	-0.042

* = significant at α = 0.05, ** = significant at α = 0.10

6.3.3.1 Socio-economic and socio-demographic variables

SED variables might be correlated with each other. For example, social status is related to education, employment status and household income, and stage of life depends on age, marital status and household composition. Factor analyzing the commonly used SED variables could provide us some interesting new factors. We expected to obtain one factor referring to social status and another factor referring to stage of life. Instead, we extracted three factors all referring to stage of life (principal axis factoring, promax rotation, 59.5% variance explained). The first factor refers to students living at home and is determined by five variables (loadings in parentheses): presence of children in the household (0.946), number of older children in the household (0.938), household position as a child (0.739), highly educated (-0.390) and full-time employment (-0.320). A second factor is determined by six variables: age (0.558), household income (0.446), full-time employment (0.444), household position as a child (-0.321), highly educated (0.273), presence of children in the household (0.242). A high score on this factor thus indicates an older family with employed adults. A third factor refers to a young family and is characterized by the number of young children in the household (0.937), the presence of children in the household (0.361), and the number of older children in the household (-0.271). Other SED variables such as gender were excluded from the analysis because the results were unsatisfactory. However, gender will be included as a separate variable in further analyses of travel behaviour.

As we already mentioned, stage of life is one of three dimensions that influence lifestyles. In his discussion on the origins and function of lifestyles, Ganzeboom (1988) argues that changeable characteristics such as stage of life should be distinguished from stable SED background variables such as gender. Table 6.5 illustrates that lifestyles are associated with changeable variables (i.e., stages of life) as well as stable variables (i.e., gender). Students living at home are more likely to have a friends-and-trends lifestyle or a low-budget-and-active/creative lifestyle. Young and older families are mainly associated with a family-oriented lifestyle (i.e., home-oriented but active family), but members of older families might also exhibit a more non-traditional lifestyle (i.e., culture lovers).

6.3.3.2 The built environment

Using information from various land use and transport databases, we calculated several spatial characteristics of the built environment of the respondent's residence. These characteristics include density measures (population density, job density, built-up density), diversity measures (jobs-housing balance, land use mix) and accessibility measures (potential accessibility by car on several time scales ranging from 5 minutes to 60 minutes, distance to the nearest railway station, distance to the nearest town or city centre). Design aspects could not be included in the analysis due to a lack of suitable data. The calculation of these spatial variables is discussed in detail in previous research (Van Acker and Witlox, 2010a, b). However, density, diversity and accessibility are often related to each other. For example, city centres are generally characterized by high densities and high diversity, as well as by having numerous opportunities accessible within a short time span. Density, diversity and accessibility can be conceived as actually measuring the same phenomenon; to the extent that that is the case, they can be combined into one measure. In order to reveal the structure among these spatial variables, we performed a factor analysis (principal axis factoring, promax rotation, 73.6%

variance explained) which revealed five factors (see Appendix): (i) location relative to a local centre, (ii) location relative to a regional centre, (iii) local accessibility, (iv) regional accessibility, and (v) density. Diversity measures did not obtain a high loading on any of these factors, but this is consistent with Cervero and Kockelman (1997), who similarly found density and design factors, but not a diversity factor.

It is hypothesized that people with a culture-oriented lifestyle are more likely to choose a residence in an urban neighbourhood that offers many cultural activities, whereas family-oriented lifestyle groups (i.e., home-oriented but active family, home-oriented traditional family) tend to reside in a suburban or rural neighbourhood. Table 6.5 supports this hypothesis: a culture-lover lifestyle is positively associated with density, and family-oriented lifestyles are associated with residing further away from a city or town centre as well as with poor accessibility. Table 6.5 also illustrates non-significant correlations between the low-budget-and-active/creative lifestyle and various built environment characteristics.

6.3.3.3 Car ownership

Our Internet survey provided information not only on car ownership and possession of a driving license, two commonly used variables in travel behaviour research, but also on the possession of a public transport pass and the temporary availability of a car. Since all four variables might be related to each other, we performed a factor analysis (principal axis factoring, 31.4% variance explained) in order to construct one general factor related to car availability. This factor is characterized by: permanent car availability (0.940), possession of a driving license (0.385), number of cars in the household (0.381), and possession of a public transport pass (-0.278).

Table 6.5 suggests that car availability is positively associated with an active lifestyle and a family-oriented lifestyle. Having a car available seems to enable people to combine various leisure activities and household tasks. This is in contrast with the low-budget lifestyle and the culture-lover lifestyle, which seem to be negatively associated with car availability. Car availability might, thus, be discouraged by budget constraints or by rather non-traditional ways of living.

6.3.3.4 Travel behaviour

Travel behaviour is the final outcome variable in Figure 6.3. In our Internet survey we asked respondents what kind of leisure trips they performed on a monthly basis and which travel mode they generally use for this. For each travel purpose (fun shopping, family visits, and active leisure activities), we performed three analyses of modal choice (one for car use, one for public transport use, and one for cycling and walking). Hereby, modal choice is defined as a binary variable.

As with car availability, car use seems lower among culture lovers and low-budget lifestyle groups. Moreover, the use of public transport and cycling and walking seems significantly higher within these two lifestyle groups. This might suggest that modal choice is more a question of the use of car versus car alternatives, rather than one of individual versus public transport or motorized versus non-motorized transport.

6.4 Methodology: structural equation modelling

The variables described in Section 6.3 will now be used as input for the estimation of a structural equation model (SEM). Structural equation modelling is considered a suitable methodological technique for handling complex relationships. The brief literature review of Section 6.2 highlights that such complex relationships exist among lifestyles, the built environment and travel behaviour. Various variables must be accounted for and, moreover, these variables can influence each other as well. A variable can be the outcome variable (or dependent variable) in one set of relationships and at the same time a predictor (or explanatory variable) in another equation.

Structural equation modelling can be considered as a combination of factor analysis and regression analysis. The factor analysis aspect in a SEM refers to the modelling of indirectly observed (or latent) variables whose values are based on underlying manifest variables (or indicators) which are believed to represent the latent variable. This measurement model, as it is called, therefore defines the relationships between a latent variable and its indicators. All previously discussed factor analyses are in fact measurement models, and the factors could be considered latent variables within a SEM. However, the complexity of the factor analyses, and especially those related to lifestyles, indicated that it would be too cumbersome to embed all submodels into the structural model and estimate all parameters simultaneously. Thus, to reduce the dimensionality of the models, we decided to conduct separate factor analyses and incorporate these factor scores into the models. Consequently, we consider all variables, even factor scores, to be observed (or manifest) variables, and our analysis is solely based on the regression analysis aspect of SEM. Our results are based on the estimation of a series of simultaneously estimated structural (i.e. regression) equations. Because a variable can be an explanatory variable in one equation but an outcome variable in another equation, we differentiate between 'exogenous' variables and 'endogenous' variables. Exogenous variables are not caused by any other variable in the model. Instead, exogenous variables influence other variables. Endogenous variables are influenced by exogenous variables, either directly or indirectly through other endogenous variables (Raykov and Marcoulides, 2000; Byrne, 2001; Kline, 2005). The relationships between exogenous and endogenous variables are represented by the structural model and are defined by the matrices (Hayduk, 1987; Van Acker *et al.*, 2007; Oud and Folmer, 2008):

$$\boldsymbol{\eta} = \mathbf{B}\,\boldsymbol{\eta} + \boldsymbol{\Gamma}\,\boldsymbol{\xi} + \boldsymbol{\zeta} \;, \qquad [6.1]$$

where $\boldsymbol{\eta}$ = L x 1 matrix of endogenous variables,
$\boldsymbol{\xi}$ = K x 1 matrix of exogenous variables,
$\mathbf{B}$ = L x L matrix of coefficients of the endogenous variables,
$\boldsymbol{\Gamma}$ = K x K matrix of coefficients of the exogenous variables, and
$\boldsymbol{\zeta}$ = L x 1 matrix of residuals of the endogenous variables.

The estimation of a SEM is (usually) based on matching the observed covariances among $\boldsymbol{\eta}$ and $\boldsymbol{\xi}$ with the model-implied covariances. In this paper, we used the software package M-plus 4.21 (Muthén and Muthén, 2006) because of its ability to model categorical endogenous variables, including the binary modal choice variables we have.

Prior to discussing the modelling results, we consider several model specification issues. Our final outcome variable, modal choice, is categorical and this imposes some limitations on the analysis. The maximum likelihood (ML) method is a commonly used estimation procedure, but it assumes a multivariate normal distribution of all endogenous variables in the model (Kline, 2005, p. 112). Our models do not fulfil this assumption and, therefore, we use the alternative mean- and variance-adjusted weighted least squares parameter estimator (WLSMV). WLSMV is a robust estimator that does not require extensive computations and enormous sample sizes (Muthén, 1983; Satorra, 1992; Yu and Bentler, 2000).

All structural equation models were analyzed for the effect of outliers. Outliers were determined by calculating Cook's D (Cook, 1977, 1979) and a loglikelihood distance influence measure adjusted for weighted least squares estimators (Cook and Weisberg, 1982) for each observation. These outlier scores were plotted against the scores for modal choice. Next, we removed five outliers at a time and observed the changes in modal fit and individual parameter estimates. The model fit did not change considerably in any of the nine structural equation models. However, some individual parameter estimates became insignificant. Nevertheless, we retained all outliers since those outliers have interesting characteristics for our analysis. Those outliers generally refer to respondents with pronounced lifestyles or to respondents living in an interesting neighbourhood (especially neighbourhoods with many opportunities accessible in a short time span and neighbourhoods distant from a regional city centre).

We also have to note that only those variables with a significant direct influence on any endogenous variable are retained in our structural equation models. Insignificant direct influences were constrained to be zero. Nevertheless, some insignificant total effects are still reported in Tables 6.6 to 6.8. This is because of the interaction among variables. For example, we assume that stage of life not only has a direct effect on modal choice, but also an indirect effect caused by the interaction between stage of life, residential location, car availability and modal choice. This indirect effect might be insignificant (and/or have an opposing sign) resulting in an insignificant total effect which is the sum of the direct and indirect effect. Tables 6.6 to 6.8 report unstandardized as well as standardized coefficients (the latter in parentheses), and total as well as direct effects (the latter in italics). The direction (positive or negative) and the significance of the modelled relationships are represented by the unstandardized coefficient, whereas the standardized coefficients illustrate the strength of these relationships. Tables 6.6 to 6.8 also mention several model fit indices. Cut-off values indicating good modal fit are: χ^2 with p-value > 0.05, RMSEA < 0.05, WRMR < 1.000, CFI > 0.90 and TLI > 0.90 (Hu and Bentler, 1999; Yu, 1999; Byrne, 2001; Kline, 2005). All nine structural equation models have a good model fit.

6.5 Results

In what follows we discuss the results of nine structural equation models on modal choice for various types of leisure trips.

6.5.1 Modal choice for fun shopping

Table 6.6 reports how lifestyles are associated with modal choice for shopping trips. These shopping trips do not include shopping for daily groceries, but rather ‘fun shopping’. According to our data, respondents with an active family lifestyle are more likely to use a car than are those with other lifestyles. This active lifestyle combines traditional family activities with activities such as practicing sports (where the car can be a practical means of getting to sports facilities and carrying sports equipment). The other lifestyles, except a friends-and-trends lifestyle, are positively related to the use of car alternatives. More specifically, the use of public transport is associated with a traditional family lifestyle, whereas a culture-lover and a low-budget lifestyle are also associated with more cycling and walking. For some lifestyles this seems obvious. For example, cycling and walking, and the usage of public transport, fit well within a low-budget lifestyle.

The built environment has the expected effect: car use is higher for respondents living in distantly located, less dense and less accessible neighbourhoods. The opposite holds for cycling and walking, and public transport. Stage of life is also significantly associated with modal choice for fun shopping. Young families as well as older families are more likely than other stage-of-life groups to use the car for fun shopping. Students living at home seem more likely to travel by public transport than any other travel mode. This is also true for women. As expected, high car availability is positively associated with car use and negatively associated with other travel modes.

Based on the standardized total effects (reported between parentheses in Table 6.6), we can assess the strength of the previously discussed relationships. Although lifestyles have a significant influence on modal choice for fun shopping, this is rather a weak relationship compared to other variables. Car use, and cycling and walking, are influenced to a large extent by the built environment (although the built environment, in turn, is to some degree influenced by lifestyles). Interestingly, however, this is not the case for public transport. The usage of public transport is mainly influenced by stage of life, gender and car availability. This finding suggests that land use policies might influence modal choices for fun shopping, but only the assessment of travelling by car versus travelling by bike or on foot. It might also suggest that public transport does not compete with car use for long-distance shopping nor with cycling and walking for shopping at shorter distances.

Table 6.6 Total and direct effects on modal choice for fun shopping

	Car 41.5% variance explained	**Bicycle / On foot** 48.5% variance explained	**Public transport** 29.5% variance explained
Lifestyles			
culture lover	-0.219* (-0.197) _-0.151* (-0.136)_	0.194* (0.177)	0.022* (0.019)
friends and trends	-0.023* (-0.024)	-0.010 (-0.011)	-0.015* (-0.016)
home-oriented but active family	0.242* (0.212) _0.168* (0.147)_	-0.038 (-0.034)	-0.017* (-0.015)
low-budget and active/creative	-0.028* (-0.026)	0.101* (0.094)	0.014* (0.013)
home-oriented traditional family	-0.040* (-0.032)	-0.078* (-0.064)	0.203* (0.160) _0.202* (0.159)_
Built environment			
location relative to local centre	0.312* (0.377) _0.291* (0.352)_	-0.267* (-0.327) _-0.191* (-0.234)_	-0.016* (-0.020)
location relative to regional centre	0.344* (0.413) _0.305* (0.366)_	-0.342* (-0.417) _-0.201* (-0.246)_	-0.031* (-0.036)
local accessibility	-0.170* (-0.237) _-0.142* (-0.198)_	0.101* (0.143)	0.107* (0.148) _0.085* (0.117)_
regional accessibility	-0.216* (-0.240) _-0.216* (-0.240)_	-	-
density	-0.341* (-0.423) _-0.301* (-0.374)_	0.318* (0.401) _0.174* (0.220)_	0.031* (0.038)
Stage of life			
student living at home	-0.043 (-0.047)	-0.103** (-0.111) _-0.348* (-0.377)_	0.347* (0.361) _0.256* (0.267)_
older family, working	0.031 (0.030)	0.033 (0.033) _0.417* (0.412)_	-0.330* (-0.318) _-0.178* (-0.172)_
young family	0.043* (0.042)	-0.140* (-0.138)	-0.216* (-0.203) _-0.156* (-0.147)_
Gender (female)	-0.347* (-0.158) _-0.239* (-0.108)_	-0.016 (-0.007)	0.492* (0.221) _0.387* (0.174)_
Car availability	0.364* (0.331) _0.364* (0.331)_	-1.328* (-0.629) _-1.328* (-0.629)_	-0.288* (-0.255) _-0.288* (-0.255)_
Model fit:			
Chi^2 (df) p	52.691 (46) 0.2311	47.414 (42) 0.2614	54.115 (42) 0.0996
CFI	0.990	0.990	0.979
TLI	0.988	0.989	0.976
RMSEA	0.015	0.014	0.022
WRMR	0.893	0.901	0.935

* = significant at $\alpha = 0.05$, ** = significant at $\alpha = 0.10$
standardized effects shown in parentheses, direct effects shown in italics

6.5.2 Modal choice for family visits

Table 6.7 summarizes the modelling results for modal choice for family visits. The effect of lifestyles on modal choices for family visits is somewhat different compared to fun shopping. Car use is positively associated with a family-oriented lifestyle: car use seems higher among active-family lifestyle groups but also among traditional-family lifestyle groups. Contrary to fun shopping, the usage of active travel modes for family visits is not associated with a culture-lover lifestyle, but with a low-budget lifestyle and a traditional-family lifestyle. The usage of public transport on the other hand is not only associated with a culture-lover lifestyle but with a friends-and-trends lifestyle as well.

The built environment has a similar effect on modal choice for family visits compared to fun shopping: neighbourhoods close to a local or regional centre, with high density and high local accessibility are associated with more cycling and walking, and more public transport. Modal choice for family visits is also significantly influenced by stage of life. Students living at home tend to travel by bike or on foot, whereas car use is positively associated with young and older families. All stage-of-life categories are negatively associated with public transport. Whereas women are more likely than men to generally use public transport for fun shopping, this is also true for family visits. Contrary to fun shopping, women are also more likely than men to generally use the car for family visits. Similar to fun shopping, high car availability appears to result in a higher probability of car use, and lower probabilities of public transport and cycling and walking.

The standardized coefficients reveal that the built environment does not have a strong effect on modal choice for family visits (contrary to the previous model of modal choice for fun shopping). Only density has a considerable effect, and specifically on car use and usage of public transport (not on cycling and walking). Other variables are of greater interest. For example, among the explanatory variables measured, car use and public transport are most heavily influenced by car availability. Once again, the effect of lifestyles on modal choice is rather weak. However, cycling and walking is to a certain extent influenced by some lifestyles. The influence of a low-budget-and-active/creative lifestyle (0.139) is similar to the one of car availability (-0.171).

Table 6.7 Total and direct effects on modal choice for family visits

	Car 44.1% variance explained	**Bicycle / On foot** 9.9% variance explained	**Public transport** 42.0% variance explained
Lifestyles			
culture lover	-0.057* (-0.052)	-0.069* (-0.063)	0.279* (0.254) _0.113* (0.103)_
friends and trends	-0.098* (-0.097)	-0.059 (-0.058) _-0.113* (-0.112)_	0.138* (0.137) _0.098* (0.097)_
home-oriented but active family	0.139* (0.126)	-0.069* (-0.063)	-0.209* (-0.190) _-0.160* (-0.145)_
low-budget and active/creative	-0.054* (-0.052)	0.147* (0.139) _0.137* (0.130)_	0.024 (0.023)
home-oriented traditional family	0.144* (0.120) _0.199* (0.167)_	0.093* (0.078)	-0.076* (-0.063)
Built environment			
location relative to local centre	0.055* (0.065)	-0.080* (-0.012)	-0.026* (-0.031)
location relative to regional centre	0.102* (0.123)	-.0.019* (-0.023)	-0.140* (-0.168) _-0.091** (-0.109)_
local accessibility	-0.073* (-0.106)	0.014* (0.020)	0.035* (0.051)
density	-0.202* (-0.252) _-0.098* (-0.122)_	0.020* (0.025)	0.242* (0.303) _0.192* (0.240)_
Stage of life			
student living at home	-0.207* (-0.223)	0.214* (0.229) _0.175* (0.187)_	-0.106* (-0.113) _-0.257* (-0.274)_
older family, working	0.280* (0.276)	-0.173* (-0.171)	-0.042 (-0.042)
young family	0.211* (0.218) _0.177* (0.183)_	-0.070* (-0.073)	-0.110* (-0.114) _-0.134* (-0.138)_
Gender (female)	0.087* (0.043)	-0.080* (-0.039)	0.077* (0.038)
Car availability	0.965* (0.617) _0.965* (0.617)_	-0.183* (-0.171) _-0.183* (-0.171)_	-0.464* (-0.429) _-0.464* (-0.429)_
Model fit:			
Chi^2	Chi^2 = 55.482, df = 49, p = 0.2436	Chi^2 = 56.269, df = 50, p = 0.2519	Chi^2 = 50.545, df = 47, p = 0.3353
CFI	0.993	0.994	0.996
TLI	0.992	0.993	0.996
RMSEA	0.012	0.011	0.009
WRMR	0.909	0.910	0.864

* = significant at $\alpha = 0.05$, ** = significant at $\alpha = 0.10$
standardized effects shown in parentheses, direct effects shown in italics

6.5.3 Modal choice for active leisure trips

We categorized all trips for purposes to actively participate in sports or cultural activities as active leisure activities. Table 6.8 presents the total and direct effects on modal choice for these leisure trips. Active lifestyles and family-orientated lifestyles seem to make the car more likely for leisure trips. Comparable to modal choice for family visits, car use for active leisure activities is positively influenced by a friends-and-trends lifestyle, an active-family lifestyle and a traditional-family lifestyle. Culture lovers and respondents with a low-budget-but-active/creative lifestyle tend to use public transport or to cycle or walk for these active leisure activities. Public transport is also associated with a traditional-family lifestyle, and cycling and walking with a friends-and-trends lifestyle.

The effect of the built environment on modal choice for active leisure activities is similar to the previous models. Residing in traditional neighbourhoods characterized by a short distance to a local or regional centre, high densities and many accessible opportunities within a small time span favours the use of alternative travel modes to car use. The discrepancy between the use of cars and car alternatives is clearly illustrated by the influence of stage of life. Whereas older and young families tend to prefer their car for active leisure activities instead of cycling and walking or public transport, the opposite holds for students living at home. Gender has only a significant effect on public transport usage: women seem more likely to use public transport for leisure trips than men. Finally, car availability has a similar effect on modal choice for active leisure activities as for fun shopping and family visits. If cars are available to a respondent, car use is likely to be higher, and public transport usage as well as walking and cycling tends to be lower.

Based on the standardized coefficients, we find that car availability heavily influences modal choice for active leisure activities, especially for car use and public transport. The effect of lifestyle has a strength similar to that of other variables. For example, cycling and walking is influenced by a mix of lifestyles, spatial variables, stage-of-life variables and car availability: car availability (-0.201), location relative to regional centre (-0.183), older working family (-0.164), density (0.150), culture-lover lifestyle (0.140) and location to local centre (-0.115).

Table 6.8 Total and direct effects on modal choice for active leisure activities

	Car 27.1% variance explained	**Bicycle / On foot** 13.2% variance explained	**Public transport** 25.5% variance explained
Lifestyles			
culture lover	-0.209* (-0.194) *-0.167* (-0.155)*	0.151* (0.140) *0.101** (0.094)*	0.174* (0.161) *0.156* (0.145)*
friends and trends	0.061 (0.061) *0.147* (0.147)*	0.025* (0.025)	-0.068 (-0.068) *-0.136* (-0.136)*
home-oriented but active family	0.113* (0.090)	-0.078* (-0.063)	-0.115* (-0.092)
low-budget and active/creative	-0.006 (-0.005)	0.076 (0.073) *0.110* (0.106)*	0.033* (0.031)
home-oriented traditional family	0.201* (0.165) *0.246* (0.202)*	-0.095** (-0.078) *-0.150* (-0.123)*	0.069* (0.057)
Built environment			
location relative to local centre	0.026* (0.030)	-0.099* (-0.115) *-0.087** (-0.101)*	-0.046* (-0.053)
location relative to regional centre	0.121* (0.143) *0.074** (0.087)*	-0.155* (-0.183) *-0.133* (-0.156)*	-0.085* (-0.100)
local accessibility	-0.034* (-0.048)	0.016* (0.023)	0.061* (0.086)
density	-0.122* (-0.151) *-0.073** (-0.091)*	0.121* (0.150) *0.098* (0.122)*	0.087* (0.107)
Stage of life			
student living at home	-0.149* (-0.160)	0.073* (0.078)	0.205* (0.220)
older family, working	0.250* (0.249) *0.189* (0.189)*	-0.164* (-0.164) *-0.139* (-0.138)*	-0.257* (-0.256)
young family	0.133* (0.130) *0.105** (0.103)*	0.010 (0.010)	-0.141* (-0.138)
Gender (female)	0.013 (0.006)	-0.030 (-0.015)	0.100* (0.049)
Car availability	0.449* (0.380) *0.449* (0.380)*	-0.213* (-0.201) *-0.213* (-0.201)*	-0.803* (-0.460) *-0.803* (-0.460)*
Model fit			
Chi^2	Chi^2 = 57.996, df = 51, p = 0.2331	Chi^2 = 57.451, df = 51, p = 0.2485	Chi^2 = 58.961, df = 24, p = 0.299
CFI	0.990	0.991	0.993
TLI	0.989	0.990	0.992
RMSEA	0.014	0.014	0.012
WRMR	0.894	0.892	0.907

* = significant at α = 0.05, ** = significant at α = 0.10
standardized effects shown in parentheses, direct effects shown in italics

6.6 Conclusions

This paper presented the results of nine structural equation models which represent the complex relationships between lifestyles, the built environment, stage of life, car availability and travel behaviour. Models were estimated based on data from an Internet survey on lifestyles and travel behaviour. Most respondents were highly educated, but different travel patterns still occurred within this homogeneous group. Our results point out that modal choices for fun shopping, family visits and active leisure activities are significantly influenced by personal lifestyles and the built environment.

Some lifestyles, especially a low-budget lifestyle and an active-family lifestyle, have a very straightforward influence on modal choice. Regardless of leisure trip type, a low-budget lifestyle is related with less car use and more cycling, walking, and public transport, whereas the opposite holds for an active-family lifestyle. This seems obvious since purchasing a car does not always fit into a low-budget lifestyle, and on the other hand the car is a flexible transport mode that enables active families to easily combine and participate in many activities such as different sports and family activities. Culture lovers, who have a more or less non-traditional lifestyle, seem to prefer the same travel modes (i.e., public transport and cycling and walking) as respondents with a low-budget lifestyle (except for cycling and walking in the model of family visits). In sum, car use tends to be associated with an active lifestyle (ref. active-family lifestyle, and friends-and-trends lifestyle in the model of active leisure trips), whereas public transport and cycling and walking are more associated with a non-traditional lifestyle (ref. culture-lover lifestyle) or a low-budget lifestyle (ref. low-budget-and-active/creative lifestyle). Other lifestyles do not have such an obvious influence on modal choices for leisure trips. For example, modal choices of respondents with a traditional-family lifestyle depend on leisure trip type. Car use seems higher (but not for fun shopping trips), cycling and walking seems lower and public transport seems higher (but not for family visits). Similar findings can be formulated for respondents with a friends-and-trends lifestyle. Thus important differences exist within socio-economic and socio-demographic homogeneous groups. Therefore, transport planning and policy should not focus only on travel patterns by, e.g., gender, age and income groups.

On the other hand, the built environment still has an important influence on travel behaviour even when lifestyles are accounted for. Short distances between residences and local or regional centres, high densities and good local accessibility are associated with lower probabilities of car use and higher probabilities of cycling and walking as well as using public transport. In order to encourage the use of car alternatives spatial planning policies should focus on (i) residential developments connected to city centres and town centres, (ii) densifying, and (iii) the provision of opportunities close to the residence.

The suggested models can be applied to other travel behaviour aspects such as travel distance and trip chaining. Furthermore, the explained variance of modal choice in our models ranges from 9.9% to 48.5%. This indicates that our models could benefit from the inclusion of additional information, for example subjective aspects such as attitudes towards the built environment and travel modes. These specific attitudes are not included in the lifestyle concept which only includes attitudes toward general themes such as leisure orientation. Moreover, all components of the model illustrated in Figure 6.3 are concurrently and continually considered since our data is cross-sectional. However, lifestyles, stage of life and residential location can evolve over time. A longitudinal approach seems interesting in order to study the dynamics between all these components, but this requires data from a panel survey or a retrospective survey. Several venues thus exist for further research into the connection between lifestyles, the built environment and travel behaviour.

Notes

1. Although we describe residential self-selection as being a function of personal characteristics (e.g., income), attitudes and preferences, only personal SED characteristics are represented in Model 2b in Figure 6.2. This is because information on attitudes and preferences were not available for our analysis.

Appendix

Pattern matrix for built environment factors

	Location relative local centre	Regional accessibility	Density	Location relative to regional centre	Local accessibility
Distance to railway station level 1, 2, 3, 4, 5	1.061				
Distance to railway station level 1, 2, 3, 4, 5, 6	0.995				
Distance to railway station level 1, 2, 3, 4	0.768				
Distance to railway station level 1, 2, 3	0.443			0.361	
Potential accessibility 60 minutes		1.023			
Potential accessibility 45 minutes		0.969			
Distance to city level 1		-0.918			
Potential accessibility 30 minutes		0.553			0.464
Distance to railway station level 1		-0.440		0.356	
Population density			0.953		
Built up index			0.718		
Job density			0.532		
Land use mix			-0.407		
Distance to city level 1, 2, 3				0.929	
Distance to city level 1, 2, 3, 4				0.797	
Distance to city level 1, 2				0.705	
Distance to railway station level 1, 2		-0.314		0.622	
Distance to city level 1, 2, 3, 4, 5	0.350			0.515	
Potential accessibility 10 minutes					0.994
Potential accessibility 15 minutes					0.860
Potential accessibility 5 minutes			0.356		0.625

Note:
City levels correspond to categories defined in the Spatial Structure Plan of Flanders, a spatial policy plan for the Flanders region (Ministerie van de Vlaamse Gemeenschap, 1997/2004), where 1 = metropolitan area (+200,000 inhabitants), 2 = regional urban area, 3 = large urban area, 4 = medium-sized urban area, 5 = small city.

Railway station levels correspond to categories used by the Belgian national railway, where 1 - 5 have the same meaning as for city level, and 6 = local village.

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"Logica brengt je van A naar B,
maar verbeelding brengt je overal."

Albert Einstein (1879-1955)

7. Car ownership explained by the structural relationships between lifestyles, residential location, and underlying residential and travel attitudes

Van Acker, V., Mokhtarian, P.L., Witlox, F. (2010) Car ownership explained by the structural relationships between lifestyles, residential location, and underlying residential and travel attitudes. Transport Policy (submitted).

Abstract The greater part of studies in land use-travel behaviour interaction research only considers the influence of (mainly residential) land use characteristics on daily travel behaviour. However, this framework should be expanded. A first step is to explore the complex interdependencies among long-term lifestyle decisions, medium-term decisions on residential location and car ownership, and the underlying residential and travel attitudes. Doing so, travel behaviour can be placed within a hierarchy of decisions while considering the motivational background of these decisions. Using data from an Internet survey completed by +1,800 respondents in Flanders, Belgium, car ownership is in this paper defined somewhat more broadly as car availability. The results of a structural equation model show that the residential neighbourhood has a significant direct effect on car availability. However, effects are small compared to the influence of other variables, especially stage of life and travel (mode) attitude, the latter influence referring to travel-related self-selection. Moreover, one should keep in mind that residential attitudes remain important in selecting the residential neighbourhood and its land use characteristics in the first place, indicating the need to control for residential self-selection.

7.1 Introduction

Since the 1950s there has been a more than tenfold increase in the number of cars in Belgium, rising from 0.5 million cars in 1950 to 6.5 million cars in 2008. Nowadays, households tend to own one car for every two household members (http://statbel.fgov.be). This trend is not restricted to Belgium, but also occurs in other European countries (http://www.plan.be). Without doubt, widespread car ownership encourages social and economic development (Church *et al*., 2000;

Preston and Rajé, 2007; Cebollada, 2009). Car ownership is also an important factor in travel behaviour, encouraging car use (Dieleman *et al*., 2002; Van Acker and Witlox, 2010a) and facilitating long-distance travel (Bagley and Mokhtarian, 2002; Schwanen *et al*., 2002; Krizek, 2003). Increasing car numbers and expanding mobility are, however, nowadays also perceived as undesirable because of the related negative impacts on the environment, traffic safety and congestion. Therefore policy makers seek for solutions and spatial planning seems one of the possible options. Considering that most travel is utilitarian or purposive, it seems logical that an enhanced organization of the locations to which people travel might result in more efficient travel patterns. However, there is no such unambiguous and one-way relation between daily travel behaviour and the spatial characteristics of important activity locations such as the residence and the workplace. Daily travel decisions should be considered within a hierarchy of long-term lifestyle decisions and medium-term decisions on residential location and car ownership (Ben-Akiva, 1973; Salomon, 1981; Salomon and Ben-Akiva, 1983; Van Acker *et al*., 2010a). This decision hierarchy might give the impression of considering only observable behaviours and not the fundamental motivations. Attitudes are one example of subjective influences underlying behavioural decisions. By categorizing, transforming and interpreting information, an individual evaluates various aspects of a specific issue such as a residential location or owning a car. The sum of all these related evaluations then determines the general attitude toward that issue (Golledge and Stimson, 1997) and influences the individual's behaviour (Gärling *et al*., 1998; Brehn *et al*., 2005). Consequently, attitudes can be considered as cognitive, affective, normative, and intentional influences underlying decisions such as residential location and car ownership.

The attention to attitudes in travel behaviour research is not completely new: transport behavioural analysts have been aware of this for some time and many studies have discussed the role of attitudes in travel behaviour decisions (e.g., Tardiff, 1977; Dobson *et al*., 1978; Golob *et al*., 1979; Lyon, 1984; Gauthier and Shaw, 1986; Gärling *et al*., 1998; and more recently Parkany *et al*., 2004, and Thogersen, 2006). However, these studies tend to neglect the link with the spatial context. Only recently, additional subjective variables were introduced in empirical work on the relationship between land use and travel behaviour (e.g., Kitamura *et al*., 1997; van Wee *et al*., 2002; Handy *et al*., 2005; Schwanen and Mokhtarian, 2005). Many of these studies merely analyze the direct effect of all these variables on travel behaviour and attempt to deduce how travel behaviour is directly influenced by land use configurations, attitudes and lifestyles. However, ignoring the complex interdependencies *among* long-term lifestyle decisions, medium-term decisions on residential location and car ownership, and their underlying travel and residential attitudes might result in a misspecification of the land use effects on travel behaviour (Bagley and

Mokhtarian, 2002; Naess, 2005; Scheiner and Holz-Rau, 2007). People often select themselves into a residential location that matches not only their residential attitudes but also their travel attitudes (Handy *et al*., 2005; Bhat and Guo, 2007; Mokhtarian and Cao, 2008). For example, people residing in a high-density neighbourhood with nearby grocery stores and public services may choose to walk to them not simply because the spatial lay-out itself encourages them to do so, but rather because they just prefer to walk to these locations instead of using their cars every time. A similar self-selection process exists with respect to other aspects such as car ownership and modal choices (van Wee, 2009). Efforts to use urban planning policies to discourage car ownership and car use might be ineffective for people with an overall preference for auto-oriented travel and behaviour. Or as Krizek puts it: "You can take the family out of the suburbs but you can't take reliance on the Chevy Suburban out of the family" (Krizek, 2006). However, travel-related self-selection has received less attention compared to the issue of residential self-selection. Therefore, this paper analyzes the land use effects on car ownership, while accounting for attitudinal influences fundamental to the complex relationships between lifestyles, residential location choices and car ownership.

This paper is part of a series of studies of subjective influences (i.e., lifestyles and attitudes) on travel behaviour. Van Acker *et al.* (2010b) focussed on the definition and measurement of lifestyles, whereas the current paper specifically discusses how residential and travel attitudes influence residential location decisions and car ownership. A subsequent study (Van Acker *et al*., 2010c) will expand the current framework considering the interaction between these longer term decisions and daily modal choices for leisure trips.

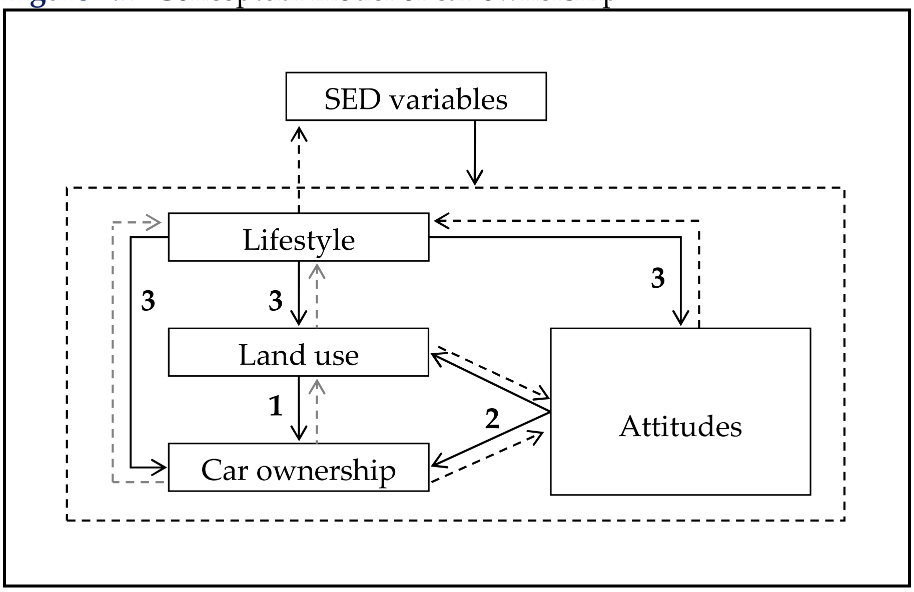
The paper is organized as follows. Section 7.2 briefly summarizes the literature on the interaction between car ownership, land use characteristics of the residence, lifestyles and fundamental residential and travel attitudes. Section 7.3 discusses the research design and the data available to this study. Section 7.4 discusses some important modelling issues and presents the empirical results. The final section summarizes the main findings of the research and points out some policy implications.

7.2 Literature review

This section presents a brief review of the literature on car ownership and summarizes some aspects which are relevant to our analysis (see Figure 7.1). A well-known study on car ownership and car dependence is the study by Kenworthy and Laube (1999). In an international overview of cities, they found that car ownership systematically varies with land use patterns. However, due to the scale effect of the modifiable areal unit problem (MAUP), it is no surprise that studies using macro-scaled aggregate land use characteristics report higher correlations between land use and car ownership (Zhang and Kukadia, 2005; Boussauw *et al*., 2010). Empirical studies focussing on much smaller regions tend to report less strong influences of land use characteristics. Instead household income appears to be a crucial factor (e.g., Dargay, 2001, 2002; Van Acker and Witlox, 2010a). Nevertheless, various studies argue that car ownership might still be significantly influenced by land use patterns (see arrow 1 in Figure 7.1). Research findings indicate that car ownership is lower in urban and traditional areas characterized by high densities, more diversity and easy access to various opportunities (Kockelman, 1997; McNally and Kulkarni, 1997; Gorham, 2002; Simma and Axhausen, 2003; Bhat and Guo, 2007; Chen *et al*., 2008; Gao *et al*., 2008). After all, in high-density and mixed-use neighbourhoods public transport can be organized more efficiently, and activity locations are within walking and cycling distance. Consequently, other alternatives for car use exist and the need to own a car might be reduced. Moreover, car ownership is more expensive in urban areas due to more congestion, limited parking space and more expensive parking (Schwanen *et al*., 2004; Giuliano and Dargay, 2006). However, the majority of empirical studies points out relationships of association rather than causality (Handy *et al*., 2005). Although there are indications that land use matters, it is not necessarily true that the land use characteristics themselves have a causal effect on car ownership. As already mentioned, residential and travel attitudes are fundamental to residential location choices and decisions on car ownership (see arrows 2 in Figure 7.1). These attitudes are as important as the objectively measured land use characteristics, indicating the significance of residential and travel-related self-selection. Based on a cross-sectional analysis, Cao *et al.* (2007) noticed that the initially observed correlation between land use characteristics of the residence and car ownership disappeared if the model was controlled for residential and travel attitudes fundamental to the residential location choice. This finding suggested that the association between land use and car ownership is primarily the result of residential self-selection. On the other hand, their analysis based on quasi-panel data suggested that land use characteristics such as outdoor spaciousness and land use mix remain significant, but their effects were found marginal compared to other socio-economic and demographic (SED) variables. Consequently, no strong evidence was found supporting the causal relationship between land use and car ownership. On the other hand, Bhat and Guo (2007) for example found that, while controlling for the effects of residential self-selection, car ownership is still significantly influenced by land use patterns. This suggests that the empirically measured correlation between land use and car ownership is not simply a spurious one caused by the intervening interaction between land use patterns and the residential attitudes of people who choose to live in a particular neighbourhood. Both studies accounted for residential self-selection, or in other words, the indirect influence of attitudes on car ownership through residential location choice. Nevertheless, it might be important to consider the direct influence of (travel) attitudes on car ownership as well, referring to the influence of travel-related self-selection. A few studies have related travel attitudes to the vehicle type choice (Kuppam *et al.*, 1999; Johansson *et al.*, 2006; Ben and Potter, 2007), but these studies did not control for differences in residential neighbourhoods. Thus, studies on travel-related self-selection in land use-travel behaviour interaction research remain so far scarce (e.g., Choo and Mokhtarian, 2004; Cao *et al.*, 2006, 2007).

Furthermore, the medium-term decisions on car ownership and residential location choice are on their turn influenced by long-term decisions on lifestyles (see arrows 3 in Figure 7.1). Lifestyles refer to opinions and motivations underlying patterns of behaviour by which someone tries to elucidate his or her social position (Munters, 1992). Within this respect, residential location choices and car ownership are examples of behaviours in which lifestyles are reflected. For example, an active lifestyle or a family-oriented lifestyle might be reflected in owning one or several cars and suburban or even rural living, contrary to a low-budget lifestyle or a non-traditional culture-lover lifestyle (Lanzendorf, 2002; Scheiner and Holz-Rau, 2007; Van Acker *et al.*, 2010b).

Figure 7.1 Conceptual model of car ownership



The dotted arrows in Figure 7.1 represent feedback mechanisms. For example, Ganzeboom (1988) argues that socio-economic and demographic (SED) characteristics of an individual might influence a lifestyle (e.g., families with grown-up children might be more involved in activities outside the house compared to families with toddlers). However, the reverse is also possible: lifestyle in its turn might influence SED characteristics such as stage of life or household composition (e.g., a family-oriented lifestyle is likely to result in larger household sizes than a work-oriented one). A similar dual relationship exists between attitudes and behaviour. We already discussed how residential and travel attitudes might influence decisions on residential location choice and car ownership, but once decisions are made and people become more familiar with the alternatives, attitudes about the choice and alternatives might change (Dobson *et al*., 1978; Lyon, 1984; Bohte *et al*., 2009) For example, having a positive attitude toward public transport might justify someone's decision on not owning a car, but since that person does not own a car and must rely on, e.g., public transport, the attitude toward public transport is strengthened. These attitudinal changes might also have repercussions for other decisions. For example, a positive attitude toward public transport might be reinforced by the lack of cars in the household, but in turn this attitude (and also the initial 'no-car' ownership decision) might influence the decision to reside in a neighbourhood with easy access to public transportation. The feedback mechanisms between lifestyles and SED characteristics, as well as between attitudes and behaviour, will be modelled. However, the feedback loops between behaviours at various time-scales are not considered due to issues such as model complexity and identification. Moreover, only cross-sectional data are available, whereas the feedback across time scales suggests a dynamic, longer-term process for which panel data would be needed. For example, residential location changes occur on much longer time frame than the impact of behaviour on underlying attitudes, and cannot be captured in cross-sectional data.

7.3 Data specification: Attitudes and other key variables

This paper aims at measuring the influence of land use on car ownership, simultaneously with accounting for residential and travel-related self-selection and considering the hierarchy between decisions on lifestyles, residential location and car ownership. Current travel behaviour surveys, however, do not offer all the necessary information and generally lack data on attitudes and lifestyles. For that reason, we conducted an Internet survey between May 2007 and October 2007. For practical reasons, the survey was initially made known to students and staff members of the University of Antwerp and the Faculty of Sciences at Ghent University, and secondly an announcement was published in regional information magazines of several villages in the larger urban region of Ghent (Flanders, Belgium). In total, 2,363 persons completed the survey, of which (after data cleaning) 1,878 were retained for further analyses. Despite our efforts, we did not obtain a well-balanced sample and especially education was found unrepresentative for the whole population (for a more complete overview of sample characteristics, see Van Acker *et al*., 2010c). Respondents in our sample have a higher education than the average inhabitant of Flanders or

Belgium. However, the focus of our research is on modelling relationships among car ownership and other key variables, and not on describing car ownership as such. Similar to Van Acker *et al*. (2010b) who discussed the concept of lifestyles and found five distinct lifestyle types (culture lover, friends and trends, home-oriented but active family, home-oriented traditional family, low-budget but active/creative), this section describes the measurement of residential and travel-related attitudes, and the correlations between these attitudes and other key variables.

7.3.1 Attitude measurement

The Internet survey contained various questions on attitudes toward residential locations, travel in general, and travel modes specifically. These questions were inspired by previous research on lifestyles, attitudes and mobility (see, e.g., Bohte *et al*., 2008, for the Netherlands; Bagley and Mokhtarian, 1999, for the USA). The responses on these survey items were factor analyzed in SPSS 15.0 (SPSS Inc., 2006) to extract the fundamental attitudes. In each factor analysis, the number of factors was determined based on interpretability of the factors, combined with interpretation of the scree plot and eigenvalues larger than one. The factor scores will then be used as input for further analyses concerning the complex relationships between car ownership, residential location, lifestyles and attitudes.

7.3.1.1 Residential attitudes

The survey included 16 statements on attitudes toward residential locations. Respondents were asked to indicate on a five-point Likert scale ranging from 'unimportant' to 'very important' which aspects (except price) influence their supposed residential location choice. These 16 variables were then factor analyzed (principal axis factoring, promax rotation, 61.6% variance explained) into five underlying dimensions: car alternatives, open space and quietness, safety and neatness, accessibility, and social contact. Table 7.1 presents the pattern matrix indicating which location statements are most strongly associated with each factor.

Two residential attitudes refer to mobility aspects within the residential location. The evaluation of the available transport infrastructure (especially non-car based infrastructure) is incorporated into the attitude toward car alternatives, whereas the aspect of having easy access to various activity locations determines the attitude toward accessibility. The attitude toward open space and quietness is associated with high scores on aspects of the natural environment, in contrast to the attitude toward social contact in which the social environment of neighbours is rated as important. Safety (i.e., social, traffic) and aesthetic aspects (i.e., architecture, neatness) are combined into a fifth residential attitude labelled 'safety and neatness'.

Since we used an oblique rotation procedure, attitudinal factors were allowed to be correlated. The two most highly-correlated factors were open spaces and quietness, and safety and neatness (0.518). These residential attitudes are probably associated with residential preferences toward residing in more suburban areas or in the country. No other correlation exceeded 0.395, and thus none are high enough to trigger multicollinearity concerns.

Table 7.1 Pattern matrix for residential attitudes

Factors on residential attitudes → **Suppose you have to choose a new residential location. What aspects are important to you? ↓**	**Car alternatives**	**Open space and quietness**	**Safety and neatness**	**Accessibility**	**Social contact**
Presence of bike paths	0.863				
Presence of sidewalks	0.822				
Traffic safety	0.420		0.403		
Close to public transport	0.375			0.334	
Presence of green areas		0.918			
Quietness		0.793			
Social safety, no crimes			0.766		
Neatness, tidiness		0.286	0.552		
Sufficient parking places			0.454		
Outlook of buildings, architecture			0.318		
Close to shops, groceries				0.738	
Close to leisure activities				0.687	
Close to family and friends				0.391	
Close to work				0.349	
Frequent contact with neighbours					0.777
Good contact with neighbours					0.761

Note: Only factor loadings higher than 0.200 (in magnitude) are reported: loadings higher than 0.300 characterize the factors to a large extent, and values between 0.200 and 0.300 are also reported because they enrich the interpretation of certain factors.

7.3.1.2 Travel attitudes and travel mode attitudes

The Internet survey included 13 statements related to travel in general for which a factor analysis (principal axis factoring, promax rotation) resulted in three general travel attitudes (see pattern matrix reported in Table 7.2). Furthermore, the survey also included 12 statements related to four specific travel modes (car, public transport, cycling and walking). Specific travel mode attitudes were obtained from factor analyses (principal axis factoring, promax rotation) for each separate travel mode (cycling and walking were combined). The pattern matrices of these analyses are reported in Table 7.3.

Turning first to the general attitudes, the frustrated traveller scale is based on statements such as 'Daily travel is boring' (loading = 0.876) and 'I love being on the road' (loading = -0.757). It seems self-evident that frustrated travellers do not enjoy travelling and being on the road. This is in contrast with frequent car users (or car addicts) who indicate that they should use their car less often according to their family and friends. Since this travel attitude refers to the opinion of family and friends, it also includes an aspect of social norms as perceived by the respondent. A third travel attitude refers to a pro-environment orientation. Pro-environment respondents are aware of the problems caused by traffic and they consider themselves able to contribute to a solution for these problems.

Respondents were also asked to indicate the aspects that characterize car, public transport, and cycling and walking. Factor analyses for each transport mode separately found similar travel mode attitudes in each case. All three modes can be perceived as comfortable. Another recurring issue is the consequences (whether positive or not) of using cars, public transport or cycling and walking on the environment but also on someone's image or health. The attitudes toward public transport produce a third factor, time-saving, which did not emerge as a separate dimension in the analysis of car attitudes and attitudes toward cycling and walking (the relevant items loaded on the comfort factor in the latter cases).

Correlations between general travel attitudes are low (less than 0.152), whereas moderately strong correlations are exhibited between travel mode attitudes. Except for the car, a positive attitude on the comfort factor seems to be correlated with a positive attitude on the positive effects factor ($R_{\text{comfort x positive effects}}$ = 0.551 for public transport, $R_{\text{comfort x positive effects}}$ = 0.475 for cycling/walking). Still, however, these correlations are not alarmingly high.

Table 7.2 Pattern matrix for general travel attitudes

Factors on general travel attitudes → **Do you agree with the next statements on mobility ↓**	**Frustrated traveller**	**Pro-environment**	**Frequent car user**
Daily travel is boring	0.876		
I love being on the road	-0.757		
Travel time is wasted time	0.643		
Arriving at my destination is the only good thing about daily travel	0.562		
Traffic makes me nervous	0.368	0.270	
I like to discover new and unfamiliar places	-0.294		
Car traffic causes serious problems		0.637	
I myself can contribute to a solution for traffic problems		0.596	
It does not matter whether I use my car or not. Other people still drive their cars.		-0.486	
According to family and friends, traffic problems are over exaggerated		-0.263	
According to family and friends, I should use public transport more often			0.757
According to family and friends, I should bike more often			0.724
According to family and friends, I should use my car only when absolutely necessary		0.301	0.323

Note: Only factor loadings higher than 0.200 (in magnitude) are reported: loadings higher than 0.300 characterize the factors to a large extent, and values between 0.200 and 0.300 are also reported because they enrich the interpretation of certain factors.

Table 7.3 Pattern matrix for specific travel mode attitudes

PUBLIC TRANSPORT			
Factors on public transport attitudes → **Which aspects characterize public transport? ↓**	**Comfort**	**Positive effects**	**Time-saving**
Comfortable	0.781		
Relaxing	0.471		
Environment-friendly		0.650	
Activities while travelling		0.340	
Safe	0.296	0.319	
Cheap		0.301	0.218
Good for image		0.249	
Healthy		0.248	
Flexible			0.633
Time-saving			0.323
Reliable			0.284
Privacy-offering			0.249

Note: Only factor loadings higher than 0.200 (in magnitude) are reported: loadings higher than 0.300 characterize the factors to a large extent, and values between 0.200 and 0.300 are also reported because they enrich the interpretation of certain factors.

Table 7.3 Pattern matrix for specific travel mode attitudes *continued*

CAR ATTITUDES		
Factors on car attitudes → **Which aspects characterize car use? ↓**	**Comfort**	**Negative effects**
Reliable	0.625	
Comfortable	0.616	
Flexible	0.596	
Time-saving	0.582	
Privacy-offering	0.472	
Safe	0.454	
Relaxing	0.372	
Good for image	0.294	
Activities while travelling	0.207	
Healthy		-0.677
Cheap		-0.483
Environment-friendly		-0.480
CYCLING/WALKING		
Factors on cycling/walking attitudes → **Which aspects characterize cycling/walking? ↓**	**Comfort**	**Positive effects**
Privacy-offering (cycling)	0.634	
Privacy-offering (walking)	0.606	
Comfortable (cycling)	0.515	
Comfortable (walking)	0.461	
Time-saving (cycling)	0.374	
Time-saving (walking)	0.223	
Safe (cycling)	0.357	
Safe (walking)	0.331	
Flexible (cycling)	0.353	0.322
Flexible (walking)	0.346	0.215
Reliable (cycling)	0.331	
Reliable (walking)	0.321	0.333
Good for image (cycling)	0.233	
Good for image (walking)	0.267	
Cheap (cycling)		0.658
Cheap (walking)		0.615
Healthy (cycling)		0.618
Healthy (walking)		0.650
Environment-friendly (cycling)		0.626
Environment-friendly (walking)		0.557
Relaxing (cycling)		0.265
Relaxing (walking)		0.304

Note: Only factor loadings higher than 0.200 (in magnitude) are reported: loadings higher than 0.300 characterize the factors to a large extent, and values between 0.200 and 0.300 are also reported because they enrich the interpretation of certain factors.

7.3.2 Correlations between attitudes and other key variables

The Internet survey also provided information on key objective variables. For example, it is common practice to control the modelling results for differences in SED characteristics of the respondent and his household. A factor analysis of the SED variables in the Internet survey provided three factors, all referring to stages of life: students living at home, older family with employed adults, and a young family. By geocoding the respondents' addresses in ArcGIS 9.2, we could add spatial information from various land use and transportation databases (for more information on these databases, see Van Acker and Witlox, 2010a, b). Similar to the SED characteristics, land use characteristics such as density, diversity and accessibility are often related to each other (Cervero and Kockelman, 1997), and a factor analysis might provide interesting new land use factors. In our case, we extracted five land use factors: location relative to a local centre, location relative to a regional centre, local accessibility, regional accessibility, and density. Car ownership is the final outcome variable in our model. The Internet survey not only provided information on car ownership, but also on the possession of a driving license or a public transport pass, and the temporary availability of a car. We felt that it might be useful to combine these four characteristics into one general car availability factor, especially with regard to further analyses of modal choices (Van Acker *et al.*, 2010c). More information on the calculation and construction of the stage of life, land use and car availability factors can be found in Van Acker *et al*. (2010b).

Calculating correlations between these key variables and attitudes already reveals a number of interesting results (see Tables 7.4 and 7.5). Urban living is more likely related with a positive attitude toward accessibility. Travel attitudes might also be associated with the decision to reside in an urban neighbourhood. Especially a general pro-environment travel attitude, and to a lesser degree the positive evaluation of public transport, and cycling and walking, correlates with urban living. On the contrary, preferring open spaces and quietness, or safety and neatness is negatively associated with density, which might indicate suburban or rural living (the correlation with safety and neatness is moderate though significant). This is also suggested to some extent by car-oriented travel attitudes. Residential and travel attitudes might also differ among population groups. Non-traditional lifestyle groups such as culture lovers are associated with urban residential attitudes and a negative evaluation of the car, whereas the opposite holds for family-oriented lifestyles and older families. A young family might also appreciate the comfort aspect of public transport, and cycling and walking. Furthermore, urban residential attitudes are more likely to be associated with lower car availability compared to suburban or rural residential attitudes. Table 7.5 shows that having lower car availability is also associated with a positive attitude toward car alternatives and a pro-environment attitude.

Note that these correlations only refer to associations and not to causal relations among variables. None of these correlations appears to be greater than 0.2 in magnitude indicating that the direct relationships discussed so far are not overly strong in any case. Nevertheless, controlling for other characteristics, as we are able to do in the subsequent multivariate analysis, can reveal relationships that are suppressed when just considering pairwise association. Section 7.4 will therefore discuss causality among lifestyles, stages of life, land use characteristics, residential and travel attitudes, and car availability.

Table 7.4 Correlations between residential attitudes and other key variables

	Residential attitudes				
	Car alternatives	**Open space and quietness**	**Safety and neatness**	**Accessibility**	**Social contact**
Lifestyles					
Culture lover	0.124*	-0.009	-0.123*	0.120*	-0.035
Friends-and-trends	-0.102*	-0.064*	0.037	0.040	0.072*
Home-oriented but active family	0.033	0.169*	0.035	-0.018	0.083*
Low-budget and active/creative	-0.009	0.002	-0.119*	-0.016	0.003
Home-oriented traditional family	-0.077*	-0.151*	0.181*	0.175*	0.001
SED characteristics					
Student living at home	-0.009	-0.073*	0.093*	-0.038	0.097*
Older family, working adults	0.040	0.082*	0.053	-0.063**	0.006
Young family	0.013	-0.047	-0.007	-0.023	0.075*
Gender (female)	0.071*	-0.012	0.067*	0.127*	0.018
Residential neighbourhood					
Location relative to local centre	-0.023	-0.005	0.005	0.037	0.044
Location relative to regional centre	0.029	0.015	0.004	-0.026	0.046
Local accessibility	0.028	-0.028	0.033	-0.030	0.015
Regional accessibility	0.058**	-0.018	-0.030	-0.011	0.008
Density	0.036	-0.104*	-0.072*	0.156*	-0.030
Car availability	-0.150*	0.023	0.182*	-0.068*	0.059**

Note: * = significant at $\alpha = 0.01$, ** = significant at $\alpha = 0.05$

Table 7.5 Correlations between travel (mode) attitudes and other key variables

	Travel attitudes			Car attitudes		Public transport attitudes			Cycling/walking attitudes	
	Frustrated traveller	Pro-environment	Frequent car user	Comfort	Negative effects	Comfort	Positive effects	Time-saving	Comfort	Positive effects
Lifestyles										
Culture lover	-0.071*	0.174*	0.025	-0.118*	0.052**	0.081*	0.060*	0.007	-0.001	0.050**
Friends-and-trends	-0.038	-0.105*	0.046	0.081*	-0.009	0.019	-0.113*	0.025	0.028	-0.104*
Home-oriented but active family	-0.028	0.063*	0.049**	0.032	-0.021	-0.078*	-0.026	0.012	-0.036	0.005
Low-budget and active/creative	-0.081*	0.056**	-0.057**	-0.020	-0.021	0.040	0.054**	0.014	0.064*	0.073*
Home-oriented traditional family	-0.054**	-0.188*	-0.021	0.237*	0.001	0.099*	-0.074*	-0.028	0.161*	-0.071*
SED characteristics										
Student living at home	0.004	-0.141*	0.028	0.107*	-0.033	0.057**	-0.061**	0.005	0.050	-0.038
Older family, working adults	0.042	0.031	0.100*	-0.092*	-0.037	-0.114*	-0.002	0.023	-0.160*	-0.006
Young family	0.015	0.010	-0.036	0.031	0.046	0.054**	0.001	-0.014	0.072*	0.025
Gender (female)	0.053**	-0.041	-0.006	0.046**	0.062*	-0.015	-0.044	-0.022	0.081*	-0.106*
Land use										
Location relative to local centre	0.018	-0.071*	0.010	0.038	0.004	0.006	-0.113*	0.011	0.019	-0.004
Location relative to regional centre	-0.012	-0.009	0.020	0.077*	0.005	0.010	-0.006	0.019	0.009	-0.052**
Local accessibility	0.024	-0.043	-0.005	0.059**	-0.023	0.014	-0.024	0.035	-0.008	0.003
Regional accessibility	0.020	0.025	0.006	-0.035	0.023	-0.060**	-0.016	-0.045	-0.024	-0.004
Density	0.002	0.136*	-0.004	-0.121*	0.025	0.050**	0.038	0.020	0.032	0.071*
Car availability	-0.021	-0.156*	0.190*	0.135*	-0.044	-0.142*	-0.131*	-0.048**	-0.134*	-0.113*

Note: * = significant at $\alpha = 0.01$, ** = significant at $\alpha = 0.05$

7.4 Structural equations model and results

The variables described in Section 7.3 will now be used as input for the estimation of a structural equations model (SEM). The conceptual model in Figure 7.1 involves multiple relationships among a set of variables. A SEM can simultaneously estimate such multiple relationships, where a particular variable is a predictor of other variables in one equation (e.g., land use characteristics that influence car availability) and at the same it is an outcome variable influenced by other variables in another equation (e.g., land use characteristics that are influenced by lifestyles) (Raykov and Marcoulides, 2000; Byrne, 2001; Kline, 2005). This section discusses some important model specification issues as well as the model results.

7.4.1 Model specification issues

A SEM is estimated by finding the model parameters that make the model-implied covariance matrix a best match to the empirically-based covariance matrix for the data. One standard estimation technique that matches these matrices is maximum likelihood (ML) which assumes that all outcome variables in the model are normally distributed (Bentler and Dudgeon, 1996; Kline, 2005). However, the assumption of normality is not always fulfilled and, therefore, the software package Mplus 4.21 offers an alternative maximum likelihood-based estimator (MLMV) which produces obust standard errors and a mean- and variance adjusted chi-square test (Muthén and Muthén, 2006).

A second model specification issue is the effect of outliers. Since all outcome variables are continuous and a ML-based estimator is used, (multivariate) outliers can be detected by calculating the Mahalanobis distance and the loglikelihood for each observation (De Maesschalck *et al*., 2000; Kline, 2005; Ghosh-Dastidar and Schafer, 2006) and plotting these outliers' scores against the scores for car availability. By removing these outliers and examining the means and variances of all variables, it became clear that outliers generally correspond with respondents who have a pronounced lifestyle and who reside in a neighbourhood with very good local accessibility or a neighbourhood distantly located from a regional centre. Those outliers are however interesting for our analysis which estimates the effect of those lifestyles and land use patterns on car availability. Moreover, removing outliers resulted in only marginal changes in the overall model fit and individual parameter estimates. Consequently, we decided to retain all outliers.

Furthermore, the overall model fit must be addressed before the individual parameter estimates can be discussed and interpreted. A widely used model fit index is the χ^2-statistic which measures the discrepancy between the observed empirically-based and the estimated model-based covariance matrices. Table 7.6 indicates that the suggested model should be rejected based on its χ^2-statistic. However, the χ^2-statistic is affected by sample size, and if sample sizes are large the value of χ^2 often leads to rejection of the model even though relatively small differences exist between observed and predicted covariances. To reduce the sensitivity of the χ^2-statistic to sample size, its value can be divided by the degrees of freedom but there are no clear-cut guidelines about desired values for this adjusted χ^2-statistic (Kline, 2005). Bollen (1989) indicates cut-off values of 2.0 or even as high as 5.0. For these reasons, most SEMs report a variety of model fit indices. The Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) are two examples of a comparative fit index which assesses the improvement of the hypothesized model over a baseline model (e.g., the independence model in which all variables are uncorrelated to each other). In contrast to the comparative fit indices, the Root Mean Square Error of Approximation (RMSEA) is an absolute model fit index and does not compare with a specific baseline model (for more information, see, e.g., Bollen, 1989; Hu and Bentler, 1999; Kline, 2005). According to several indices, model fit is generally adequate: RMSEA is lower than the maximum desired value, while CFI and TLI are only slightly below the desired minimum thresholds and the ratio between χ^2 and degrees of freedom is approximately 2.

Table 7.6 Model fit results

	χ^2 (df) p	χ^2 / df	CFI	TLI	RMSEA
Desired values	p > 0.05	< 2	> 0.95	> 0.95	< 0.05
Model-based values	336.07 (154) 0.00	2.18	0.92	0.900	0.03

7.4.2 Model results

Having specified the measurement of key variables and discussed some important model specification issues, we now turn our attention to the model results. Lifestyles, residential neighbourhood choice and car availability are all considered as outcome variables in one single model (27 endogenous variables in all). In what follows, we discuss step by step the modelling results, starting with long-term decisions on lifestyles, then medium-term decisions on residential location, and finally medium-term decisions on car availability. Each table reports standardized coefficients since we are mainly interested in the strength of the hypothesized relationships. Standardized coefficients are used to compare the effects of variables, which is especially useful since these variables are measured in different units (e.g., income in Euros and age in years).

7.4.2.1 Long-term lifestyle decisions

In his discussion on the origins and function of lifestyles, Ganzeboom (1988) considers stage of life as one of the variables that determine lifestyles. He also distinguishes stable SED background variables such as gender from changeable characteristics such as stage of life. Our analysis confirms that lifestyles are significantly influenced by stable as well as changeable SED variables (see Table 7.7). For example, compared to men, women are (all else equal) substantially more oriented toward a non-traditional lifestyle such as culture lovers and a traditional-family lifestyle, and less oriented toward a low-budget but active/creative one. The influence of gender seems negligible for a friends-and-trends and an active-family lifestyle. Those two lifestyles are mainly influenced by stage of life. People with a friends-and-trends lifestyle are oriented toward their social network of friends. Students living at home are more likely to obtain such a friends-oriented lifestyle. An active-family lifestyle is associated with families with young children and especially with older families. It seems that young and older families try to combine traditional family activities, such as visiting family members and household maintenance activities, with leisure activities such as practicing sports. Low-budget-and-active/creative lifestyles as well as traditional-family lifestyles are not only strongly influenced by gender, but also by stage of life. Among students living at home a larger variety of lifestyles exists. They can be involved in active and creative leisure activities (ref. low-budget-and-active/creative lifestyle) or conversely in traditional family activities (ref. traditional-family lifestyle), contrary to young and older families who combine both type of activities into one lifestyle (ref. active family).

Lifestyles in their turn might influence stages of life. We initially tried to model the effect of lifestyles on all stages of life, but due to problems with model identification we had to simplify the model and estimate the effect of lifestyles on one specific stage of life, i.e. young families. This particular stage of life is likely to be influenced by a family-oriented lifestyle, which is partly confirmed by Table 7.7. The transition from being a child within the family to being a responsible parent oneself seems to be a function of having a family-oriented lifestyle, but only an active family lifestyle and not a traditional family lifestyle.

Table 7.7 Standardized total and direct effects on lifestyles and stage of life (young family)[1]

	Lifestyles					Stage of life
	Culture lover	**Friends & Trends**	**Home-oriented but active family**	**Low-budget & active/ creative**	**Home-oriented traditional family**	**Young family**
SED characteristics						
student living at home	0.010 *-0.055***	0.227* *0.211**	-0.345* *-0.333**	0.239* *0.218**	0.190* *0.211**	-0.113*
older family, working	-0.131* *-0.099***	-0.303* *-0.295**	0.362* *0.357**	-0.377* *-0.367**	-0.190* *-0.201**	0.054
young family	-0.424* *-0.575**	-0.101* *-0.138**	0.080* *0.108***	-0.140* *-0.190**	0.138* *0.187**	-0.262*
gender (female)	0.238* *0.242**	-0.001 -	0.067* *0.066**	-0.316* *-0.315**	0.301* *0.300**	0.007
Lifestyles						
culture lover	-0.216*	-0.052*	0.041**	-0.071*	0.070*	0.375* *0.509**
friends & trends						-
home-oriented but active family	-0.051*	-0.012	0.010*	-0.017**	0.017	0.089** *0.120**
low-budget & active/ creative						-
home-oriented traditional family	0.172*	0.041*	-0.032**	0.057*	-0.056*	-0.300* *-0.406**

Note: direct effects shown in italics, - = direct effect tested but found insignificant and consequently constrained to zero[2], * significant at $\alpha = 0.05$, ** significant at $\alpha = 0.10$

7.4.2.2 Medium-term decisions on residential location

A second group of outcome variables in our model consists of land use characteristics of the residential neighbourhood and its related residential and travel attitudes. Mokhtarian and Cao (2008) consider two sources which influence residential location choices and from which residential self-selection occur: objective personal characteristics and subjective attitudes. Our analysis results confirm this finding (see Table 7.8). Young and older families tend to live in less dense neighbourhoods that are distantly located from a city or town centre and that have poor local accessibility. Lifestyles and attitudes are also associated with residential location choices, but our results suggest that particularly density is influenced by these subjective variables. Density is generally considered as an important spatial characteristic of the residential neighbourhood which influences travel behaviour to a great extent (Steiner, 1994; Levinson and Kumar, 1997; Chen *et al*., 2008). In this respect, it is no surprise that most subjective variables considerably influence density and to a lesser degree the other spatial characteristics. Or in other words, based on the standardized coefficients, density seems to be mainly influenced by lifestyles and attitudes, more than by objective variables such as stage of life and gender. Respondents who prefer open spaces and quietness reside in less dense neighbourhoods, whereas the opposite holds for a positive attitude toward car alternatives and having access to opportunities, and a pro-environment travel attitude. Culture lovers and friends-and-trends lifestyle groups tend to reside in dense neighbourhoods, which generally have a larger variety of cultural and leisure opportunities in accordance with their lifestyles. Traditional-family lifestyle groups seem also to reside in similar urban neighbourhoods. An active lifestyle (either low-budget or not) is associated with residing in a less dense and more rural neighbourhood. Those neighbourhoods seem to offer more opportunities for outdoor and adventurous activities.

Residential location choices are partly based on residential attitudes, but the opposite is also true. Attitudes toward the residential neighbourhood might change once the residential location is chosen. In our model, the influence of the residential land use characteristics on residential attitudes is of even greater importance than the reverse relationship, suggesting that residential attitudes are shaped mainly after the residential location choice-process. For example, a positive attitude toward having access to car alternatives does not directly result in choosing a residential location in which these car alternatives are provided. However, residing in a high-density and highly accessible neighbourhood that is located close to a town or city centre favours a positive view of car alternatives. Similarly but with opposite signs, having positive attitudes toward social contact, and safety and neatness, do not directly affect residential location, but residing in suburban or even rural neighbourhoods tends to lead to more positive attitudes on these dimensions.

Table 7.8 Standardized total and direct effects on residential land use characteristics and residential attitudes[1]

	Residential land use characteristics					Residential attitudes				
	Location relative to local centre	**Location relative to regional centre**	**Local accessibility**	**Regional accessibility**	**Density**	**Car alternatives**	**Open space and quietness**	**Safety and neatness**	**Accessibility**	**Social contact**
SED characteristics										
student living at home	0.007*	0.170*	0.021*	-0.023**	-0.108*	0..011	-0.106*	0.050	0.027*	0.084*
	-	*0.170**	-	-	*-0.166**	*0. 201**	*0.169**	*-0.079**	-	-
older family, working	-0.006*	-0.144*	-0.022*	0.023**	-0.085*	-0.010	0.117*	0.120*	-0.037*	-0.024*
	-	*-0.144**	-	-	-	*-0.125**	-	*0.135**	-	-
young family	0.006**		-0.005**	0.007	-0.059*	-0.050*	-0.023	0.111*	-0.018	0.054*
	-	-	-	-	-	-	-	-	-	*0.055**
gender (female)	0.005*		-0.004*	-0.046*	0.033*	0.042**	0.003	0.098*	0.061*	-0.002
	-	-	-	-	-	*0.076**	*0.091**	-	-	-
Lifestyles										
culture lover	-0.005		-0.003	-0.039*	0.129*	0.081*	0.010	-0.083*	0.077*	*-0.018*
	-	-	-	-	*0.123**	*0.082**	*-0.128**	*-0.078**	*0.083**	-
friends & trends	0.006*			0.032*	0.016	-0.079*	-0.053*	-0.011	-0.002	0.052**
	-	-	-	-	-	*-0.107**	*-0.064***	-	-	*0.061**
home-oriented but	-0.006*		-0.063*	-0.016	-0.104*	0.036	0.182*	0.015	-0.001	0.052*
active family	-	-	*-0.062**	-	-	*0.123**	*0.284**	*-0.059**	-	-
low-budget &	-0.004**			0.004**	-0.037*	-0.009*	0.074*	-0.108*	0.000	0.011*
active/creative	-	-	-	-	-	-	*0.103**	*-0.123**	-	-
home-oriented	0.020*		0.002	-0.049*	0.116*	-0.107*	-0.162*	0.211*	0.138*	-0.041*
traditional family	-	-	-	*-0.098**	-	*-0.119**	*-0.241**	*0.284**	*0.128**	-
Residential neighbourhood										
location relative to	0.000			0.056*	0.107*	-0.139*	-0.171*	0.099*	-0.004	0.141*
local centre						*-0.217**	*-0.258**	*0.154**	-	*0.183**
location relative to	0.000			0.093*	0.142*	-0.230*	-0.227*	0.155*	-0.006	0.192*
regional centre						*-0.347**	*-0.343**	*0.232**	-	*0.250**
local accessibility	0.001			-0.168*	-0.149*	0.417*	0.239*	-0.189*	0.011	-0.156*
						*0.593**	*0.361**	*-0.282**	-	*-0.226**
regional accessibility	-0.003			-0.230*	-0.006*	0.573*	-0.004*	-0.132*	-0.048*	-0.105*
						*0.746**	-	*-0.174**	*-0.063**	*-0.138**

Note: direct effects shown in italics, - = direct effect tested but found insignificant and consequently constrained to zero[2], * significant at $\alpha = 0.05$, ** significant at $\alpha = 0.10$

Table 7.8 Standardized total and direct effects on residential land use characteristics and residential attitudes[1] *continued*

	Residential land use characteristics					Residential attitudes				
	Location relative to local centre	**Location relative to regional centre**	**Local accessibility**	**Regional accessibility**	**Density**	**Car alternatives**	**Open space and quietness**	**Safety and neatness**	**Accessibility**	**Social contact**
Residential neighbourhood										
density	0.000			-0.069*	-0.338*	0.172*	0.539*	-0.271*	0.004	-0.199*
						*0.339**	*0.815**	*-0.427**	-	*-0.315**
Residential attitudes										
car alternatives	0.001			-0.309*	0.002**	-0.230*	0.002**	0.053*	0.019**	0.042*
	-	-	-	*-0.402**	-					
open space and	0.000			0.044*	-0.416*	-0.108*	-0.339*	0.170*	-0.003	0.125*
quietness	-	-	-	-	*-0.629**					
safety and neatness	-	-	-	-	-					
accessibility	0.060*	-	-	-0.008*	0.119*	0.021*	0.082*	-0.040*	0.001	-0.026*
	*0.060**			-	*0.171**					
social contact	-	-	-	-	-					
Travel attitudes										
frustrated traveller	-	-	-	-	-					
pro-environment	-0.065*			-0.016*	0.107*	0.039*	0.104*	-0.053*	0.001	-0.043*
	*-0.065**	-	-	-	*0.172**					
frequent car user	-	-	-	-	-					

Note: direct effects shown in italics, - = direct effect tested but found insignificant and consequently constrained to zero[2], * significant at $\alpha = 0.05$, ** significant at $\alpha = 0.10$

7.4.2.3 Medium-term decisions on car availability

While controlling for the influence of decisions on long-term lifestyles and medium-term residential location, Table 7.9 indicates that land use patterns still have a direct influence on car availability. The residential neighbourhood has the expected effect on car availability: dense neighbourhoods with good local accessibility and that are closely located to a regional centre are associated with lower car availability. That is to say, in these neighbourhoods car ownership and possession of a driving license is likely to be lower, cars are more often only temporarily available and the possession of a public transport pass is higher. However, we have to keep in mind that, as discussed in the previous section, the choice to reside in such a traditional or urban neighbourhood is based on fundamental residential attitudes referring to mobility aspects in the neighbourhood (i.e., car alternatives, having easy access to opportunities) and a pro-environment travel attitude. The association between car availability and the residential neighbourhood is thus not necessarily simply and solely influenced by the residential land use characteristics. Underlying residential and travel attitudes remain important, supporting the need to account for residential self-selection. Furthermore, the general pro-environment travel attitude not only has an indirect effect through its influence on residential location choice, but it has an important direct effect on car availability as well. Combined with a considerably large influence of the more specific attitude toward cars as comfortable transport mode, this indicates that travel-related self-selection also occurs. In addition, the influences of these travel (mode) attitudes on car availability are of greater importance compared to the residential neighbourhood. Other important determinants of car availability are stages of life. It seems that cars are less available for students living at home. Other stages of life are associated with higher levels of car availability.

Although they are not strongly related to car availability, Table 7.9 also suggests that lifestyles have a significant influence. Car availability tends to be higher among respondents with a more active lifestyle, i.e. an active-family lifestyle oriented toward combining family activities with leisure activities, and a friends-and-trends lifestyle in which social activities with friends are important. Although not significant, car availability tends to be negatively influenced by having a non-traditional lifestyle (i.e., culture lover), a low-budget lifestyle (i.e., low-budget and active/creative) or a traditional-family lifestyle.

Comparable to our findings related to the residential location choice and underlying attitudes, a dual relationship also exists between car availability and travel (mode) attitudes. Travel (mode) attitudes not only influence car availability, but the reverse interaction is also true. For example, a positive car attitude does not only result in higher levels of car availability, but the reverse is even more important. Having a high degree of car availability tends to lead the respondent to think that family and friends want him or her to reduce his or her travelling (B = 0.184), more than the reverse (B = 0.008). High levels of car availability also tend to result in a disliking of public transport and cycling and walking.

Table 7.9 Standardized total and direct effects on car availability and travel (mode) attitudes[1]

	Car availability	Travel attitudes			Car attitudes		Public transport attitudes			Cycling and walking attitudes	
		Frustrated traveller	Pro-environment	Frequent car user	Comfort-able	Negative effects	Positive effects	Comfort-able	Time-saving	Positive effects	Comfort-able
SED characteristics											
student living at	-0.229*	-0.003	-0.086*	-0.042*	0.122*	-0.011*	0.112*	-0.028*	0.012**	0.128*	-0.021**
home	*-0.268**	-	-	-	*0.103**	-	*0.075**	-		*0.090**	-
older family,	0.398*	0.074*	0.064*	0.073*	-0.089*	0.008*	-0.185*	0.008	-0.027*	-0.211*	-0.004
working	*0.415**	*0.062**	-	-	*-0.092**	-	*-0.123**	-		*-0.155**	-
young family	0.145*	0.039*	-0.105*	0.027*	0.103*	-0.014*	-0.050*	-0.033*	-0.011*	-0.005	-0.051*
	*0.147**	-	-	-	-	-	-	-		-	-
gender (female)	0.009	0.005	-0.028**	0.002	0.046*	-0.004**	-0.016	-0.029*	-0.001	0.021*	-0.051*
	-	-	-	-	-	-	*-0.065**	-	-	-	*-0.060**
Lifestyles											
culture lover	0.006	-0.065*	0.149*	0.001	-0.098*	0.020*	0.091*	0.027*	0.005	0.004	0.089*
	-	*-0.090**	*0.202**	-	*-0.091**	-	*0.115**	-	-	-	*0.066**
friends & trends	0.018*	-0.001*	-0.099*	0.003*	0.029*	-0.013*	-0.002*	-0.144*	-0.001	-0.002*	-0.143*
	-	-	*-0.099**	-	-	-	-	*-0.128**	-	-	*-0.124**
home-oriented but	0.026**	0.004	0.096*	0.005**	0.086*	0.013*	-0.007**	0.010**	-0.002	-0.002	0.012
active family	-	-	*0.109**	-	*0.105**	-	-	-	-	-	-
low-budget &	-0.007	-0.086*	0.056*	-0.001	-0.016*	0.007**	-0.004	0.017*	0.007*	0.001	0.017*
active/creative	-	*-0.086**	*0.056**	-	-	-	-	-	-	-	-
home-oriented	-0.001	-0.020*	-0.176*	0.000	0.196*	-0.023*	0.088*	-0.101*	0.002	0.069*	-0.023*
traditional family	-	-	*-0.218**	-	*0.174**	-	*0.074**	*-0.078**	-	*0.073**	-
Residential neighbourhood											
location to local	-0.010*	0.001**		-0.002*	0.000*		0.001*	0.001*	0.000	0.001*	0.001*
centre	-	-	-	-							
location to	0.084*	-0.007*		-0.001	0.001**		-0.008*	-0.009*	-0.004	-0.009*	-0.007*
regional centre	*0.098**	-	-	-							
local accessibility	-0.085*	0.007*		0.000	-0.001**		0.008*	0.010*	0.004	0.009*	0.008*
	*-0.099**	-	-	-							
regional	0.001**	0.000		0.000	0.000		0.000	0.000	0.000	0.000	0.000
accessibility	-	-	-	-							

Note: direct effects shown in italics, - = direct effect tested but found insignificant and consequently constrained to zero[2], * significant at α = 0.05, ** significant at α = 0.10

Table 7.9 Standardized total and direct effects on car availability and travel (mode) attitudes[1] *continued*

	Car availability	Travel attitudes			Car attitudes		Public transport attitudes			Cycling and walking attitudes	
		Frustrated traveller	Pro-environment	Frequent car user	Comfort-able	Negative effects	Positive effects	Comfort-able	Time-saving	Positive effects	Comfort-able
Residential neighbourhood											
density	-0.064*	0.005*		-0.012*	-0.001**		0.006*	0.007*	0.003	0.007*	0.006*
	_-0.097*_	-	-	-							
Residential attitudes											
car alternatives	0.000	0.000		0.000	0.000		0.000	0.000	0.000	0.000	0.000
	-										
open space and quietness	0.041*	-0.003*		0.007*	0.000**		-0.004*	-0.005*	-0.002	-0.004*	-0.004*
	-										
safety and neatness	-										
accessibility	-0.012*	0.001*		-0.002*	0.000**		0.001*	0.001*	0.000	0.001*	0.001*
	-										
social contact	-										
Travel attitudes											
frustrated traveller							0.060*	-0.094*	-0.079*		-0.080*
	-				-	-	_0.060*_	_-0.094*_	_-0.079*_	-	_-0.080*_
pro-environment	-0.206*	0.016*		-0.038*	-0.292*	0.132*	0.020*	0.160*	0.010*		0.197*
	_-0.156*_				_-0.290*_	_0.132*_	-	_0.136*_	-	-	_0.178*_
frequent car user	0.008*	-0.001**		0.002*	0.061*	-	-0.001**	-0.001*	0.000	-0.054**	-0.068*
	-				_0.061*_		-	-	-	_-0.054**_	_-0.067*_

Note: direct effects shown in italics, - = direct effect tested but found insignificant and consequently constrained to zero[2], * significant at $\alpha = 0.05$, ** significant

Table 7.9 Standardized total and direct effects on car availability and travel (mode) attitudes[1] *continued*

	Car availability	**Travel attitudes**			**Car attitudes**		**Public transport attitudes**			**Cycling and walking attitudes**	
		Frustrated traveller	**Pro-environment**	**Frequent car user**	**Comfort-able**	**Negative effects**	**Positive effects**	**Comfort-able**	**Time-saving**	**Positive effects**	**Comfort-able**
Travel mode attitudes											
car = comfortable	0.138* *0.138**	-0.011*		0.025*			-0.014*		-0.006	-0.015*	-0.012*
car = negative effects	-										
public transport = comfortable	-										
public transport = positive effects	-										
public transport = time-saving	-										
bike/on foot = comfortable	-										
bike/on foot = positive effects	-										
Car availability	0.002*	-0.079* *-0.079**	 -	0.184* *0.184**	0.011* -	 -	-0.094* -	-0.120* *-0.120**	-0.047** *-0.053***	-0.106* *-0.096**	-0.089* *-0.083**

Note: direct effects shown in italics, - = direct effect tested but found insignificant and consequently constrained to zero[2], * significant at $\alpha = 0.05$, ** significant at $\alpha = 0.10$

7.5 Conclusions

This paper examined car availability and how it might be influenced by residential land use characteristics. Using information collected from an Internet survey, structural relationships have been estimated between lifestyles, residential location choices and car availability, and the underlying residential and travel attitudes. Our results point out that, while controlling for these attitudes, residential land use patterns might still have the expected influence on car availability. Car availability tends to be lower in dense neighbourhoods with good local accessibility and that are closely located to a regional centre. In this respect spatial planning policies can contribute to a reduction in car availability.

However, we note that residential and travel attitudes have an important influence on selecting the land use characteristics of the residence in the first place (i.e., the residential location decision), supporting the need to account for residential self-selection. Attitudes with respect to mobility characteristics of the residential neighbourhood and a general pro-environment travel attitude are associated with residing in a traditional or urban neighbourhood. For example, the preferences to have sidewalks and bike paths within the residence's vicinity and to have access to public transport seem to underlie the decision to reside in a high-density neighbourhood. Moreover, travel (mode) attitudes also have a significant and considerable influence indicating that the decision to own a car is not only urged by the land use characteristics of the residence but also, and perhaps more important, by someone's (car) travel liking. It also indicates that a second type of self-selection related to travel should be accounted for. Residential self-selection and travel-related self-selection are two reasons why the aims and goals of objective spatial planning policies (e.g., a reduction in car ownership) are not always achieved. These underlying self-selection processes result in direct effects of the built environment on car availability that are often larger in magnitude compared to their total effects. This indicates that considering direct effects of the built environment alone would overestimate the role of each of those spatial variables. Conversely, the direct effects of attitudes on car availability are often smaller in magnitude (or even non-existing), compared to the total effects. This indicates, as previously stated, that the role of attitudes is indirect (through the impacts on residential location, for example) as well as direct.

The structural model not only considered the complex relationships between car availability, residential neighbourhood, lifestyles, and underlying attitudes. It also considered the dual relationship between behaviour and underlying attitudes. Residential and travel attitudes influence residential location choices and car availability, but the reverse is also true. Moreover, our results suggest that, although residential attitudes influence residential location choice to some extent, residential attitudes are mainly shaped after the residential location is chosen. Such a dual relationship also exists with respect to car availability and travel (mode) attitudes. However, the question remains whether it is car availability that directly affects travel (mode) attitudes, or rather the interaction between car availability, actual modal choices and travel (mode) attitudes. Answering this question would involve expanding the current framework with short-term decisions on modal choices, we would like to report on this topic in future work (Van Acker *et al*., 2010c).

Notes

1. At first sight, figures in grey tones might seem awkward. For example, it seems strange that lifestyles have an effect on themselves. However, this is due to the dual relation between lifestyle and stage of life. For example, 'culture lovers' influence 'young families', but 'young families' also influence 'culture lover'. Consequently, culture lovers have an indirect effect through young family on their own. We decided to retain these figures in the tables since they are a legitimate and pertinent feature of the final model.
2. Direct effects between variables found insignificant were constrained to be zero. However, due to interactions with other variables an insignificant indirect (and total) effect might still occur. In other cases, a significant direct effect was found, but this direct effect might diminish as a consequence of interactions with other variables resulting in a total effect that has become insignificant. For these reasons, Tables 7.7 to 7.9 often report insignificant total effects.

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"Alle moeilijke dingen vinden hun oorsprong in dat wat gemakkelijk is, en alle grote dingen in dat wat klein is."

Lao Tse (sixth century BC)

8. GOING SOFT
ON HOW SUBJECTIVE VARIABLES EXPLAIN MODAL CHOICES

Van Acker, V., Mokhtarian, P.L., Witlox, F. (2010) Going soft: On how subjective variables explain modal choices. Environment and Planning A (submitted).

Abstract Most studies on the link between the built environment and travel behaviour use objective or 'hard' variables to characterize and model this relationship. Recently, attention has also been paid to the importance of 'soft' variables such as the subjective perception of the built environment and the inclusion of location attitudes, resulting in models that take account of both the objective and subjective characteristics of the built environment. Expanding the analysis to also include both objective and subjective personal characteristics (i.e., stage of life, gender and lifestyles) and travel characteristics (i.e., car availability, general travel attitudes and specific travel mode attitudes) is the purpose of this paper. To this end, a modal choice model for leisure trips is developed using data on personal lifestyles and attitudes, collected via an Internet survey, and estimated using a structural equation approach. The results show that modal choice is not determined by objective characteristics alone, but rather by a mix of objective and subjective characteristics at various model levels.

8.1 Introduction

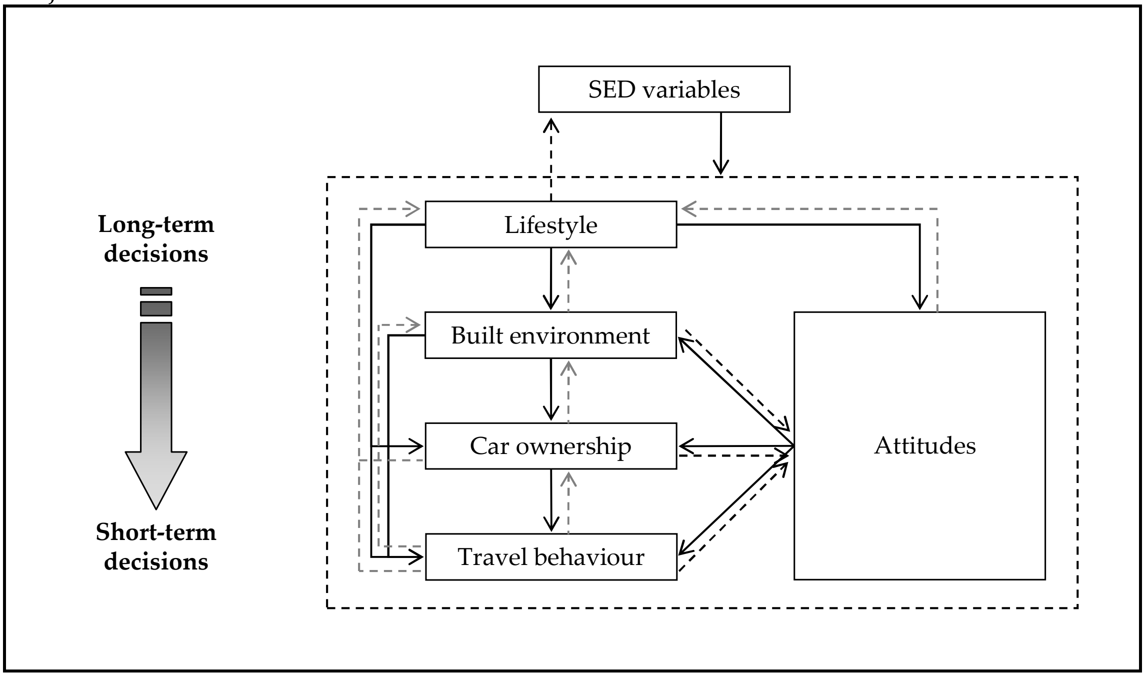
The relationship between the built environment and daily travel behaviour has long been of interest to many researchers in the fields of urban planning and transportation. It was first articulated by Mitchell and Rapkin (1954) but today is still heavily researched. Recent reviews (e.g., Crane, 2000; Ewing and Cervero, 2001; Stead and Marshall, 2001; Handy, 2002, 2005; Van Acker *et al*., 2010a) summarize various objective or 'hard' variables that are commonly used to explain the relationship between the built environment and travel behaviour. The built environment is characterized by such variables as population density, land use mix, jobs-housing balance and accessibility, and the objective socio-economic and socio-demographic (SED) characteristics of the traveller relate to age, gender, household size, educational level and household income. Recently, some researchers have argued in favour of including more subjective or 'soft' variables as well. After all, it is possible that different travel patterns exist within socio-economically and socio-demographically homogeneous population groups (van Wee, 2002). This indicates that travel behaviour modelling is not just about measuring objective variables, but that more subjective variables such as personal attitudes, personality traits and lifestyles are involved. Transport behavioural analysts have been aware of this for some time, and many studies discuss the role of attitudes in travel behaviour decisions (e.g., Tardiff, 1977; Dobson *et al*., 1978; Golob *et al*., 1979; Lyon, 1984; Gauthier and Shaw, 1986; Gärling *et al*., 1998; and more recently Parkany *et al*., 2004, and Thogersen, 2006). However, these studies tend to neglect the link with the built environment. Only recently, additional subjective variables were introduced in empirical work on the relationship between the built environment and travel behaviour (e.g., Kitamura *et al*., 1997; Bagley and Mokhtarian, 2002; van Wee *et al*., 2002; Schwanen and Mokhtarian, 2005; Scheiner and Holz-Rau, 2007).

Many empirical studies focus on the direct effect of all these variables on travel behaviour, but indirect effects resulting from interactions among variables might be important as well. For example, attitudes and lifestyles influence travel behaviour, but these variables themselves are also influenced by other personal SED variables (Ganzeboom, 1988; Scheiner and Holz-Rau, 2007). After all, it seems logical that people's attitudes and lifestyles depend on, e.g., their stage of life. Young couples without children might have a more adventurous lifestyle than families with children. However, lifestyles might also influence SED characteristics (e.g., a family-oriented lifestyle is likely to result in larger household sizes, while a work-oriented lifestyle may lead to higher incomes) and, thus, a dual relationship might exist between lifestyles and SED variables. The built environment of the residential location influences travel behaviour, but again residential location choices are in turn influenced by attitudes, lifestyles and personal SED variables (Timmermans *et al*., 1992; Shiftan, 2003; Bhat and Guo, 2004; Prashker *et al*., 2008). For example, couples with young children may prefer a child-friendly and suburban residential neighbourhood, whereas older people might prefer and enjoy the centrality of living in the city centre. Another mediating variable is car ownership, which can be considered as an aspect of travel behaviour that has to be explained (e.g., Bagley and Mokhtarian, 2002; Dieleman *et al*., 2002; Schwanen *et al*., 2002; Krizek, 2003), or as a variable that explains other aspects of travel behaviour such as car use and travel distance (e.g., Dargay, 2002; Giuliano and Dargay, 2006; Bhat and Guo, 2007; Cao *et al*., 2007a). Only a limited number of studies combines both research approaches and considers car ownership as mediating the relationship between the built environment and travel behaviour (e.g., Schimek, 1996; Simma and Axhausen, 2003; Cao *et al*., 2007b; Scheiner and Holz-Rau, 2007). Van Acker and Witlox (2010a) found that ignoring car ownership as a mediating variable generally results in an overestimation of the effect of the built environment on car use. Furthermore, besides all the previously mentioned mediating variables, bidirectional relationships such as those between lifestyles and SED characteristics also exist between attitudes and behaviours. Perhaps the most commonly assumed hypothesis is that attitudes cause behaviour. That is, people's decisions (and, thus, behaviour) are based on their attitudes about their available alternatives. But once choices are made and someone gains experience about his/her alternatives, perceptions and attitudes about the alternatives might change (Dobson *et al.*, 1978; Lyon, 1984; Bohte *et al.*, 2009;). For example, a positive attitude toward public transport might encourage someone to use public transport for daily travel, but using public transport regularly might also reinforce (or diminish) this positive attitude. This in turn might have repercussions for other earlier decisions. For example, it justifies (or challenges) the decision to not own a car and to reside in a neighbourhood with easy access to public transportation.

There also exists a fundamental question of causation (Kockelman, 1997; Handy *et al.*, 2005; van Wee, 2009). For example, under certain conditions, the built environment seems to influence travel behaviour, but this finding can mask underlying linkages that are more important. Ultimately, the challenging question is whether travel behaviour is influenced by the built environment itself or by these underlying linkages for which the built environment is only a proxy. The question of residential self-selection is a clear example (e.g., Bagley and Mokhtarian, 2002; Cao *et al.*, 2006; Bhat and Guo, 2007; Pinjari *et al.*, 2007; Walker and Li, 2007; Naess, 2009). People might select themselves into a residential neighbourhood according to their personal attitudes, preferences and lifestyles. For example, a household with public transport preferences will likely choose a residential neighbourhood with good public transport services so that they are able to travel in accordance with their travel preferences. Consequently, the connection between the built environment and travel behaviour may be in part a matter of personal attitudes, preferences and lifestyles. Moreover, this suggests that the true influence of the built environment cannot be determined without accounting for the effects of these personal attitudes, preferences and lifestyles. The evidence on whether residential self-selection or the built environment itself has the greater impact on travel behaviour is, however, mixed (Bagley and Mokhtarian, 2002; Handy *et al.*, 2005; Cao *et al.*, 2006; Bhat and Guo, 2007; Pinjari *et al.*, 2007; 2009)

Clearly, complex relationships exist between travel behaviour and various objective and subjective variables. Hence, in order to explain travel behaviour as completely and properly as possible, studies should include objective as well as subjective variables while accounting for residential self-selection and mediating variables such as car ownership. The aim of this paper is to unravel these complex relationships (see Figure 8.1) using structural equation models, and to discuss the added value of including subjective variables into the analysis. The feedback mechanisms between lifestyles and SED characteristics, as well as between attitudes and behaviour, will be modelled. However, the feedback loops between behaviours at various time-scales are not considered due to issues such as model complexity and identification.

Figure 8.1 Complex relationships between travel behaviour, objective and subjective variables



Our analysis focuses on the modal choice for several types of leisure trips (active leisure activities, family visits and fun shopping) because we assume that lifestyles and the built environment have a larger impact on optional or discretionary trips than on routine or recurrent trips (like commuting). Figure 8.1 illustrates how short-term decisions on daily travel behaviour are related to long-term decisions on lifestyles, residential location and car ownership (Van Acker *et al.*, 2010a).

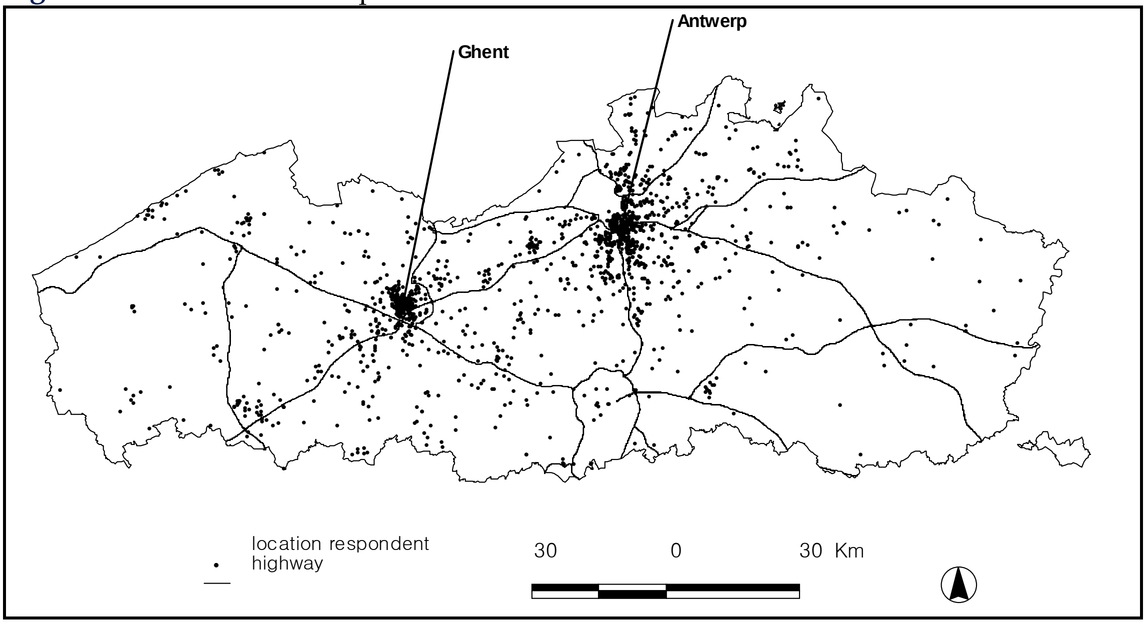
The paper is, therefore, organized as follows. Section 8.2 introduces the data. We conducted an Internet survey since information on personal lifestyles and attitudes is generally not included in traditional travel surveys or diaries. This paper is part of a series of studies based on this Internet survey. Van Acker *et al.* (2010b) focussed on the measurement of lifestyles, which are subjective variables at the level of the longest term decisions in our model (see Figure 8.1), and a subsequent paper (Van Acker *et al.*, 2010c) discussed the specification of residential and travel attitudes underlying decisions on residential location and car ownership. The current paper specifically assesses the added value of these subjective variables in explaining modal choices. We expand our analyses by including subjective variables at other levels of our model, such as residential and travel attitudes as well. The third section discusses the methodology. We use structural equation models (SEM) which can simultaneously handle complex relationships among different types of variables. Results are presented and discussed in Section 8.4. Finally, in Section 8.5, our most important conclusions for future research and policy-making are summarized.

8.2 Data and measurement of key variables

8.2.1 Description of the sample

For practical reasons, the survey was initially made known to students and staff members of the University of Antwerp and the Faculty of Sciences at Ghent University. Since this resulted in an overrepresentation of highly-educated respondents concentrated in the cities of Antwerp and Ghent (Flanders, Belgium), a second announcement was published in regional information magazines of several villages in the larger urban region of Ghent (Destelbergen, Gent, Lochristi, Merelbeke and Oosterzele). In total, 2,363 persons completed the survey, of which (after data cleaning) 1,878 were retained for further analyses. Figure 8.2 illustrates the residential locations of these respondents.

Figure 8.2 Locations of respondents in Flanders



Despite our efforts, we did not obtain a well-balanced sample as can be seen in Table 8.1. Women, married couples, people with full-time employment and younger people are overrepresented. But the most remarkable difference is in education. Highly-educated respondents are heavily overrepresented in the sample: 66% has a college or university degree, which is considerably higher than the average of 25% for Flanders. Although the sample is not representative of the entire population of Flanders, we feel that this does not devalue it for our research purposes and results. Our purpose is to model relationships among variables, not to ascertain the univariate distributions of variables in isolation. Our analysis can still properly capture the conditional influence of having a given level of education on travel behaviour, even if the proportion of people having that amount of education differs between our sample and the population. The sample also permits demonstration of our premise that, conditional on a given level of education, subjective variables such as personal attitudes, preferences and lifestyles can still explain a significant additional amount of variance in modal choices.

Table 8.1 Socio-economic and socio-demographic characteristics of the respondents

	Sample (survey)		Reference (Flanders)	
Gender, female	58.7%		51.1%	
Marital status				
single	23.6%		37.7%	
married/cohabiting	74.5%		62.3%	
Education				
primary school	0.2%		20.7%	
secondary school, 3 years	1.5%		21.6%	
secondary school, 6 years	32.4%		33.4%	
college, university	66.0%		24.7%	
Employment, full-time	82.4%		76.3%	
Monthly household income				
	0-749 €	9.6%	0-833 €	19.1%
	750-1,499 €	6.7%	834-1,666 €	32.1%
	1,500-2,249 €	14.2%	1,667-2,500 €	21.2%
	2,250-2,999 €	18.6%	2,501-3,333 €	10.4%
	3,000-3,749 €	24.8%	3,334-4,166 €	6.6%
	3,750-4,499 €	13.2%	+ 4,167 €	10.5%
	4,500-5,249 €	6.2%		
	5,250-5,999 €	3.8%		
	+ 6,000 €	2.9%		
Possession driving licence	81.5%		81.0%	
Average age	30.6 years		40.8 years	
Average car ownership	1.4 cars/household		1.2 cars/household	

8.2.2 Subjective variables

The Internet survey included many questions on lifestyle orientation, attitudes toward the residential neighbourhood and attitudes toward mobility in general and specific travel modes. These questions are inspired by similar surveys on lifestyles, attitudes and mobility (e.g., for the Netherlands: Bohte *et al.*, 2008; and for the USA: Bagley and Mokhtarian, 1999). We used a factor analysis to reveal the data structure and to reduce the many observed variables into a smaller number of underlying factors. The scores on these factors will then be used as input for the structural equation models which estimate the relationships between travel behaviour, the subjective and the objective variables.

8.2.2.1 Lifestyle

Lifestyles refer to the individual's opinions and motivations, or orientations toward general themes such as leisure, family and work (Salomon and Ben-Akiva, 1983; Bootsma *et al.*, 1993). Using this definition of lifestyle, the Internet survey included among other variables a list of more than 100 types of holiday aspects, literary interests and leisure activities. Respondents had to mark how they spent their holidays, on what subjects they had recently read and how they spent their weekends. These questions actually refer to aspects of lifestyle expressions (behaviours) instead of the underlying orientations. Nevertheless, these orientations are internal to the individual and hard to observe by an outsider. Therefore, we used these lifestyle expressions as indicators of the underlying lifestyles. For convenience, we will refer to our measures as 'lifestyles' in the remainder of this paper. In Van Acker *et al*. (2010b) the concept of lifestyles and the estimation of the lifestyle factors are explained into full detail, and will not be repeated here. It was found that five lifestyles could be defined: i.e., culture lover, friends and trends, low-budget and active/creative, home-oriented but active family, and home-oriented traditional family.

8.2.2.2 Residential attitudes

The Internet survey contained 16 statements on attitudes toward residential locations. Respondents were asked to indicate on a five-point Likert scale ranging from 'unimportant' to 'very important' which aspects influence their residential location choice. These 16 variables were then factor analyzed into five underlying dimensions: open space and quietness, car alternatives, accessibility, safety and neatness, and social contact. Van Acker *et al*. (2010c) report the estimation of these residential attitudes in more detail.

8.2.2.3 Travel attitudes

Residential attitudes are associated with long-term residential location choices, whereas travel attitudes are associated with short-term decisions on daily travel behaviour. The Internet survey included 13 statements related to travel in general as well 12 statements related to travel modes specifically (car, public transport, cycling/walking). Factor analyses resulted in three general travel attitudes (frustrated traveller, pro-environment and frequent car user according to family and friends), and two mode-specific attitudes for each mode (comfort, and the repercussions for the environment and an individual's image or health).

Related to public transport, we found a third attitude referring to time-saving. This aspect did not emerge as a separate dimension for cars or cycling and walking, but in those cases was included in the comfort factor. More information on these travel attitudes is presented in Van Acker *et al*. (2010c).

8.2.3 Other (objective) variables

The Internet survey also gave information on various objective variables. The survey included a section on socio-economic and demographic characteristics of the respondents and their households. We also geocoded the respondent's address in order to add spatial information from various land use and transportation databases. Since this paper emphasizes the added value of subjective variables, we only present a brief description of these other objective variables. More information can be found in Van Acker and Witlox (2010a, b).

8.2.3.1 Stage of life

Socio-economic and socio-demographic variables might be correlated with each other, and factor analysis could provide interesting new factors. We expected to obtain one factor referring to social status (related to education, employment status and household income) and one factor referring to stage of life (related to age, marital status and household composition). Instead, we extracted three factors, all referring to stage of life (principal axis factoring, promax rotation, 59.5% variance explained): students living at home, older family with employed adults, and a young family. However, this is not surprising since our sample consists of a large group of students in higher education (42.7%) and another large group of highly-educated workers (46.5%).

8.2.3.2 The built environment

Spatial characteristics of the respondent's residential neighbourhood include density measures (population density, job density, built-up density), diversity measures (jobs-housing balance, land use mix) and accessibility measures (potential accessibility by car on several time scales ranging from 5 minutes to 60 minutes). Design aspects could not be included in the analysis due to a lack of suitable data. However, density, diversity and accessibility are often related to each other (Cervero and Kockelman, 1997). For example, city centres are generally characterized by high densities and high diversity as well as high levels of accessibility to several opportunities within a short time span. A factor analysis (principal axis factoring, promax rotation, 73.6% variance explained) revealed five factors: location in relation to a local centre, location in relation to a regional centre, local accessibility, regional accessibility, and density.

8.2.3.3 Car availability

Figure 8.1 identifies car ownership as one of the long-term decisions influencing daily travel behaviour. Our Internet survey provided information on not only car ownership and possession of a driving license - two traditionally-used variables in travel behaviour research - but also on the possession of a public transport pass and the temporary availability of a car. Since all four variables are related to each other, we again performed a factor analysis (principal axis factoring, 31.4% variance explained) in order to construct one general factor related to car availability.

8.2.3.4 Travel behaviour

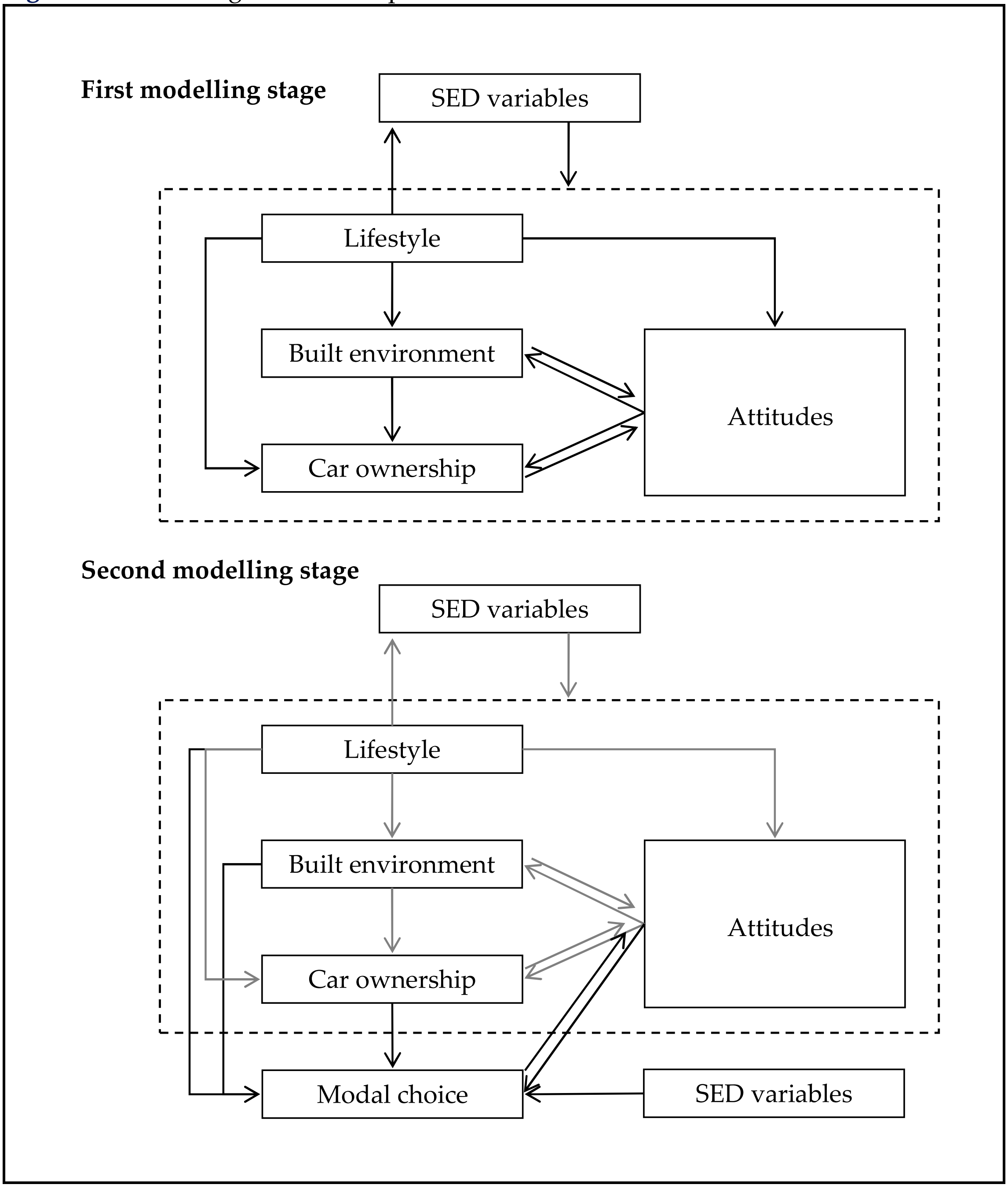
Travel behaviour is the final outcome variable in our structural equation models. In our Internet survey, respondents had to report what kind of leisure trips they perform on a monthly basis and which travel mode they generally use for this. For each leisure motive (active leisure activities, family visits and fun shopping) we performed three analyses of modal choice (one for car use, one for public transportation and one for cycling/walking). In each of these structural equation models, modal choice is a binary variable.

8.3 Methods and modelling characteristics

The complex relationships, as depicted in Figure 8.1, between travel behaviour and various subjective and objective variables can be formalized as a series of regression equations. We use structural equation modelling (SEM) to simultaneously estimate these equations. In such an approach, a variable can be an explanatory variable in one equation (e.g., car ownership influencing travel behaviour) but an outcome variable in another equation (e.g., car ownership influenced by the built environment). Therefore, the concepts ‘endogenous’ and ‘exogenous’ variables are used (Raykov and Marcoulides, 2000; Byrne, 2001; Kline, 2005). Exogenous variables are not influenced by any other variable in the model, but instead exogenous variables influence other variables. Endogenous variables are influenced by exogenous variables, either directly or indirectly through other endogenous variables.

Structural equation models are estimated by finding the coefficients that best match the resulting model-implied covariance matrix to the empirically-based covariance matrix for the data. As in other statistical techniques, a standard estimation technique in SEM is maximum likelihood (ML), which assumes a multivariate normal distribution of all endogenous variables in the model (Bentler and Dudgeon, 1996; Kline, 2005). However, our final outcome variable, modal choice, is binary and, thus, not normally distributed. We used the software package M-plus 4.21 because of its ability to model categorical endogenous variables. By default, M-plus then uses an alternative estimator: a mean- and variance-adjusted weighted least squares parameter estimator (WLSMV) which we used instead of ML. WLSMV is an estimator generating robust standard errors that does not require extensive computations or enormous sample sizes. In addition to robust estimation, a robust mean-adjusted and mean- and variance-adjusted chi-square test statistic can be produced (Muthén, 1983; Satorra, 1992; Yu and Bentler, 2000).

Figure 8.3 Two-stage estimation procedure



In order to keep the number of equations in the model to a manageable size, we conducted the modelling process in two stages (see Figure 8.3). Van Acker *et al.* (2010c) discusses the results of the first modelling stage, in which relationships among lifestyles, attitudes, the built environment and car ownership are estimated. These long-term decisions do not depend on the motives for daily travel. For example, the influence of the built environment on car ownership is presumably not different for commuting or leisure trips. Coefficients from this first modelling stage are then used as if they were 'true' in the second modelling stage in which modal choice is explained for several leisure motives. That is, we actually replaced the observed explanatory variables in the second stage with their 'predicted values' obtained from the first-stage model, which considerably facilitated model estimation. Doing so, we estimated the effects of lifestyles, attitudes, the built environment and car availability on modal choice. Note that this two-stage estimation procedure where only 'limited information' is used in each stage gives estimators that are not efficient. Since the estimates from the first stage are taken as 'true' in the next stage, the reported standard errors of the second-stage estimators are not exactly correct. Therefore, we used a stricter standard for hypothesis testing on the second-stage model (significant at $\alpha = 0.05$) than on the first-stage model (significant at $\alpha = 0.10$).

Another model specification issue is the effect of outliers. Outliers are commonly detected by calculating the Mahalanobis distance and the loglikelihood for each observation. The Mahalanobis distance requires continuous endogenous variables and the loglikelihood assumes ML-estimators, two assumptions that are not fulfilled in our model. However, M-plus also calculates Cook's D (Cook, 1977, 1979) and a loglikelihood distance influence measure adjusted for weighted least squares estimators (Cook and Weisberg, 1982) for each observation. By plotting these outlier scores against the scores for modal choice, we were able to detect outliers for each model presented in Section 8.4. Removing the outliers led to changes in the overall model fit and individual parameter estimates, but the effects were only minimal. The overall model fit did not change considerably in any of the models and only a limited number of individual parameter estimates became insignificant. However, by removing outliers the means and variances of all variables in the reduced samples were different from the ones in the original sample. Outliers generally correspond to respondents with a pronounced lifestyle or to respondents living in a residential neighbourhood with, for this analysis, interesting spatial traits (especially neighbourhoods with good local accessibility and neighbourhoods distant from a regional city centre). Those outliers are interesting for our analysis. After all, we want to estimate the influence of lifestyles and the built environment on modal choices. Consequently, we decided to retain all outliers and model results in Section 8.4 are based on the full dataset.

Finally, the quality of the model specifications has to be assessed before the model results can be interpreted. Most SEM software packages report a large variety of model fit indices. The χ^2-statistic is a commonly used model fit index which measures the discrepancy between the empirically-based and the model-based covariance matrices. However, χ^2 values increase with sample size and, thus, models based on large sample sizes might be rejected based on their χ^2 value even though only small differences exist between the empirically-based and model-based covariance matrices. The standard χ^2-statistic is, therefore, transformed into a dozen alternative model fit indices. The simplest transformation is to divide the χ^2 value by the degrees of freedom (χ^2/df), but more sophisticated fit indices exist as well. For example, the Comparative Fit Index (CFI) assesses the improvement of the hypothesized model over the independence model with only unrelated variables. It ranges from 0 to 1, with 1 indicating perfect model fit. Another comparative fit index is the Tucker-Lewis Index (TLI). It indicates where the fitted model is situated on a continuum between two hypothetical models: an independence model with only unrelated variables and an ideal model that fits perfectly. Doing so, TLI corrects for model complexity and it favours simpler models. TLI also ranges from 0 to 1 with larger values indicating better model fit. Values above 1 are possible, but remain rare. Another widely used model fit index is the Root Mean Square Error of Approximation (RMSEA). The RMSEA measures the degree of discrepancy between the hypothesized model and the observed data per degree of freedom, while controlling for sample size. It ranges from 0 to very large values, where small values are preferred. The Weighted Root Mean Square Residual (WRMR) is a residual-based model fit index and measures the weighted average differences between the sample and the estimated population variances and covariances. It ranges from 0 to very large, with smaller values preferred. Studies such as Bollen (1989), Hu and Bentler (1999) and Kline (2005) suggest cut-off values for these model fit indices: $\chi^2/df < 2.0$, CFI and TLI > 0.95, RMSEA < 0.05 and WRMR < 1.00 for adequate model fit. Yu (2002) confirmed these cut-off values for models with categorical outcomes. In correspondence with various scholars (Hu and Bentler, 1999; Byrne, 2001, Yu, 2002; Kline, 2005), Table 8.2 reports model fit indices from several different index families (i.e., indices of comparative fit to a baseline model, error-of-approximation-based indices, and residual-based indices). According to most indices, model fit is generally adequate.

Table 8.2 Model fit results

	Chi² (df) p	Chi² / df	CFI	TLI	RMSEA	WRMR
Desired values	p > 0.05	< 2	> 0.95	> 0.95	< 0.05	< 1.00
car use for AL	184.63 (142) 0.01	1.30	0.96	0.96	0.02	1.02
car use for FV	243.66 (151) 0.00	1.61	0.94	0.94	0.03	1.12
car use for FS	190.66 (128) 0.00	1.49	0.92	0.93	0.03	1.09
public transport for AL	187.55 (146) 0.01	1.28	0.95	0.96	0.02	1.02
public transport for FV	229.13 (148) 0.00	1.55	0.94	0.94	0.03	1.11
public transport for FS	188.18 (126) 0.00	1.49	0.92	0.92	0.03	1.10
cycling/walking for AL	190.25 (146) 0.01	1.30	0.95	0.95	0.02	1.02
cycling/walking for FV	237.54 (153) 0.00	1.55	0.94	0.94	0.03	1.12
cycling/walking for FS	191.93 (130) 0.0	1.48	0.92	0.93	0.03	1.08

Note: AL = active leisure activities, FV = family visits, FS = fun shopping

8.4 Model results

Having specified the measurement of the key variables and some important model specification issues, we now turn our attention to the model results. The aim of this paper is to assess the objective and subjective influences on modal choices for leisure trips, while accounting for the complex interrelations among these influences. The results of the first modelling stage which considers the interrelations between long-term decisions on lifestyles, the built environment and car availability are reported in Van Acker *et al*. (2010c). This paper presents the results of the second modelling stage, focussing on short-term decisions on daily travel behaviour and, more specifically, the influence of lifestyles, the built environment, car availability, and the underlying residential and travel attitudes on modal choice for various leisure trips.

Tables 8.3 summarizes the results of the second modelling phase and illustrates the influences of objective and subjective variables on car use, public transport use, and cycling and walking, respectively, for active leisure activities, family visits and fun shopping. The explained variance values for each model are quite large for models on disaggregate data. This suggests that the hypothesized models account for a significant amount of variation in modal choice for leisure trips, especially for car use for fun shopping (R^2 = 80.5%).

For each travel mode, the influences of objective and subjective variables tend to be similar for active leisure activities and family visits as well as fun shopping. Moreover, the modelling results for public transport use generally resemble the results for cycling and walking, but are opposite to those for car use. Unlike the findings of other studies (e.g., Scheiner and Holz-Rau, 2007), this suggests a dichotomy in modal choice between cars and car alternatives rather than between motorised and non-motorised transport or between public and individual transport.

8.4.1 The causal influence of the built environment

The built environment has the expected influence on modal choice. High densities, good accessibility and a short distance between the residence and the city or town centre seem to discourage car use and to encourage public transport as well as cycling and walking. Based on the standardized total effects, the built environment seems to considerably influence modal choices but especially the decision to drive by car for leisure trips, to use public transport for family visits, and to cycle or walk for active leisure activities and for fun shopping. This suggests that spatial planning policies encouraging further densification, developing residential quarters near town or city centres, and providing facilities such as jobs and shops within the residential neighbourhood might have the desired effect on modal choices.

However, the question remains whether it is really the built environment itself that influences modal choices more than, or as much as, the underlying residential attitudes and preferences in the first place. Table 8.3 illustrates that residential and travel attitudes fundamental to the residential location choices have small but significant indirect effects on modal choices (for more details, see Van Acker *et al*., 2010c). Car use is positively associated with the importance of open space and quietness (typically for suburban and rural residents with high levels of car availability), and negatively associated with the importance of having access to locations such as workplaces and shops (typically for urban residents with low levels of car availability). The opposite is true for public transport use, and cycling and walking. This finding indicates that residential self-selection occurs to some extent. This is also supported by the influence of lifestyle groups on modal choice. Table 8.3 indicates that lifestyles exhibit a consistent influence on modal choice for leisure trips. For all leisure activity types, non-traditional (i.e., culture lover) and low-budget (i.e., low-budget and active) lifestyle groups seem to be associated with less car use, and more public transport use and especially more cycling and walking. The opposite is true for family-oriented (i.e., active family, traditional family) and active (i.e., friends and trends, active family) lifestyle groups. The interrelations between lifestyles and modal choice are not always that strong. It depends on which travel mode and which leisure activity type is considered. For example, a traditional-family lifestyle is likely to have a strong direct (positive) effect on car use for family visits, whereas a low-budget-and-active/creative lifestyle tends to strongly (positively) influence cycling and walking for active leisure activities. It is no surprise that these two lifestyles have an important effect on these leisure trips in particular. After all, these leisure trips (family visits, and active leisure activities) are an essential part of the lifestyles concerned (traditional family, and low-budget and active/creative respectively). However, because of the interaction with among others the built environment, the influence of lifestyles is in many cases mainly indirect. Van Acker *et al.* (2010c) pointed out that non-traditional lifestyle groups such as culture lovers might prefer to reside in an urban neighbourhood, whereas active lifestyle groups tend to reside in suburban or rural neighbourhoods. Consequently, the supposed influence of the built environment on modal choice is partly explained by residential preferences of particular lifestyle groups.

8.4.2 Other important influences on modal choice for leisure trips

Modal choices seem to be mainly influenced by car availability. High levels of car availability are associated with more car use, less public transport use, and less cycling and walking. In other words, car use tends to be higher for respondents who have several cars, who possess a driving license (and not a public transport pass) and/or who have cars permanently available. Our results suggest that car availability has a strong effect on car use and public transport use, but a less strong effect on cycling and walking (probably reflecting that those modes are often adjuncts or supplements to driving, not just substitutes for it). Other variables have a comparable effect or even a more pronounced effect on cycling and walking for leisure trips, especially the built environment for fun shopping.

Again, the causal relation between car availability and modal choice can be questioned. Car availability generally has a strong direct effect on modal choice. Nevertheless, general travel attitudes and specific travel mode attitudes underlie the decision to own a car. Van Acker *et al.* (2010c) found that a pro-environment travel attitude has an important negative direct influence on car availability, whereas car availability was found positively associated with the perception of a car as a comfortable transport mode. Table 8.3 indicates an important indirect effect of these travel (mode) attitudes on modal choices for leisure trips, indicating that travel-related self-selection occurs to some extent in addition to the direct effect of car availability on modal choices. Respondents with a pro-environment attitude are more likely than their less supportive counterparts to use public transport and to cycle and walk, and less likely to drive their cars, and our results also indicate that perceiving driving a car as comfortable is associated with more car use and less use of car alternatives. This seems to confirm the dichotomy between cars and car alternatives. Other travel (mode) attitudes only have a small effect on modal choice. A frustrated travel attitude is associated with more car use. This indicates that frustrated travellers, who do not enjoy being on the road, tend to use travel modes that might be perceived as more private than public transport or faster than cycling and walking. Frequent car users, according to the respondent's family and friends, also tend to use their cars more often which possibly refers to the existence of habits in modal choices. Interesting to note is that public transport as well as cycling and walking are not significantly influenced by travel mode attitudes specifically toward public transport (respectively cycling and walking), but only by the specific attitude of cars as comfortable transport modes. It indicates that car attitudes not only explain car use, but also dominate the decision of using car alternatives.

Furthermore, our results suggest that stage of life and gender influence modal choice for leisure trips, but mainly indirectly. Students living at home are likely to use travel modes other than cars. They are more likely than others to use public transport for active leisure activities and fun shopping, and to cycle and walk more often for family visits. Contrary to students, young and older families seem to prefer their car for all types of leisure trips. A remarkable difference in modal choice can be noticed between women and men. Women are significantly less likely than men to cycle or walk for leisure, whereas the opposite holds for car use for active leisure activities and family visits, and for public transport for fun shopping. However, the relationship between gender and modal choice is negligible compared to other objective and subjective variables (except for public transport for fun shopping).

8.4.3 Attitudes and behaviour

We also simultaneously estimated reverse relationships, to test whether travel attitudes are influenced by modal choices (see Table 8.4). The effect of modal choices on travel (mode) attitudes is generally small and, moreover, the use of public transport does not seem to significantly influence travel-related attitudes. However, car use and cycling and walking do have a significant direct effect on some particular travel (mode) attitudes which is even more important than the reverse effect. We found that a pro-environment attitude is significantly influenced by modal choices. Cycling and walking encourages a pro-environment attitude, whereas a pro-environment attitude is reduced by car use. Initial car use also encourages frequent car use, especially for family visits, whereas cycling and walking prevent frequent car use (according to family and friends). Furthermore, using cars seems to result in a positive perception of the car as a comfortable transport mode, whereas the opposite holds for cycling and walking.

Table 8.3 Standardized direct and total effects on modal choice for different leisure trips

	Car use			Public transport			Cycling and walking		
	AL N = 633 (53.7% no, 46.3% yes)	**FV** N = 903 (25.2% no, 74.8% yes)	**FS** N = 577 (46.8% no, 53.2% yes)	**AL** N = 633 (90.4% no, 9.6% yes)	**FV** N = 903 (87.4% no, 12.6% yes)	**FS** N = 577 (62.0% no, 38.0% yes)	**AL** N = 633 (37.3% no, 62.7% yes)	**FV** N = 903 (68.5% no, 31.5% yes)	**FS** N = 577 (56.0% no, 44.0% yes)
SED characteristics									
student living at	-0.031	0.005	0.019	0.133*	-0.043	0.416*	0.029	0.241*	-0.130*
home	-	-	-	-	-	_0.242*_	-	_0.189*_	-
older family,	0.235*	0.125*	0.228**	-0.213*	-0.184*	-0.293*	-0.144*	-0.109*	-0.044
working	-	-	-	-	-	-	-	-	-
young family	0.222*	0.103*	0.137*	-0.081*	-0.123*	-0.110*	-0.101*	-0.061*	-0.071*
	-	-	-	-	-	-	-	-	-
Gender (female)	0.046*	0.090*	0.006	-0.005*		0.259*	-0.051*	-0.060*	-0.024
	-	-	-	-	-	_0.274*_	-	-	-
Lifestyles									
culture lover	-0.136*	-0.014	-0.069*	-0.004*	0.072*	-0.013*	0.032*	0.006	0.078*
	_-0.142*_	-	-	-	-	-	-	-	-
friends & trends	0.025*	-0.004	-0.008	-0.011*	0.008**	-0.008*	-0.012*	-0.161*	-0.137*
	-	-	-	-	-	-	-	_-0.153*_	_-0.137*_
home-oriented	0.068*	0.058*	0.114*	-0.013*	-0.112*	-0.034*	-0.040*	-0.018*	-0.080*
but active family	-	-	-	-	-	-	-	-	-
low-budget &	0.001	-0.144*	0.016*	0.004*	-0.018*	0.006*	0.137*	0.169*	0.108*
active/creative	-	_-0.150*_	-	-	-	-	_0.131*_	_0.166*_	0.124*
home-oriented	0.157*	0.096*	-0.047*	0.001*	0.058*	-0.008*	-0.019	-0.020**	0.061*
traditional family	_0.207*_	_0.139*_	-	-	-	-	-	-	-
Built environment									
location relative	0.229*	0.087	0.449*	0.006*	-0.239*	0.019*	-0.153*	0.003*	-0.437*
to local centre	_0.276*_	_0.129*_	_0.523*_	-	_-0.330*_	-	_-0.168*_	-	_-0.494*_
location relative	0.383*	0.199*	0.439*	-0.045*	-0.454*	-0.044*	-0.232*	-0.021*	-0.516*
to regional centre	_0.376*_	_0.228*_	_0.488*_	-	_-0.526*_	-	_-0.218*_	-	_-0.573*_
local accessibility	-0.247*	-0.131**	-0.323*	0.048*	0.331*	0.223*	0.006	0.023*	0.184*
	_-0.257*_	_-0.177*_	_-0.410*_	-	_0.436*_	_0.192*_	-	-	_0.255*_
regional	-0.148*	-0.107*	-0.297*	0.000*	0.222*	0.152*	-0.001**	0.000*	-0.002*
accessibility	_-0.192*_	_-0.138*_	_-0.370*_	-	_0.292*_	_0.197*_	-	-	-

Note: direct effects shown in italics, - = direct effect estimated but found insignificant and therefore constrained to zero, * significant at $\alpha = 0.01$, ** significant at $\alpha = 0.05$

Table 8.3 Standardized direct and total effects on modal choice for different leisure trips *continued*

	Car use			Public transport			Cycling and walking		
	AL N = 633 (53.7% no, 46.3% yes)	**FV** N = 903 (25.2% no, 74.8% yes)	**FS** N = 577 (46.8% no, 53.2% yes)	**AL** N = 633 (90.4% no, 9.6% yes)	**FV** N = 903 (87.4% no, 12.6% yes)	**FS** N = 577 (62.0% no, 38.0% yes)	**AL** N = 633 (37.3% no, 62.7% yes)	**FV** N = 903 (68.5% no, 31.5% yes)	**FS** N = 577 (56.0% no, 44.0% yes)
Built environment									
density	-0.229*	*-0.219**	-0.457*	0.036*	0.448*	0.035*	0.129*	0.017*	0.421*
	*-0.289**	*-0.313**	*-0.635**	-	*0.656**	-	*0.155**	-	*0.605**
Residential attitudes									
car alternatives	0.060*	0.042*	0.114*	0.000*	-0.088*	-0.058*	0.000**	0.000*	0.001*
	-	-	-	-	-	-	-	-	-
open space and	0.145*	0.137*	0.285*	-0.023*	-0.279*	-0.022*	-0.082*	-0.011*	-0.263*
quietness	-	-	-	-	-	-	-	-	-
safety and	-	-	-	-	-	-	-	-	-
neatness									
accessibility	-0.025*	-0.031*	-0.052*	0.006*	0.061*	0.007*	0.013**	0.003*	0.046*
	-	-	-	-	-	-	-	-	-
social contact	-	-	-	-	-	-	-	-	-
Travel attitudes									
frustrated	0.011*	-	-	-	-	-	-	-	-
traveller	-								
pro-environment	-0.223*	-0.095*	-0.220*	0.114*	0.201*	0.148*	0.161*	0.090*	0.128*
	-	-	-	-	-	-	-	-	-
frequent car user	0.015*	0.002*	0.006*	-0.005*	-0.005*	-0.006*	-0.016*	-0.009*	-0.001**
	-	-	-	-	-	-	-	-	-

Note: direct effects shown in italics, - = direct effect estimated but found insignificant and therefore constrained to zero, * significant at $\alpha = 0.01$, ** significant at $\alpha = 0.05$

Table 8.3 Standardized direct and total effects on modal choice for different leisure trips *continued*

	Car use			**Public transport**			**Cycling and walking**		
	AL N = 633 (53.7% no, 46.3% yes)	**FV** N = 903 (25.2% no, 74.8% yes)	**FS** N = 577 (46.8% no, 53.2% yes)	**AL** N = 633 (90.4% no, 9.6% yes)	**FV** N = 903 (87.4% no, 12.6% yes)	**FS** N = 577 (62.0% no, 38.0% yes)	**AL** N = 633 (37.3% no, 62.7% yes)	**FV** N = 903 (68.5% no, 31.5% yes)	**FS** N = 577 (56.0% no, 44.0% yes)
Travel mode attitudes									
car = comfortable	0.105* -	0.036* -	0.083* -	-0.078* -	-0.073* -	-0.097* -	-0.266* _-0.209*_	-0.152* _-0.116*_	_-0.022**_ -
car = negative effects	-	-	-	-	-	-	-	-	-
public transport = comfortable	-	-	-	-	-	-	-	-	-
public transport = positive effects	-	-	-	-	-	-	-	-	-
public transport = time-saving	-	-	-	-	-	-	-	-	-
bike/on foot = comfortable	-	-	-	-	-	-	-	-	-
bike/on foot = positive effects	-0.138* _-0.137*_	-	-	-	-	-	-	-	-
Car availability	0.624* _0.606*_	0.259* _0.253*_	0.598* _0.567*_	-0.489* _-0.488*_	-0.499* _-0.499*_	-0.555* _-0.555*_	-0.308* _-0.295*_	-0.266* _-0.264*_	-0.164* _-0.160*_
R^2	***62.2%***	***22.3%***	***80.5%***	***23.8%***	***62.3%***	***49.6%***	***29.6%***	***18.3%***	***49.7%***

Note: direct effects shown in italics, - = direct effect estimated but found insignificant and therefore constrained to zero, * significant at $\alpha = 0.01$, ** significant at $\alpha = 0.05$

Table 8.4 Standardized direct and total effects on travel (mode) attitudes

	Travel attitudes			Car attitudes		Public transport attitudes			Cycling and walking attitudes	
	Frustrated traveller	**Pro-environment**	**Frequent car user**	**Comfortable**	**Negative effects**	**Comfortable**	**Positive effects**	**Time-saving**	**Comfortable**	**Positive effects**
Car use for AL	-0.001*		0.003*	0.115*		-0.002*	-0.002*	-0.001*	-0.002*	-0.001*
	-	-	-	0.114*	-	-	-	-	-	-
Car use for FV	-0.005*	-0.158*	0.135*	0.245*	-0.025*	-0.006*	-0.028*	-0.003*	-0.013*	-0.041*
	-	-0.154*	0.121*	0.187*	-	-	-	-	-	-
Car use for FS	-0.005*	-0.183*	0.011*	0.242*	-0.021*	-0.006*	-0.031*	-0.003*	-0.006*	-0.038*
	-	-0.173*	-	0.178*	-	-	-	-	-	-
Public transport for AL										
	-	-	-	-	-	-	-	-	-	-
Public transport for FV										
	-	-	-	-	-	-	-	-	-	-
Public transport for FS						0.174*				
	-	-	-	-	-	-	-	-	-	-
Cycling/walking for AL	0.003*	0.207*	-0.172*	-0.069*	0.037*	0.004*	0.033*	0.002*	0.014*	0.050*
	-	0.200*	-0.158*	-	-	-	-	-	-	-
Cycling/walking for FV										
	-	-	-	-	-	-	-	-	-	-
Cycling/walking for FS	0.003*	0.196*	-0.137*	-0.067*	0.022*	0.004*	0.031*	0.002*	0.011*	0.174*
	-	0.191*	-0.127*	-	-	-	-	-	-	0.123*

Note: direct effects shown in italics, - = direct effect estimated but found insignificant, * significant at $\alpha = 0.01$, ** significant at $\alpha = 0.05$
AL = active leisure activities, FV = family visits, FS = fun shopping

8.4.4 Ignoring subjective variables in travel behaviour research

In this section we assess the consequences of ignoring subjective variables in travel behaviour research by comparing the results of the previously discussed models which included objective as well as subjective variables to the results of models with only objective variables.

Comparing Table 8.2 with Table 8.5 illustrates that ignoring subjective variables in travel behaviour research does not result in poor model fit. All our models with only objective variables obtain good model fit. However (see Table 8.6), the explained variances of car availability and modal choice for leisure trips tend to be lower for models that do not account for subjective influences (see, e.g., Biddle and Marlin, 1987; Barrett, 2007; and Goffin, 2007 for discussions about goodness of fit versus 'predictive ability' or explained variance in SEMs, including the observation that a model can fit nearly perfectly while explaining very little variance, or not fit well despite explaining a great deal). In other words, it seems that lifestyles, residential attitudes and travel attitudes have an important influence of their own on modal choice for leisure trips.

Table 8.5 Model fit results while ignoring subjective influences

	Chi^2 (df) p	Chi^2 / df	CFI	TLI	RMSEA	WRMR
Cut-off value	p > 0.05	< 2	> 0.95	> 0.95	< 0.05	< 1.00
car use for AL	26.46 (23) 0.28	1.15	0.99	0.99	0.02	0.78
car use for FV	27.28 (23) 0.24	1.19	1.00	0.99	0.01	0.83
car use for FS	27.19 (20) 0.13	1.36	0.99	0.98	0.02	0.84
public transport for AL	28.46 (26) 0.34	1.09	1.00	1.00	0.01	0.82
public transport for FV	26.61 (22) 0.23	1.21	1.00	0.99	0.02	0.82
public transport for FS	26.97 (20) 0.14	1.35	0.99	0.98	0.02	0.84
cycling/walking for AL	28.23 (25) 0.30	1.13	1.00	0.99	0.01	0.81
cycling/walking for FV	30.02 (24) 0.18	1.25	0.99	0.99	0.02	0.87
cycling/walking for FS	27.71 (21) 0.15	1.32	0.99	0.98	0.02	0.85

Note: AL = active leisure activities, FV = family visits, FS = fun shopping

Furthermore, our findings suggest that ignoring subjective influences results in an *under*estimation of the effects of the built environment on modal choice for leisure trips (compare Tables 8.3 with Tables 8.6). Spatial characteristics such as location relative to a town or city centre and accessibility have a significant effect, even when subjective influences are accounted for, but this effect diminish if subjective influences are ignored. According to our findings, ignoring the effect of subjective influences might also result in a misspecification of the effect of car availability on modal choices.

Table 8.6 Standardized direct and total effects on modal choice for different leisure trips while ignoring subjective influences

	Car use			Public transport			Cycling and walking		
	AL	FV	FS	AL	FV	FS	AL	FV	FS
	N = 684 (53.1% no, 46.9% yes)	N = 969 (24.5% no, 74.6% yes)	N = 617 (46.8% no, 53.2% yes)	N = 684 (90.5% no, 9.5% yes)	N = 969 (87.5% no, 12.5% yes)	N = 617 (61.8% no, 38.2% yes)	N = 684 (37.9% no, 61.2% yes)	N = 969 (68.4% no, 31.6% yes)	N = 617 (56.1% no, 43.9% yes)
SED characteristics									
student living at home	-0.002	-0.073*	-0.001	0.107*	-0.180*	0.364*	0.033	0.241*	-0.142*
	-	-	-	-	_-0.257*_	_0.306*_	-	_0.193*_	-
older family, working	0.147*	0.165*	0.156*	-0.187*	-0.200*	-0.325*	-0.207*	-0.087*	0.022
	-	-	-	-	-	_-0.229*_	_-0.124*_	-	-
young family	0.072*	0.223*	0.077*	-0.069*	-0.219*	-0.169*	-0.031*	-0.036*	-0.013
	-	_0.156*_	-	-	_-0.137*_	_-0.130*_	-	-	-
gender (female)	0.019*	0.003*	-0.160*	-0.003*	-0.004*	0.227*	-0.002*	-0.002*	-0.020*
	-	-	_-0.176*_	-	-	_0.229*_	-	-	-
Built environment									
location relative to local centre	0.265*	0.039*	0.372*	-0.044*	-0.047*	-0.025*	-0.020*	-0.020*	-0.397*
	_0.218*_	-	_0.322*_	-	-	-	-	-	_-0.388*_
location relative to regional centre	0.444*	0.071*	0.424*	-0.080*	-0.086*	-0.045*	-0.36*	-0.037*	-0.535*
	_0.361*_	-	_0.334*_	-	-	-	-	-	_-0.519*_
local accessibility	-0.349*	-0.059*	-0.271*	0.066*	0.072*	0.231*	0.030*	0.031*	0.215*
	_-0.280*_	-	_-0.200*_	-	-	_0.195*_	-	-	_0.202*_
regional accessibility	-0.206*	-	-0.250*	-	-	0.148*	-	-	-
	_-0.206*_		_-0.250*_			_0.148*_			
density	-0.382*	-0.207*	-0.484*	0.086*	0.334*	0.048*	0.145*	0.040*	0.493*
	_-0.293*_	_-0.132*_	_-0.389*_	-	_0.242*_	-	_0.106*_	-	_0.477*_
Car availability	0.471*	0.431*	0.506*	-0.401*	-0.538*	-0.293*	-0.244*	-0.233*	-0.111*
	_0.471*_	_0.431*_	_0.506*_	_-0.401*_	_-0.538*_	_-0.293*_	_-0.244*_	_-0.233*_	_-0.111*_
R^2	***16.7%***	***23.9%***	***48.8%***	***16.1%***	***45.6%***	***30.0%***	***10.4%***	***9.7%***	***29.7%***

Note: direct effects shown in italics, - = direct effect estimated but found insignificant and therefore constrained to zero, * significant at $\alpha = 0.01$, ** significant at $\alpha = 0.05$

8.5 Conclusions

This paper aimed at contributing to the research on the link between the built environment and travel behaviour by evaluating the objective and subjective influences on modal choice for leisure trips. Moreover, our analysis also accounts for complex interrelations due to issues such as residential self-selection and mediating variables like car availability. The dataset we used, stemming from an Internet survey on personal attitudes, preferences and lifestyles, allowed us to include subjective influences on each level of the hypothesized model. Doing so, our analysis results are controlled for the influence of subjective personal characteristics (i.e., lifestyles), subjective attitudes toward the built environment (i.e., location attitudes), and subjective attitudes toward mobility and travel (i.e., general travel attitudes and specific travel mode attitudes). By comparing the results of models with only objective variables and the results of models with both objective and subjective variables, we found that subjective variables seem to explain an important additional amount of variance in modal choice for several types of leisure trips. Moreover, neglecting subjective variables likely result in a misspecification of the effect of the built environment on modal choice. Our findings also suggest that modal choice is more a question of car use versus use of car alternatives (public transport, walking/cycling) rather than the assessment of individual (car, walking/cycling) versus public transport or motorized (car, public transport) versus non-motorized (walking/cycling) transport.

Based on our results, it is hard to say which one is more important: objective variables or subjective variables. For example, car use and public transport use are considerably influenced by stage of life. However, a traditional family lifestyle is strongly associated with car use for active leisure activities and, thus, the influence of lifestyles cannot always be ignored. Another example is the assessment of the influence of objective and subjective spatial characteristics. At first sight, the built environment seems to influence modal choices to a larger extent than residential attitudes. However, residential attitudes have an important influence on selecting the spatial characteristics of the built environment in the first place (i.e. the residential location decision), supporting the need to account for residential self-selection in assessing the impacts of the built environment on modal choice. A last example refers to objective and subjective travel aspects. Car availability seems to be a major influence on modal choice, but our results indicate that travel attitudes and travel mode attitudes should be accounted for as well. This refers to a second type of self-selection with respect to travel. We suppose it is more accurate to say that modal choice can be explained properly only by a mix of objective and subjective variables.

The explained variance values of some models are quite high, especially for the models explaining car use for active leisure activities and fun shopping. Other models indicate that improvement is still possible. For further research, one should keep in mind that our analysis focuses on the individual and his or her modal choice for leisure trips. We did not take into account the interactions among individuals. This might become important, especially for leisure trips since leisure activities are often jointly performed with other individuals. Consequently, it seems appropriate to analyze the individual's travel behaviour within a broader (social) context.

Based on our findings some policy implications might be formulated as well. The results suggest that objective spatial characteristics remain important in the discussion on the link between the built environment and daily modal choices. Spatial planning can contribute to a more sustainable mobility by means of (i) densifying, (ii) fostering residential developments close to town and city centres, and (iii) providing facilities at neighbourhood-level. However, our results also point out that these suggested spatial planning policies might only be successful for a specific group of respondents. Non-traditional lifestyle groups and people with a positive attitude toward having access would possibly prefer to reside in such urban neighbourhoods. The suggested spatial planning policies seem likely to be unsuccessful for active and family-oriented lifestyles groups and people with a positive attitude toward open space and quietness, who prefer a suburban or rural neighbourhood. These neighbourhoods are generally associated with more car use and less use of car alternatives. However, there still exist some possibilities to reduce car use, especially by means of transport planning. Our results suggest that car use is influenced by a positive attitude toward cars. Transport planning policies should focus on improving the image of travelling by public transport or cycling and walking. This can be done by underlining their positive effects for the environment and, especially for cycling and walking, their relaxing (and physical health) effects. After all, these two aspects were found to be associated with a positive attitude toward public transport use and cycling and walking. Consequently, an integration of spatial planning and transport planning seems useful. Moreover, policy should not only focus on designing and developing objective plans (e.g., a more sustainable lay-out of residential neighbourhoods), but should also be aware of their subjective implications (e.g., image building of travel modes).

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*"I may not have gone where I intended to go,
but I think I have ended up where I intended to be."*

Douglas Noël Adams (1952-2001)

9. CONCLUSIONS AND DISCUSSION

9.1 Introduction

Policymakers acknowledge that the need to travel can be altered by, among others, a better spatial organization of the activities in which people participate. Spatial planning policies are but one suitable instrument to achieve sustainable travel patterns characterized by less (long-distance) trips, less car use, more public transport and more cycling and walking. The possible interaction between land use and travel behaviour has received a lot of academic attention as well. Notwithstanding the considerable progress that has been made, findings and results of the numerous land use-travel behaviour interaction studies remain ambiguous. Several reasons for this are mentioned in the introduction of this dissertation.

The aim of this dissertation was threefold. First, due to differences in, among others, urbanization patterns and culturally defined norms and values between the USA and Europe, findings from mainly USA studies cannot be extrapolated to a European context without further notice. Therefore, it was suggested to extend the existing research debate by European evidence. Especially Belgium, Flanders, seemed to be an interesting case-study since spatial planning in Belgium is not restricted to town planning and is, thus, area covering. Moreover, Belgium does not have a long-lasting spatial planning tradition compared to neighbouring countries such as the Netherlands and Great-Britain. An integrated vision on spatial planning merely emerged in the 1990s. Second, instead of studying the land use effects on one specific travel aspect such as modal choice or travel distance, this dissertation considered the interrelations among various travel behaviour aspects. Moreover, whereas commuting behaviour has received most attention so far, more research was needed on non-work travel as well. Third, the inclusion of subjective variables such as lifestyles, travel and residential attitudes, beside commonly used objective influences was felt to improve our understanding of the relationship between land use and travel behaviour. In sum, this dissertation tried to measure the effects of land use patterns on the complexity of travel behaviour for Flanders, Belgium, while controlling for the traveller's objective and subjective characteristics. This overall aim was further refined into seven more specific research questions:

1. *Which theoretical framework justifies a relationship between daily travel behaviour and land use, while accounting for socio-economic and demographic influences as well as socio-psychological influences?*
2. *How is travel behaviour influenced by land use characteristics and objective socio-economic and demographic characteristics related to social status and responsibility within the household? And if land use remains important, what is the joint effect of land use patterns on travel behaviour?*
3. *What is the role of car ownership within land use-travel behaviour interaction research?*
4. *Should tour complexity be considered as an endogenous variable to be explained or not?*
5. *How to measure lifestyles and how to incorporate lifestyles in land use-travel behaviour interaction research?*
6. *How are attitudes related to medium-term decisions on residential location and car ownership?*
7. *Is daily travel behaviour influenced by objective spatial and socio-economic and demographic characteristics, or rather by subjective lifestyles, travel attitudes and residential attitudes?*

Addressing the abovementioned research questions first involved combining and linking theories stemming from different backgrounds. Using key-variables from these theories, a conceptual model for travel behaviour was developed in the first phase of this doctoral research (see Chapter 2). In a second phase, the conceptual model was put into practice, by estimating various types of structural equation models (SEM). These empirical analyses were based on data from the 2000-2001 Travel Behaviour Survey for Flanders or for Ghent. Contrary to Chapter 3, which is an initial exploration of the land use-travel behaviour interaction in Flanders, Chapter 4 presented a basic model which relates land use with car ownership and car use. This basic model was then extended in the subsequent chapters. Chapter 5 also analyzed the interaction with travel distance, travel time and tour complexity, whereas Chapter 6 to 8 introduced long-term decisions on lifestyles and underlying residential and travel attitudes. However, this kind of subjective information is not readily available in commonly used travel behaviour surveys. Therefore, an additional Internet survey was conducted between May 2007 and October 2007.

This final chapter summarizes the most important findings and results from the conceptual model and the empirical analyses. Section 9.2 relates the main findings to the seven research questions. Section 9.3 provides a more critical discussion of the results and also presents directions for further research. Finally, section 9.4 concludes with implications for spatial planning and transportation planning policies.

9.2 Summary of results

This dissertation consists of a series of seven academic research papers, which attempted to measure spatial and social variations in travel behaviour, and incorporate lifestyles and attitudes into land use-travel behaviour interaction research. This section relates the main findings of these papers to the seven research questions and points out some overall conclusions.

1. *Which theoretical framework justifies a relationship between daily travel behaviour and land use, while accounting for socio-economic and demographic influences as well as socio-psychological influences?*

Land use-travel behaviour interaction research dates back to the 1950's and 1960's (e.g., Mitchell and Rapkin, 1954; Marble, 1959; Levinson and Wynn, 1963; Hurst, 1969) and, so far, our understanding has certainly increased. Recent literature reviews such as Bartholomew and Ewing (2009) and Handy (2002, 2005) indicate that empirical studies do not only include land use variables to explain travel behaviour aspects, but generally control their results for socio-economic and demographic (SED) differences, and to a lesser extent socio-psychological differences, among individuals and households. Consequently, variables used in empirical studies refer to three dimensions: (i) a spatial dimension (e.g., density, diversity, design), (ii) an objective socio-economic and demographic dimension (e.g., age, gender, income), and (iii) a subjective socio-psychological dimension (e.g., lifestyles, attitudes). Although empirical studies are inspired by a specific theoretical background such as microeconomics (e.g., Crane, 1996; Bhat and Guo, 2007) or the activity-based approach (e.g., Maat and Arentze, 2003; Naess, 2006; Chen and McKnight, 2007), almost none refer to a more comprehensive theoretical or conceptual framework that justifies the inclusion of these three dimensions, and the interaction between land use and travel behaviour from several points of view.

Chapter 2 attempted to establish such an authoritative framework by using key-concepts from theories mainly in transport geography and social psychology. After all, theories in transport geography determine the mechanisms determining travel behaviour, whereas social psychology rather refers to specific factors underlying travel behaviour (Handy, 2005). In other words, theories in transport geography justify the influence of factors external to the individual (or the external spatial, or even spatiotemporal, context in which travel behaviour is performed) contrary to theories in social psychology which focus on behavioural factors internal to the individual (or internal processes such as reasoned and unreasoned influences). The conceptual model discussed in the second chapter combined both theoretical fields.

First, daily travel behaviour is embedded in a decision hierarchy ranging from short-term activity decisions, over medium-term location decisions to long-term lifestyle decisions. A theoretical justification of why to consider travel behaviour as part of such a decision hierarchy can be found in the activity-based approach from transport geography and the lifestyle theory from sociology. Most travel is a derived demand since people want to participate in activities such as working, shopping and recreating in spatially separated locations. Consequently, someone's travel behaviour is directly influenced by the spatial and temporal characteristics of his or her activity behaviour. This idea has been further elaborated in the activity-based approach with important contributions by Hägerstrand (1970), Chapin (1974) and Cullen and Godson (1975). In a next step of the decision hierarchy, short-term travel and activity behaviours are related to medium-term location decisions such as residential location choices. Fried *et al*. (1977) and Cullen (1978) acknowledge the direct influence of activity behaviour on travel behaviour, but also underline the occurrence of adaptation processes reducing the possible imbalance between someone's activity needs and the currently available activity opportunities to choose from. Such adaptations range from small activity and travel adjustments to more fundamental changes such as residential or workplace relocation. The longest term decision within the hierarchy of decisions is the choice of a lifestyle. Weber (1972), Bourdieu (1984) and Ganzeboom (1988) rely on each other, but they all agree on the communicative character of lifestyles. According to them, lifestyles refer to patterns of behaviour elucidating someone's social position. However, the lifestyle concept is also used with respect to opinions and motivations, including beliefs, interests and attitudes, underlying these patterns of behaviour. This is rather confusing and, therefore, Munters (1992) distinguishes lifestyles (i.e., the individual's opinions and motivations, or orientation) from lifestyle expressions (i.e., observable patterns of behaviour). Within this respect, location behaviour, activity behaviour and travel behaviour are some behavioural patterns in which lifestyles are reflected. This way, lifestyle also influences daily travel behaviour. Second, the previously described decision hierarchy is then considered as the result of an assessment of reasoned and unreasoned influences. After all, neglecting these underlying influences might come across as 'physicalist', as only considering the observable patterns in behaviour. Therefore, the objective decision hierarchy was extended with subjective concepts from theories in social psychology. For example, the theory of reasoned action (Fishbein and Ajzen, 1972; Fishbein, 1980) and the theory of planned behaviour (Ajzen, 1991) both consider behaviour as the result of rational choices and, consequently, emphasize the influence of reasoned influences such as perceptions, attitudes and preferences on behaviour. Nevertheless, people are not always conscious of their behaviour (Simon, 1950; Pred, 1967) and, therefore, other unreasoned influences such as habits (Triandis, 1977; Ronis *et al*., 1989) should be accounted for as well. The individual decision hierarchy with its underlying reasoned and unreasoned influences describe travel behaviour from the perspective of one individual. However, this individual is influenced by factors external to that individual. Social cognitive theory (Bandura, 1986) mainly focus on the influence of the social environment (e.g., the household), whereas environmental psychology underline the influence of the spatial environment (e.g., the residential neighbourhood). Important to note, these environments include objective characteristics external to the individual as well as subjective processes internal to the individual (Lewin, 1936; Stokols, 1977). So finally, the conceptual model as a whole is placed within (i) an individual level, (ii) a social context and (ii) a spatial context.

Putting this conceptual model into practice firstly involved collecting appropriate data. Therefore, the subsequent six chapters use cross-sectional data from the 2000-2001 Travel Behaviour Survey Flanders or Ghent, or data from a self-organized Internet survey, completed with spatial information from various databases. Another issue was the use of a suitable modelling technique. Since the research focus was on disentangling the complexity between various components of the conceptual model, structural equation modelling is advanced.

2. *How is travel behaviour influenced by land use characteristics and objective socio-economic and demographic characteristics related to social status and responsibility within the household? And if land use remains important, what is the joint effect of land use patterns on travel behaviour?*

Similar to the majority of land use-travel behaviour interaction studies, Chapter 3 addressed the question how important land use characteristics are in the explanation of travel behaviour. So far, no distinct answer exists to this question: some studies (e.g., Abreu e Silva *et al*., 2006; Vance and Hedel, 2007; Maat and Timmermans, 2009a) found that land use influences are important, whereas others state the opposite (e.g., Krizek, 2000; Bhat and Guo, 2007; Cao *et al*., 2007a, b). In that respect, Chapter 3 presents an initial analysis of travel behaviour in relation to activity and spatial behaviour in Flanders. However, it characterizes land use patterns somewhat differently from what is commonly accepted in empirical studies. Most studies use various spatial characteristics such as residential density, jobs/housing balance and distance to the nearest railway station, and estimate the effect of each particular spatial variable while controlling for other (spatial) characteristics. However, one might argue that the combined effect of various land use characteristics together is more relevant to someone's travel behaviour than the influence of each these characteristics separately. Another way to characterize land use is, therefore, the use of a categorization of neighbourhoods which considers this joint effect of land use patterns, for example, urban versus suburban (Friedman *et al*., 1994; McNally and Kulkarni, 1997) or varying degree of urbanization (Dieleman *et al*., 2002; Schwanen *et al*., 2002). However, the disadvantage of such a categorization is that complex land use patterns are reduced to a limited number of categories (Bagley and Mokhtarian, 2002). A possible solution is the construction of latent variables that reflect the multidimensionality of land use patterns and which are continuous rather than discrete. Combined with SEM, Chapter 3 not only accounted for the multidimensionality of land use patterns, but also the complexity of the land use-travel behaviour interaction.

Using data from the 2000-2001 Flanders Travel Behaviour Survey, the estimation results of this SEM with latent variables were as expected. Residing in an urban environment, in this analysis characterized by a larger degree of urbanization (objectively measured as well as subjectively perceived by the respondent) and a shorter distance to public transportation, was associated with shorter travel distances, shorter travel times and fewer trips per day. However, land use seemed not to be the most important influence factor of daily travel patterns. Instead, travel behaviour seemed mainly influenced by social status: respondents with higher social status (i.e., higher education, full-time employed, high job status, high income, and higher car ownership) were more likely to travel in more complex ways than respondents from low status groups. Moreover, the results pointed out that examining only direct effects could be misleading. For example, less complex travel patterns are directly associated with having more household responsibilities (i.e., adults, married or cohabiting, full-time employed, small households without young children). However, respondents with more household responsibilities were also more likely to obtain a higher social status, and thus exhibit a complex travel behaviour with more trips per day and longer travel distances and times. The opposite signs of direct and indirect effects of household responsibility could indicate the effect of different niches of older respondents. It can be assumed that the older and less active respondents (indicated by characteristics such as age, small household sizes and the absence of young children) were responsible for the negative direct effect on travel behaviour, whereas the positive indirect effect was also due to older respondents but who were still very active (e.g., full-time employed white-collars, which are important characteristics of social status). This indirect effect was even more important than the direct effect, resulting in an overall positive total effect of household responsibility on travel behaviour. Another type of indirect effect on travel behaviour was caused by the interaction between social status and land use. Taken into account this type of interaction, results were (partly) controlled for the effects of residential self-selection. Higher social status groups were found more likely to reside in urban neighbourhoods and through this interaction, have less complex travel patterns. Nevertheless, this indirect effect was rather small and could be neglected.

This initial analysis drew attention to the importance of indirect effects. It clarified that due to interrelations among land use and SED characteristics indirect effects exist that can be as important as the direct effects on travel behaviour. However, since commonly used techniques such as regression analysis can only estimate the direct effects on travel behaviour, indirect effects have been neglected for a long time in land use-travel behaviour interaction research. This was considered an important shortcoming in the debate so far. Consequently, the subsequent chapters also paid attention to the distinction between direct, indirect and total effects.

3. *What is the role of car ownership within land use-travel behaviour interaction research?*

Chapter 4 discussed the dual role of car ownership in land use-travel behaviour interaction studies, and more specifically the consequences of ignoring this specific role. Most studies consider car ownership as one of many other explanatory variables that influence daily travel behaviour. For example, owning several cars seems to encourage car use and enable long-distance travel (e.g., Bagley and Mokhtarian, 2002; Dieleman *et al*., 2002; Schwanen *et al*., 2002; Krizek, 2003). On the other hand, car ownership in itself is influenced by land use patterns and various SED characteristics. For example, it is assumed that higher densities and more diversity results in fewer cars per household, but many studies pointed out that SED characteristics, and especially income, are more important decisive factors (e.g., Kockelman, 1997; Bhat and Guo, 2007; Cao *et al*., 2007a, b; Potoglou and Kanaroglou, 2008). Since car ownership is fundamentally interconnected with long-term decisions on residential and employment locations, and short-term decisions on daily travel behaviour (Ben-Akiva and Atherton, 1977; Scott and Axhausen, 2006), it might be useful to combine both research approaches and consider car ownership as a variable mediating the relationship between land use and travel behaviour. Only a few studies did so (e.g., Simma and Axhausen, 2003; Scheiner and Holz-Rau, 2007), but rather from a pragmatic point of view than providing an in-depth discussion of the modelling consequences of ignoring this dual relationship. The fourth chapter, therefore, compared the results of one SEM with car ownership as a variable mediating the interaction between land use and car use, and another SEM without this.

Based on data from the 2000-2001 Ghent Travel Behaviour Survey, the results supported the importance of land use in car travel behaviour research. Higher car ownership and more car use were associated with residing in a suburban or even rural neighbourhood, in this analysis characterized by lower densities and more diversity, good car accessibility and located further away from the city centre or a railway station. Results also indicated that especially high-income groups prefer this type of residential neighbourhoods. However, a comparison of the results of both SEMs clarified that ignoring car ownership as a mediating variable is likely to result in an overestimation of the land use effects on car use. All else being equal, total effects of the distance between the residence and the nearest railway station as well as local accessibility by car were found on average 2.5 times higher if the dual relationship of car ownership was not accounted for. On the other hand, other residential land use characteristics such as land use diversity and distance to the CBD of Ghent were reported as non-significant, whereas the full SEM found small but significant total effects. Moreover, the effect of car ownership itself on car use was also slightly overestimated. The dual role of car ownership with respect to the interaction between land use and car use was also confirmed by the interpretation of the modelling results. For example, the income effect on car use probably exists only through car ownership, and not directly as commonly assumed by several studies (e.g., Kockelman, 1997; Schwanen *et al*., 2002; Dargay and Hanly, 2004). For all these reasons, the analyses in the next four empirical chapters all consider the dual relationship of car ownership in the interaction between land use and travel behaviour.

4. *Should tour complexity be considered as an endogenous variable to be explained or not?*

The effects of a second example of interdependencies, namely between land use, tour complexity and travel behaviour, was considered in Chapter 5. Similar to car ownership, tour characteristics such as number of trips per tour or tour complexity might mediate the relationship between land use and travel behaviour. Land use policies such as the New Urbanism in the USA and the Compact City Policy in Europe both aim at controlling and reducing travel through the development of high-density and mixed-use neighbourhoods in which distances between activity locations are shortened. Because various activities are more closely located to each other, individual trips are likely to be combined and linked into one chain of trips. It is also assumed that within such neighbourhoods more trip-chaining reduces daily travel distances and times (Banister, 1997; 1999) and discourages car use in favour of more public transport and more cycling and walking (Ministerie van de Vlaamse Gemeenschap, 2001). These assumed relationships between land use, trip chaining and travel behaviour were confirmed by empirical studies such as Strathman *et al*. (1994) and Ewing (1995). However, counter-evidence also exists. Trip-chaining in traditional neighbourhoods might occur more frequently, but in a less complex way (Ewing *et al*., 1994; Krizek, 2003; Limanond and Niemeier, 2004), overall resulting in longer daily travel distances (Maat and Timmermans, 2006). Moreover, participating in complex tours is found to be associated with more car use instead of more public transport and more cycling and walking (Hensher and Reyes, 2000; Ye *et al*., 2007; Chen *et al*., 2008). Therefore, Chapter 5 first discussed the dual role of tour complexity.

By comparing the results of a SEM with and without tour complexity, the fifth chapter addressed the question whether tour complexity should be considered as an endogenous variable that mediates the relationship between land use and commuting behaviour, or not. Using data from the 2000-2001 Ghent Travel Behaviour Survey results indicated that ignoring the mediating role of tour complexity did not result in a misspecification of the land use effects on commuting behaviour. This suggested that tour complexity is rather a variable outside the model that predefines different tour types. However, land use might still have a different effect on commuting behaviour across these different tour types. For example, Srinivasan (2002) and Frank *et al.* (2008) discussed how land use influences modal choices for trips in different tour types, but they did not consider whether these differences across tour types are statistically significant. For example, it can be assumed that land use is more important for commuting trips in simple work-only tours (home-work-home) compared to commuting trips in more complex tours that combine working with other non-working activities. After all, in work-only tours commuting decisions are based on an assessment of the land use characteristics of only the workplace, whereas in more complex tours land use characteristics of all stops in this tour, and not only the workplace, must be considered. For example, despite good access by public transport at the workplace, people will not commute by public transport if it is not available at other stops in their tours as well (Vande Walle and Steenberghen, 2006). This assumption is only partly confirmed by the modelling results of a multiple group SEM reported in Chapter 5. Land use characteristics of the workplace were found indeed more important for commuting time in simple work-only tours compared to more complex work tours, but the opposite holds for car use. Workplaces close to a railway station, with poor car accessibility and at which parking is difficult are associated with less car use, even if working is combined with other non-working activities. These types of workplaces are possibly characterized by higher densities and more land use mixing as well, offering possibilities to participate in other non-working activities such as shopping and recreating within the vicinity of the workplace. Consequently, commuting by car is in such circumstances not always necessitated. Furthermore, results pointed out that neglecting these differences across tour types tends to result in an underestimation of the land use effects on commuting in simple work-only tours. With respect to the second aim of this dissertation, the analysis in Chapter 5 also provided insight in the interrelations among various commuting behaviour aspects such as car use, commuting distance and commuting time. A SEM estimated the relationships among each of these commuting aspects as well as with land use. In correspondence with other studies (e.g., Abreu e Silva and Goulias, 2009), findings indicate that interactions among commuting aspects might complicate the relationship between land use and commuting behaviour. For example, contrary to what one might expect, respondents residing in high-density, mixed-use and well accessible neighbourhoods were found to have on average longer commuting times. However, these longer commuting times are simply the result of the interaction between land use and modal choices. Commuting times are not directly lengthened because of density, diversity and accessibility, but because of more frequent use of slower travel modes. Consequently, it suggests that the interaction between land use and travel behaviour can only be correctly estimated if the interrelations among various travel behaviour aspects are considered at the same time.

5. *How to measure lifestyles and how to incorporate lifestyles in land use-travel behaviour interaction research?*

Each of the previous three empirical chapters only used objectively measured variables to assess the interaction between land use and travel behaviour. Moreover, by assuming a relationship from SED characteristics to various residential land use characteristics, travel behaviour is considered as derived from other medium-term decisions such as residential location choices, and in addition results of all models are (partly) controlled for residential self-selection. However, the conceptual model presented in the second chapter also considered the influence of long-term decisions on lifestyles. Differences in lifestyles might explain why people with a similar socio-economic and demographic background still behave differently (van Wee, 2002). This also indicates that more subjective variables such as lifestyles need to be taken into account. Lifestyles can be considered as general orientations toward themes such as leisure, work, family, consumption and housing (Salomon and Ben-Akiva, 1983; Bootsma *et al*., 1993). Due to processes of decreasing social control and increasing individualization (Ferge, 1972; Bootsma *et al*., 1993), people are relatively free to choose, for example, from various recreation activities (e.g., attending the opera or cocooning at home) or housing types (e.g., a traditional farm-style house or a modern villa). Through these behavioural decisions, people elucidate their social status. This underlines the communicative character of lifestyles (Weber, 1972; Bourdieu, 1984; Ganzeboom, 1988). Lifestyles, referring to the underlying orientations, are internal to the individual, which are then expressed in patterns of behaviour reflecting someone's social status (Munters, 1992). Although the concept of lifestyle is frequently used, it has been elaborated pragmatically rather than in correspondence with the previously mentioned theoretical considerations. For example, marketing studies such as Mitchell (1983) cluster analyzed numerous variables and each cluster was then referred to as another lifestyle. Since results are data-dependent, it is no surprise that each study finds so-called new lifestyles (Sobel, 1983). Moreover, other studies combined various objective SED characteristics and used this as a proxy for lifestyles (e.g., Salomon and Ben-Akiva, 1983; Cooper *et al*., 2001; Hildebrand, 2003), but in fact this referred to stage-of-life or household composition. Although lifestyles and SED characteristics are interrelated, both have a different meaning and should therefore be separated from each other (Ganzeboom, 1988; Regterschot, 2002). In order to clarify some issues on lifestyles, Chapter 6 focussed on the definition and measurement of lifestyles in relation with modal choices for leisure trips.

Since current travel behaviour surveys lack information on lifestyles, a specific Internet survey on lifestyles and mobility was conducted between May 2007 and October 2007. This survey contained questions on aspects of leisure orientation (holidays, literary interests, and recreational activities) and the assessment of the work-family balance, in correspondence with the definition of lifestyles. Moreover, the answers to choose from were constructed in such a way reflecting the three dimensions (i.e., economic, cultural and stage-of-life) that influence the underlying lifestyle orientations (Ganzeboom, 1988). For example, respondents had to choose from a list what is important on their holidays. Possible answers were, among others, 'inexpensive holiday' or 'luxury holiday' (referring to the economic dimension), 'culture' (referring to the cultural dimension), and 'child-friendly' (referring to stage-of-life dimension). A first factor analysis of each separate aspect of leisure orientation retrieved factors reflecting the three dimensions that influence lifestyles. Since factors such as 'culture lover' appeared across more than one group (e.g., in cultural holidays as well as in cultural literary interests), the factor scores of the first analyses were used as input and factor-analyzed in a second-order factor analysis. This provided the five final lifestyle factors: (i) culture lover, (ii) friends and trends, (iii) home-oriented but active family, (iv) low-budget and active/creative, (v) home-oriented traditional family. Other SED and land use characteristics were also factor analyzed, revealing three stage of life dimensions (i.e., student living at home, older family with employed adults, young family), five residential land use dimensions (i.e., location relative to a local centre; location relative to a regional centre, local accessibility, regional accessibility, density) and one car availability dimension. A correlation analysis provided some first insights in how lifestyles are related with these dimensions, and a subsequent SEM estimated the effect of lifestyles on modal choices for leisure trips while taken into account the complex interrelations with medium-term decisions on residential location and car availability. Compared to other variables such as residential land use characteristics (for fun shopping trips) and car availability (for all leisure trips), lifestyles might have a rather weak influence on modal choices for leisure trips. Nevertheless, their influence remained significant and clear. Car use was found to be associated with an active lifestyle, whereas public transport, cycling and walking appeared more important among low-budget and non-traditional lifestyle groups such as culture lovers. After all, the car is a flexible transport mode that enables active respondents to combine activities such as sports with family activities, and on the other hand car use might be discouraged due to budget constraints or non-traditional ways of living. Accordingly, important subjective differences exist, and land use-travel behaviour interaction studies should not only focus on explaining travel patterns by objective characteristics such as gender, age and income.

6. *How are attitudes related to medium-term decisions on residential location and car ownership?*

Preceding four empirical chapters all consider a hierarchy of long-term lifestyle decisions, medium-term decisions on residential location and car ownership, and short-term activity and travel decision. However, the underlying influences as depicted in the conceptual model of the second chapter were neglected. Attitudes are one example of such underlying influences. Although a huge body of literature on attitudes exists in social psychology (for a review, see, e.g., Fishbein, 1967; Kraus, 1995), attitude studies gained importance in travel behaviour research only recently. Parkany *et al*. (2004) reviewed that most of these studies only use those attitudes directly related to transport and travel behaviour, for example, the perception of public transport and attitudes toward travel aspects such as time-saving, flexibility and environmental consequences of transport. The link with medium-term decisions on residential location and car ownership, and their underling residential and travel attitudes tends to be neglected. Chapter 7, therefore, considered the influence of attitudes as one particular type of reasoned influences, underlying medium-term decisions on residential location and car ownership.

Using data from the Internet survey, Chapter 7 defined car ownership in a somewhat broader sense of the word. Car ownership was combined with other related characteristics such as the possession of a driving license into the concept of car availability. Results from a path analysis indicated that car availability is positively associated with a pro-car attitude (i.e., car is comfortable), and negatively associated with a pro-environment travel attitude. Moreover, these subjective travel attitudes, together with the objective stages-of-life, were the most important influences on car availability. The reverse relationship between behaviour and attitude was also confirmed: having several cars available seems to encourage a frequent car user-attitude (or car ‘addict’) and to discourage a frustrated traveller-attitude. Furthermore, while accounting for subjective attitudes, objective residential land use characteristics retained having a significant influence on car availability, but less strong compared to other variables. Car availability seemed lower in dense neighbourhoods with good local accessibility and that are closely located to a regional centre. These residential location choices are on their turn influenced by residential and travel attitudes. Results indicated that a positive attitude toward open spaces and quietness is associated with residing in less dense neighbourhoods, whereas the opposite was found for a positive attitude toward car alternatives and having access to opportunities, and a pro-environment travel attitude. Of all residential land use characteristics, especially density was influenced by these attitudes. This is no surprise since density is generally considered as one of the most important land use characteristics (Steiner, 1994; Levinson and Kumar, 1997; Chen *et al*., 2008). Again, these subjective attitudes were the most important predictors. These findings illustrated that residential and travel attitudes are both important explanatory variables of residential location choice and car availability, and should be accounted for in further analyses.

7. *Is daily travel behaviour influenced by objective spatial and socio-economic and demographic characteristics, or rather by subjective lifestyles, travel attitudes and residential attitudes?*

Since the 1950s and 1960s, most empirical land use-travel behaviour interaction studies only used objective or 'hard' variables. For example, land use has been characterized by variables such as population density, land use mix and accessibility. However, the more precise SED differences were being controlled for, the more it became clear that there is no such simple and objective relationship between land use and travel behaviour (Ewing and Cervero, 2001). On the contrary, attention should also be paid to underlying subjective influences such as attitudes allowing for a more behavioural analysis that has been lacking so far (Handy, 1996). At the same time, this indicated the growing awareness that differences in travel behaviour were no longer considered being simply related to differences in land use patterns, but rather to people's selective residential location choices and their subjective residential location attitudes and preferences (e.g., Handy *et al*., 2005; Pinjari *et al*., 2007). For example, people who prefer to travel by public transport might choose a residential location that favours their travel preferences. These neighbourhoods are likely characterized by high densities and more diversity since public transportation can only be efficiently organized in such neighbourhoods. Explaining modal choices by focussing only on objective land use characteristics would point out a relationship between modal choices and land use, but this masks the underlying travel and residential preferences. Consequently, objective dimensions should be considered simultaneously with subjective dimensions (Scheiner and Holz-Rau, 2007). Chapter 8, therefore, extended the analysis of the previous chapter, and assesses the influence of objective and subjective variables on modal choices for leisure trips against each other.

By comparing the results of the models which included objective as well as subjective variables to the results of the models with only objective variables, the last empirical chapter discussed the consequences of ignoring subjective variables. It seemed that subjective variables as a group explain a large amount of variance in modal choices for leisure trips. Although the model with only objective variables obtained good model fit, explained variances of modal choice were significantly lower for models that did not account for lifestyles, residential attitudes and travel attitudes. Moreover, findings suggested that ignoring subjective influences also resulted in an underestimation of the land use effects on modal choice for leisure trips. However, it remained difficult to point out whether objective or subjective variables are most important, and it is more likely a mix of both. For example, at first sight it seems that objective land use characteristics are more important than residential attitudes. Residential land use characteristics exerted an important (direct) effect on modal choices whereas residential attitudes only had a small indirect effect. However, as Chapter 7 also indicated, residential attitudes had an important influence on the residential location choice in the first place, supporting the need to account for residential self-selection. Results indicated that car use is positively associated with the attitude toward open space and quietness (typical for respondents with suburban and rural residential preferences), and negatively associated with the attitude toward high accessibility (typical for respondents with an urban residential preference). Similar conclusions can be drawn related to the assessment of objective car availability and subjective general travel attitudes. Objective car availability was found to be a major influence of modal choices for leisure travel, whereas general travel attitudes only had a small indirect effect. Nevertheless, as mentioned before car availability in itself is influenced by these general travel attitudes to an important extent. Consequently, results should not only be controlled for self-selection related to residential location choices, but also with respect to other aspects such as car ownership (van Wee, 2009). Furthermore, important feedback mechanisms were found indicating that travel mode decisions on their turn influence travel attitudes. Cycling and walking seemed to enhance a pro-environment travel attitude and to prevent the development of a frequent car use attitude, whereas the opposite was found for car use. Moreover, the use of a particular travel mode likely encourages a positive attitude toward that travel mode. These findings underline that the relationship between land use and travel behaviour is not just a simple and straightforward one. Land use-travel behaviour interaction research should rather account for various issues such as (residential or travel) self-selection, the assessment of objective and subjective influences, and the distinction between direct, indirect and total effects due to complex interrelations among various variables.

9.3 Critical reflections and avenues for further research

The structural equation models in the different research papers all estimated some aspects of the suggested conceptual model of travel behaviour, especially with respect to the decision hierarchy and the underlying reasoned influences. In this section four issues are critically reviewed which may have been insufficiently addressed throughout the various empirical chapters. First, the main results of the previous section are reviewed in relation with some aspects of the research design of this dissertation. Second, some comments can be made with respect to the definition and measurement of the land use characteristics used in this dissertation. Third, the commonly used objective variables can be related to the newly introduced subjective variables. Finally, this section concludes with some remarks on how information on daily travel behaviour can be collected. Within each of these four issues several possibilities for further research exist.

9.3.1 Research design

The findings of the empirical chapters in this dissertation tend to confirm the assumption of many urban planners that spatial planning contributes to more sustainable travel patterns, and especially with respect to reducing car use in favour of public transport, cycling and walking. Even while controlling for issues such as self-selection and mediating variables such as car ownership, land use retained a significant and direct effect on modal choices. Compared to the various analyses on modal choice, other aspects such as travel distance and travel time are not that systematically analyzed in this dissertation. Nevertheless, these other travel aspects might also be sensitive to land use characteristics (Schwanen *et al*., 2002; Schwanen and Mokhtarian, 2005a; Maat and Timmermans, 2009b). Consequently, it might be interesting to examine this in more detail.

On the other hand, results can be interpreted in such a way that the land use-travel behaviour interaction is less obvious. For example, despite a significant and direct effect of land use patterns on modal choices, other variables such as car ownership (or car availability in a broader sense) and social status, are equally or even more important. Moreover, all analyses report relatively large amounts of explained variances in modal choices, but still leave room for model improvement. Sceptics thus argue that the observed relationship between land use and travel behaviour might be a spurious one, so that the land use effects on travel behaviour are rather caused by underlying unobserved phenomena. One of such underlying phenomena is self-selection. It is often related to residential location choice: households with a preference toward a specific way of travelling choose a residential neighbourhood that meets these travel preferences (Mokhtarian and Cao, 2008; Bohte *et al*., 2009). All empirical analyses in this dissertation have been controlled for this issue in one way or another. Models that specifically accounted for underlying subjective residential and travel attitudes obtained larger explained values compared to models that only included objective variables. However, self-selection is only one example of underlying unobserved phenomena. Another example refers to the effect of generalized costs on travel behaviour. Residing in an urban neighbourhood is often associated with lower car use and more public transport. It is possible that the urban land use pattern itself does not matter, but rather the shorter travel times and lower travel costs for public transport compared to the car that go along with such land use patterns (Crane and Crepeau, 1998; Badoe and Miller, 2000; Chen *et al*., 2008). Many (if not most) land use-travel behaviour interaction studies have, however, failed to simultaneously account for travel time and travel costs (Cervero, 2002; Rajamani *et al*., 2002; Chen *et al*., 2008). Omitting measures of generalized costs, however, might result in an overestimation of the land use influences on travel behaviour (Cervero, 2002). For example, common land use-travel behaviour interaction studies might indicate that someone is more likely to commute by public transport if his or her workplace is located nearby a railway station compared to someone whose workplace location is situated in the city's outskirts. However, it remains possible that the decision to commute by public transport is not influenced by higher densities or shorter distances to the city centre in the first place, but rather by differences in generalized costs between travel modes. Further research should be aware that the initially assumed effects on travel behaviour of land use characteristics such as density might only act as a proxy for underlying issues.

Furthermore, not all aspects of the suggested conceptual model of travel behaviour have been fully discussed in this dissertation. Especially two aspects have not been considered in relation to the land use-travel behaviour interaction: (i) the effect of unreasoned influences such as habits and impulsive decisions, and (ii) the influence of the social context of, e.g., family members, friends and colleagues. Both aspects have received more attention in activity-based research, but the link with land use tends to be neglected. For example, the first aspect of unreasoned influences relates to issues such as activity scheduling and rescheduling processes (Doherty *et al*., 2002; Joh *et al*., 2004, 2005; Doherty, 2005; Roorda and Ruiz, 2008). An activity schedule consists of activities with varying time horizons. Some activities are more a matter of routines or habits than of well-reasoned pre-planned behaviour, and occur every week (e.g., grocery shopping) or day (e.g., going to work). Other activities relate to events-of-the-day which might be pre-planned (e.g., a business meeting with colleagues) or rather impulsive (e.g., meeting friends after receiving their phone call). These types of activities have been studied with respect to their consequences on travel behaviour (e.g., Golob, 2000; Bowman and Ben-Akiva, 2001; Chung and Ahn, 2002; Ramadurai and Srinivisan, 2006; Chung *et al*., 2009), but the land use causes of these activity types tend to be neglected (e.g., Arentze *et al*., 2001). Another second neglected aspect is the influence of the social context on travel behaviour (Carrasco and Miller, 2006; Paéz and Scott, 2007; Arentze and Timmermans, 2008; Schwanen, 2008). Some activity-based travel studies argue that travel behaviour is insufficiently explained by commonly used SED characteristics such as age, gender and income. One must also consider the social network emerging from the interaction between families, friends and colleagues among other, and its characteristics such as network composition and physical distance between network members. However again, the influences of land use are generally ignored in this type of travel studies (e.g., Dugundji and Walker, 2005). To gain further insights into the interaction between land use and travel behaviour it would be worthwhile to pay more attention to these two so-far neglected aspects as well.

Thus far, further land use-travel behaviour interaction studies are suggested to account for underlying unobserved phenomena, the effect of unreasoned influences and the social context. Consequently, several relationships must be simultaneously considered. This kind of interdependency can best be analyzed using structural equations models (SEM), as illustrated by the various empirical chapters in this dissertation. However, the above mentioned influence of social network suggests a second type of interdependencies referring to a nested data structure. After all, individuals are nested within households, and households within residential neighbourhoods. Multilevel analysis can be used to study such a nested data structure, and it can be combined with SEM so that both kinds of interdependencies are accounted for. However, due to limitations in software packages and various modelling issues related to such complex models, only two-level SEMs have been estimated which consider complex travel behaviour of individuals within households (e.g., Chung *et al*., 2004; Kim *et al*., 2004). So far, the influence of the third level of the (residential) neighbourhood tends to be neglected.

Estimating a (multilevel) SEM implies a series of simultaneously estimated equations, or in other words, all components of the estimated model are concurrently and continually considered. However, dynamics might exits among various model components. For example, attitudes cause behaviour but once choices are made attitudes about the alternatives to choose from might change (e.g., Dobson *et al*., 1978; Lyon, 1984; Bohte *et al*., 2009). Similarly, long- and medium-term decisions on lifestyles, stage-of-life, residential location and car ownership can evolve over time (e.g., Levinson, 1997; Clark *et al*., 2003; Scheiner, 2006; Cao *et al*., 2007a, b). Studying these dynamics would therefore involve a longitudinal approach instead of a cross-sectional one, but this requires data from a panel survey or a retrospective survey.

Finally, common land use-travel behaviour interaction studies might come across as deterministic and not considering the underlying behavioural mechanisms (Handy, 1996). This dissertation therefore attempted to add social and socio-psychological insights related to lifestyles and attitudes respectively. An Internet survey provided the necessary data on lifestyles and attitudes. Data were then statistically and quantitatively processed in order to provide a first outline of the importance of these subjective influences compared to other influences, and to measure and explain the relationships between travel behaviour and various objective and subjective variables. It might be useful to complete these first attempts with more qualitative research in order to gain more precise insights into the causality among land use-travel behaviour interactions. This would enable us to analyse how the underlying behavioural mechanisms really operate. More qualitative-oriented research has been undertaken, e.g., attitudinal research with respect to modal choices (e.g., Train, 1986; Beirão and Sarsfield Cabral, 2007) but once again the link with land use tends to be neglected. Nevertheless, qualitative research might be useful in identifying those land use characteristics that really matters to travel decisions (Handy *et al*., 2002).

9.3.2 Measuring spatial variations

Two important aspects of land use patterns have been considered in this dissertation. First, land use characteristics such as density, diversity and accessibility were combined into broadly-defined and all-encompassing latent variables that capture the joint effect of land use patterns on travel behaviour (see Chapter 2 and 6-8). But similar land use characteristics have also been considered as individual aspects in order to accurately estimate which land use aspect influences which travel behaviour aspect (Chapter 4-5). Second, it is relevant to include land use characteristics at both trip origins and destinations. Chapter 5 illustrated this by considering land use characteristics of the residence as well as of the workplace, two important anchor points around which travel and activity patterns are organized (Cullen and Godson, 1975). With respect to this second aspect, it would also be useful to consider land use characteristics of other destinations such as schools (e.g., Ewing *et al*., 2004; McMillan, 2007), but also of the route along which someone travels (e.g., Landis *et al*., 2001; Muraleetharan and Hagiwara, 2007; Rodriguez *et al*., 2009).

This dissertation collected and measured land use characteristics such as density and diversity at the level of census tracts, the most fine-grained geographical scale at which statistical data is readily available in Flanders (Belgium). Such micro-scaled zones might approximate to the direct neighbourhood of someone's residence or workplace. However, it remains unclear whether the boundaries of these zones really coincide with the mental demarcation of its users (inhabitants, employees, etc.). Guo and Bhat (2007) pointed out the spatial definition of neighbourhood has received very little attention in the literature. Some people relate 'neighbourhood' to their own street, other people widen it to their residential quarter (Kearns and Parkinson, 2001). Meurs and Haaijer (2001) are one of the few who explained modal choices by considering land use characteristics of various geographical scales ranging from the dwelling and the street to the larger urban area. The influences of these geographical scales significantly differed by mode of transport and travel motive (more important for daily shopping than for commuting). The home and street characteristics were found more important for daily shopping and walking than for commuting and car use. This is no surprise since the average distance for daily shopping might be shorter than for commuting, and the area which can be covered on foot is much smaller and relates more to the immediate home environment (Boussauw *et al*., 2010). Consequently, depending on what travel motive and transport mode is investigated it remains important to collect and aggregate land use characteristics at the appropriate geographical scale. Land use characteristics at micro-scaled zones might be more relevant for transport modes with a small radius (e.g., walking and cycling) than for fast transport modes (e.g., car and train), and vice versa. Moreover, studies with macro-scaled aggregated land use characteristics tend to report higher correlations between land use and travel behaviour compared to similar empirical studies that use spatial information of micro-scaled zones (for an illustration, see, e.g., Zhang and Kukadia, 2005; Boussauw *et al*., 2010). It is a well-known problem that statistical results change with different sizes of areal units for which data are collected. This scale effect is known in statistics as one aspect of the modifiable areal unit problem (MAUP), and is intrinsic to any quantitative analysis of spatially aggregated data (Openshaw, 1984; Fotheringham and Wong, 1991). Another aspect of this problem is the zoning effect, describing the possible variation in results caused by the regrouping of the data into different configurations at the same scale. Empirical studies typically use zones such as census tracts, zip code areas or transport analysis zones (TAZ) as surrogates for neighbourhoods because data is readily available for such zones. Nevertheless, the use of such administrative boundaries might be troublesome. In many cases, city centres and high density areas are covered by more fine-meshed zones than the outskirts and less developed neighbourhoods. With the proliferation of geographical information systems (GIS), it is now possible to aggregate all data into a grid of squared cells apart from any pre-defined administrative boundaries. However, applications in land use-travel behaviour interaction remain scarce (e.g., Kockelman, 1997). For all these reasons, further research is needed on the definition of 'neighbourhoods'.

9.3.3 Measuring social variations

This dissertation (partly) responded to the need for a more behavioural approach in land use-travel behaviour interaction research (Handy, 1996) by accounting for differences in lifestyles, residential attitudes and travel attitudes. These subjective influences were included in addition to commonly used objective land use and SED characteristics. However, subjective and objective characteristics have not been balanced against each other. This would however offer two interesting avenues for further research.

First, the Internet survey contained statements on attitudes toward residential locations. Respondents had to indicate whether aspects such as traffic safety and quietness would influence a future residential location choice. A factor analysis revealed five underlying residential preferences, which where then related to the objective land use characteristics of the present residential location (see Chapters 7 and 8). The modelling results indicated that someone with a preference for open spaces and quietness is more likely to reside in less dense neighbourhoods, whereas the opposite holds for a positive attitude toward car alternatives and having access to opportunities. However, it does not offer insights in whether residential preferences are really matched with actual residential location choices. This might have important consequences for our understanding of the interaction between land use and travel behaviour (e.g., Schwanen and Mokhtarian, 2003; 2005a, b).

Second, the Internet survey also included questions on how people perceive their current residential location (contrary to the first point that refers to the desired residential location). This information has not been analyzed so far, but it might be interesting to know whether the perception of the current residence corresponds with the objectively measured land use characteristics. This would offer insights in the accuracy of someone's knowledge about their actual residential neighbourhood. For example, the distance between the residence and the nearest bus stop can objectively be measured but there are no guarantees that a short distance might also perceived as such. Especially non-public transport users might not be aware that a bus stop is within close distance of their residence.

9.3.4 Measuring daily travel behaviour

In this dissertation, information on daily travel behaviour have been deduced from the 2000-2001 Travel Behaviour Survey for Flanders and Ghent which consists of a two-day travel diary (Chapters 3-5) or the self-organized Internet survey (Chapters 6-8). Both types of survey provide without doubt a riches ness of travel information with sufficient observations to estimate complex structural equation models. Those surveys generally report, among others, modal choice, travel distance and travel time for each trip. These are all objective characteristics of travel patterns. Based on this, researchers can deduce, e.g., which spatial and social characteristics are associated with less long-distance trips and more cycling and walking. Or in other words, it becomes clear which land use patterns, which SED characteristics, and even which attitudes and lifestyles, contribute to more sustainable travel patterns. However, there are no indications that the same respondents perceive their travel behaviour as sustainable or otherwise. For example, depending on how they perceive their travel, some people might be convinced that their travelling is restricted although the objective figures state the opposite. This would prevent people from changing their travel behaviour in a sustainable way, especially people whose subjective mobility evaluation mismatches the objective travel figures. The Internet survey included some questions on attitudes toward travel modes and travel in general, but it did not ask about how people perceive their own travel behaviour. Therefore, it seems interesting to extend travel behaviour surveys with questions such as 'Do you feel you travel a lot?' and 'Could you have made this trip with another transport mode?' (Cao and Mokhtarian, 2005; Ory and Mokhtarian, 2009; Van Exel and Rietveld, 2009)

Furthermore, common travel behaviour surveys remain self-reported by the respondent with all its consequences. Short trips tend to be underreported due to survey fatigue, and data quality on aspects such as travel time and destination locations is generally poor. Recent tracking technologies such as mobile phones and GPS offer new possibilities of data collection (Turner, 1996; Asakura and Hato, 2004; Du and Aultman-Hall, 2007; Bohte and Maat, 2009). Participants no longer have to fill out long surveys, but instead are tracked with their mobile phones or other tracking devices. This might not only reduce the burden for people participating in research studies, but it also facilitates future research on aspects such as route choice which have been difficult to analyze so far.

9.4 Implications for spatial planning and transportation policies

Policy initiatives such as the New Urbanism Policy in the USA and the Compact City Policy in many European countries depart from the basic idea that residing in traditional neighbourhoods is associated with less car use and shorter travel distances. The study findings of this dissertation tend to support this, but the effect of land use can only be correctly understood if the complex interdependencies with other aspects such as mediating variables (i.e., car ownership) and subjective influences are accounted for.

Land use patterns, especially on a micro-scale, seem to have the expected influence on modal choices. Residing in high-density, mixed-use neighbourhoods close to a town or regional centre is significantly associated with less car use and more public transport and more walking and cycling. Modelling results also suggests that modal choice is rather a dichotomy between car use versus car alternatives, rather than between motorized versus non-motorized or individual versus public transport. In order to encourage the use of car alternatives spatial planning policies could, therefore, focus on (i) residential developments connected to city centres and town centres, (ii) densifying, and (iii) the provision of opportunities close to the residence. These three spatial principles might then be translated into more specific and advanced neighbourhood designs (Grava, 2003; Marshall, 2005).

Despite their significant influence land use characteristics are not always the main influences of modal choices. Other variables especially car ownership, or in a broader sense car availability, influence car use to a greater extent. Due to the interaction with car ownership, modal choices are indirectly rather than directly influenced by land use patterns. This might conveys the impression that car ownership acts as a proxy of land use patterns. However, this is only partly true. Car ownership replaces the influence of some but not all land use characteristics: especially density remains having an important direct influence on modal choices. This corresponds the findings of other studies (e.g., Chen *et al*., 2008) indicating density as one of the most important land use characteristics influencing travel behaviour. Consequently, spatial planning policies can influence modal choices in two ways: directly by measures of increasing density and diversity, but also indirectly through car ownership. Besides making cars directly more expensive to own and operate, i.e. through registration fees, gasoline taxes and road pricing, spatial planning policies might develop residential neighbourhood types that do not necessitate owning a car in order to participate in spatially separated activities.

The interaction with car ownership indicated that the effect of land use on modal choices is not as straightforward as initially expected. This also holds for the interaction with other travel behaviour aspects. For example, commuting times were found surprisingly longer in residential neighbourhoods with high-densities, mixed-use and easy access to public transportation. However, commuting times are not directly lengthened because of high density, more diversity and better public transport access, but rather because of lower car use which is also associated with this kind of residential neighbourhoods. Land use policies aiming at reducing commuting time by, e.g., densifying, could fail if the interaction with car use is ignored. After all, such land use policies are also likely to result in less car use and, consequently, more use of slower transport modes. The latter is without doubt also a positive consequence of these land use policies.

Spatial planning policies must not only focus on the spatial development of the residence which is an important origin for many trips, but also on destination locations such as the workplace. This corresponds to the results of the limited number of studies that also included workplace characteristics (e.g., Abreu e Silva *et al*., 2006; Chen *et al*., 2008; Maat and Timmermans, 2009a). Spatial planning policy in Flanders tries to match the activity's mobility profile with the accessibility profile of its location. For example, offices generating major traffic flows are concentrated at important nodes of public transport (e.g., central railway stations). This seems promising especially in order to discourage car use. However, other spatial principles such as densifying and workplace developments close to city centres and town centres might also be fruitful. Moreover, car ownership seems to be discouraged by parking difficulties at the workplace. This indicates that the medium-term decision on owning a car is not influenced by the residential land use characteristics, but probably by land use patterns at the workplace as well. Pursuing a restrictive parking policy at workplaces might therefore also discourage car ownership and car use.

Finally, despite some promising indications the suggested spatial planning policies seem not to work for all people. Policies such as densification might only be successful for a specific population group, and it remains important for policymakers to know what kind of people prefers what type of residential neighbourhood (Schwanen and Mokhtarian, 2007). The findings suggested that people will opt for residing in a (neo-) traditional or urban neighbourhood if this fits their non-traditional urban lifestyle or it enables them having easy access to services, shops, jobs, etc. Other population groups prefer lower-density living in suburban and rural neighbourhoods, despite all efforts of spatial planners. The three suggested spatial principles seem to be insufficiently for people with an active or a family-oriented lifestyle or for those who prefer the openness and quietness of the countryside. Among these population groups car use is higher to the detriment of the use of other car alternatives. This car use is even encouraged by a positive attitude toward cars. However, other possibilities for reducing car use can still be found, especially in transport planning policies. By underlining the positive consequences on the environment and, especially for public transport, the time-saving effects, the image of travelling by other transport modes than the car can be improved. Consequently, integrating spatial planning with transport planning seems appropriate. Moreover, policy must not only focus on designing and developing objective plans (e.g., a more sustainable lay-out of residential neighbourhoods) but should also be aware of its subjective implications (e.g., image building of travel modes).

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"Alles wat gezegd kan worden,
kan ook duidelijk gezegd worden.."

Ludwig Wittgenstein (1889-1951)

SAMENVATTING

Inleiding

Zoals in andere landen neemt ook in België de vraag naar mobiliteit alsmaar toe: elk jaar worden langere afstanden afgelegd en groeit het autobezit gestaag. Een verhoogde mobiliteit bevordert zonder twijfel de sociale en economische ontwikkeling, maar het veroorzaakt evenzeer allerlei problemen zoals congestie, luchtverontreiniging, lawaaioverlast en verkeersonveiligheid. Bijgevolg zoeken beleidsmakers en politici naar gepaste maatregelen en acties. Na het jarenlang uitbreiden van het aanbod aan transportinfrastructuur verschoof vanaf de jaren '90 van vorige eeuw de politieke aandacht naar het beheersen van de mobiliteitsvraag waarbij men vooral het afgeleide karakter van mobiliteit benadrukte. Meestal verplaatst men zich niet voor het plezier, maar om te kunnen deelnemen aan activiteiten zoals wonen, werken, winkelen en recreëren. In België en Vlaanderen zijn deze activiteiten en functies over de jaren heen alsmaar verder van elkaar gelokaliseerd waardoor het logisch is dat men jaarlijks grotere afstanden aflegt en frequenter de auto gebruikt. Daarom lijkt het aannemelijk dat een ruimtelijke ordening waarbij het wonen mogelijk is nabij diverse andere activiteiten en functies, bijdraagt tot een duurzame mobiliteit. Verondersteld wordt dat hogere woondichtheden en een betere functiemenging het autogebruik kan verminderen. De kans is dan immers groter dat activiteiten en functies op wandel- of fietsafstand gelegen zijn, terwijl hogere dichtheden tevens het draagvlak voor het openbaar vervoer vergroten. Sinds 1997 zijn deze assumpties met de goedkeuring van het Ruimtelijk Structuurplan Vlaanderen (RSV) vervat in het ruimtelijk beleid in Vlaanderen. Het RSV biedt een ruimtelijke visie welke gebaseerd is op een aantal ruimtelijke principes. Eén van deze principes is de 'gedeconcentreerde bundeling' wat staat voor het concentreren van de groei van het wonen, het werken en de andere maatschappelijke activiteiten en functies in de steden en kernen, maar tevens rekening houdend met het bestaande spreidingspatroon en met de gespreid voorkomende dynamiek van de activiteiten en functies in Vlaanderen (Ministerie van de Vlaamse Gemeenschap, 1998). Dit principe sluit naadloos aan bij het 'Compacte Stad' beleid in andere Europese landen en het 'New Urbanism' in de VS. De politieke interesse voor de idee dat verdichting en functiemenging bijdragen tot een vermindering van het autogebruik heeft het wetenschappelijk onderzoek zonder meer gestimuleerd. Vandaag de dag tracht een groot aantal empirische studies de relatie tussen ruimtelijke ordening en verplaatsingsgedrag te achterhalen. Daarbij wordt vaak het effect van ruimtelijke kenmerken zoals dichtheid, diversiteit, design en bereikbaarheid gemeten op een specifiek aspect van verplaatsingsgedrag zoals het aantal verplaatsingen, de verplaatsingsafstand en de vervoerswijzekeuze. Toch blijft het moeilijk om een eenduidig antwoord te formuleren op de vraag of het ruimtelijke ordening werkelijk het verplaatsingsgedrag beïnvloedt (Verroen *et al*., 2000). Hiervoor kunnen verschillende redenen aangehaald worden. Eén daarvan is het feit dat het onderzoek tot dusver vooral in de VS gebeurde. De resultaten van deze studies kunnen echter niet zomaar doorgetrokken worden naar een Europese context. Tussen Noord-Amerikaanse en Europese steden bestaan immers belangrijke verschillen in o.a. patronen van verstedelijking, systemen van ruimtelijke ordening en planning, en culturele factoren (Simma and Axhausen, 2001; Martens *et al*., 2002; Schwanen, 2002). Daarenboven is de relatie tussen ruimtelijke ordening en verplaatsingsgedrag veel complexer dan aanvankelijk gedacht. Het gaat niet zozeer om een directe en rechtstreekse relatie van objectieve ruimtelijke kenmerken op het dagelijkse verplaatsingsgedrag, maar men dient tevens rekening te houden met beslissingen over leefstijlen op lange termijn en residentiële woonplaatskeuze en autobezit op middellange termijn. Deze tussenliggende keuzes zijn deels gebaseerd op subjectieve socio-pyschologische invloeden zoals attitudes en voorkeuren (Kitamura *et al*., 1997; Bagley and Mokhtarian, 2002; van Wee *et al.*, 2002; Handy *et al*., 2005). Bovendien kan een studie van het verplaatsingsgedrag niet herleid worden tot de analyse van één welbepaald aspect zoals autobezit, verplaatsingsafstand of vervoerswijzekeuze zonder de interactie tussen de verschillende verplaatsingsaspecten te beschouwen (Maat and Timmermans, 2006; Susilo and Maat, 2007; Chen *et al*., 2008). Dit doctoraat beoogt dan ook om inzicht te verschaffen in de invloed van ruimtelijke ordening op de complexiteit van het verplaatsingsgedrag in Vlaanderen (België), rekening houdend met subjectieve kenmerken zoals attitudes en leefstijlen. Deze algemene doelstelling wordt verder uitgewerkt in zeven hoofdstukken die gebaseerd zijn op artikelen die al dan niet gepubliceerd zijn in internationale wetenschappelijke tijdschriften. Elk artikel bestudeert één van de volgende specifieke onderzoeksvragen:

1. *Welk theoretisch kader biedt inzicht in de relatie tussen dagelijks verplaatsingsgedrag en ruimtelijke ordening, rekening houdend met objectieve socio-economische en demografische invloeden alsook subjectieve socio-psychologische invloeden?*
2. *Hoe wordt het verplaatsingsgedrag beïnvloed door ruimtelijke ordening en objectieve socio-economische en demografische kenmerken verwijzend naar sociale status en huishoudelijke verantwoordelijkheid? Indien de invloed van ruimtelijke ordening belangrijk is, wat is de gezamenlijke invloed van verschillende kenmerken van ruimtelijke ordening op verplaatsingsgedrag?*
3. *Wat is de rol van autobezit in onderzoek naar de interactie tussen ruimtelijke ordening en vervoerswijzekeuze?*
4. *Moet ketencomplexiteit al dan niet beschouwd worden als een te verklaren endogene variabele?*
5. *Hoe meet men leefstijlen en hoe kunnen leefstijlen opgenomen worden in het onderzoek naar de interactie tussen ruimtelijke ordening en vervoerswijzekeuze?*

6. *Hoe zijn attitudes gerelateerd aan middellangetermijnbeslissingen over residentiële locatie en autobezit?*
7. *Wordt vervoerswijzekeuze beïnvloed door objectieve ruimtelijke, socio-economische en demografische kenmerken of evenzeer door subjectieve leefstijlen, mobiliteitsattitudes en residentiële attitudes?*

Het is duidelijk dat een studie van deze onderzoeksvragen niet mogelijk is vanuit één enkele theoretische achtergrond. Door het combineren van inzichten vanuit diverse theoretische kaders wordt in de eerste fase van dit doctoraatsonderzoek een conceptueel model opgesteld dat verplaatsingsgedrag verklaart (zie Hoofdstuk 2). In een volgende fase wordt dit conceptueel model geoperationaliseerd door het schatten van diverse soorten structurele vergelijkingsmodellen. Deze empirische analyses zijn gebaseerd op data van het Onderzoek Verplaatsingsgedrag, uitgevoerd in 2000-2001 voor Vlaanderen en Gent. In tegenstelling tot Hoofdstuk 3, dat een initiële verkenning is van de interactie tussen ruimtelijke ordening en verplaatsingsgedrag op basis van deze gegevens, zijn de volgende hoofdstukken meer specifieke analyses van vervoerswijzekeuze. Hoofdstuk 4 beschrijft hoe ruimtelijke ordening gerelateerd is aan autobezit en autogebruik, terwijl Hoofdstuk 5 nog stap verder gaat en tevens de interactie met verplaatsingsafstand, reistijd en ketencomplexiteit bestudeert. Hoofdstukken 6 tot 8 koppelen vervoerswijzekeuze aan langetermijnbeslissingen over leefstijlen en de onderliggende residentiële en mobiliteitsattitudes. Dergelijke subjectieve informatie is echter niet zomaar beschikbaar in de gebruikelijke mobiliteitsenquêtes. Daarom werd tussen mei 2007 en oktober 2007 een bijkomende internetenquête uitgevoerd. In wat volgt worden de onderzoeksvragen en de resultaten van het onderzoek samengevat en toegelicht.

Conclusies

Onderzoek naar de interactie tussen ruimtelijke ordening en verplaatsingsgedrag dateert van de jaren ’50 en ’60 van vorige eeuw (vb., Mitchell en Rapkin, 1954; Marble, 1959; Levinson en Wynn, 1963; Hurst, 1969) en sindsdien is onze kennis hierover alsmaar uitgebreid. Recent literatuuronderzoek zoals dat van Bartholomew en Ewing (2009) en Handy (2002, 2005) tonen aan dat empirisch onderzoek niet alleen ruimtelijke variabelen opneemt ter verklaring van verplaatsingsgedrag, maar tevens controleert voor socio-economische en demografische (SED) verschillen alsook, zij het in mindere mate, voor socio-psychologische verschillen tussen individuen en gezinnen. Hoewel deze empirische studies geïnspireerd zijn door een welbepaald theoretisch kader zoals een micro-economische (vb. Crane, 1996; Bhat en Guo, 2007) of een activiteitengebaseerde benadering (vb. Maat en Arentze, 2003; Naess, 2006; Chen en McKnight, 2007) verwijst geen enkele studie naar een breder (theoretisch of) conceptueel kader waarbij de interactie tussen ruimtelijke ordening en verplaatsingsgedrag vanuit verschillende standpunten bekeken wordt. Hoofdstuk 2, dat aanvaard is voor publicatie in *Transport Reviews*, tracht een dergelijk conceptueel kader te schetsen door het combineren van verschillende theorieën uit voornamelijk de transportgeografie en de sociale psychologie. Eerst en vooral wordt het dagelijkse verplaatsingsgedrag beschouwd binnen een hiërarchie van beslissingen gaande van kortetermijnbeslissingen over activiteiten, locatiebeslissingen op middellangetermijn tot leefstijlbeslissingen op langetermijn. Het merendeel van de verplaatsingen gebeurt immers met een duidelijk doel voor ogen, namelijk het deelnemen aan ruimtelijk gescheiden activiteiten zoals wonen, werken, winkelen en recreëren. Bijgevolg is het logisch om te veronderstellen dat het verplaatsingsgedrag rechtstreeks beïnvloed wordt door de ruimtelijke en temporele kenmerken van het activiteitenpatronen (Hägerstrand, 1970; Chapin, 1974; Cullen and Godson, 1975). Het is echter mogelijk dat de behoefte om deel te nemen aan activiteiten niet overeenstemt met de huidige beschikbare keuzemogelijkheden waardoor bepaalde aanpassingen zich opdringen. Deze aanpassingen kunnen kleine veranderingen in verplaatsingsgedrag of activiteitenpatronen inhouden, maar het kan tevens gaan om meer ingrijpende beslissingen zoals verhuizen naar een andere buurt (Fried *et al*., 1977; Cullen, 1978). Tenslotte wordt de invloed van leefstijlbeslissingen op lange termijn beschouwd. Het begrip 'leefstijl' verwijst naar de onderliggende opinies en motivaties van gedrag waarmee men zijn of haar sociale positie tracht te verduidelijken aan anderen (Munters, 1992). Dagelijkse verplaatsingen, activiteitenpatronen en woonplaatskeuze zijn enkele gedragspatronen die leefstijlen weerspiegelen. Vervolgens wordt deze beslissingshiërarchie beschouwd als het resultaat van een afweging tussen beredeneerde en niet-beredeneerde invloeden. Indien deze afweging genegeerd wordt, dan krijgt men de indruk enkel de objectieve gedragspatronen te bestuderen en niet de onderliggende subjectieve invloeden. Enerzijds wordt gedrag vaak beschouwd als het resultaat van rationele keuzes die gebaseerd zijn op beredeneerde invloeden zoals percepties, attitudes en voorkeuren (Fishbein and Ajzen, 1972; Fishbein, 1980; Ajzen, 1991). Anderzijds zijn personen niet ten alle tijden bewust van hun gedrag (Simon, 1950; Pred, 1967). Bijgevolg moeten beredeneerde invloeden afgewogen worden tegenover niet-beredeneerde invloeden zoals gewoonten en impulsiviteit (Triandis, 1977; Ronis *et al*., 1989). Tot dusver zijn deze beslissingshiërarchie en de onderliggende beredeneerde en niet-beredeneerde invloeden beschreven vanuit het individu. Dit individu maakt echter deel uit van een sociale omgeving van familie, vrienden en collega's (Banudra, 1986) alsook van een fysieke omgeving die ruimer is dan de eigen woonplaats. Daarom moet het conceptuele model rekening houden met het geheel van (i) een individuele context, (ii) een sociale context, en (iii) een ruimtelijke context. In de volgende hoofdstukken worden delen van dit conceptueel model van verplaatsingsgedrag empirisch getest. Hiervoor heeft men niet alleen geschikte data nodig, maar ook een methodologie die rekening houdt met de complexe relaties tussen de verschillende componenten van het conceptueel model. In structurele vergelijkingsmodellen kan een welbepaalde variabele een effect hebben op andere variabelen en tegelijkertijd nog door andere variabelen beïnvloed worden. Daarom wordt deze methodologie in de volgende hoofdstukken gebruikt.

Hoofdstuk 3, dat verschenen is in *Transportation Planning and Technology*, is een eerste analyse van de relatie tussen ruimtelijke ordening en verplaatsingsgedrag in Vlaanderen. In tegenstelling tot de meeste empirische studies die het effect van verscheidene ruimtelijke kenmerken afzonderlijk van elkaar nagaan, wordt in dit derde hoofdstuk het gecombineerde effect van al deze ruimtelijke kenmerken samen geschat. Dit gebeurt niet door een categorisering van buurten op een schaal van stedelijk tot landelijk waarbij heel wat ruimtelijke informatie verloren zou gaan, maar wel door het construeren van latente variabelen die de multidimensionaliteit van ruimtelijke ordening weerspiegelen. De interpretatie van de resultaten van een structureel vergelijkingsmodel met latente variabelen verduidelijkt dat het wonen in een stedelijke omgeving geassocieerd is met minder complexe verplaatsingspatronen die gekenmerkt worden door minder verplaatsingen, en kortere verplaatsingsafstanden en reistijden. Ondanks een significante ruimtelijke invloed in dergelijke buurten blijkt het verplaatsingsgedrag voornamelijk beïnvloed door de sociale status. Personen met een hogere sociale status (d.w.z. hogere opleiding, fulltime tewerkstelling, belangrijke jobstatus, hoog inkomen, hoger autobezit) zijn meer geneigd om zich op een complexe manier te verplaatsen dan personen uit lagere statusgroepen. Daarenboven benadrukt dit hoofdstuk dat een analyse van enkel directe effecten misleidend kan zijn. Door interacties tussen SED kenmerken en ruimtelijke kenmerken ontstaan indirecte effecten op het verplaatsingsgedrag die even belangrijk kunnen zijn. Bijvoorbeeld, de rol binnen het huishouden heeft een significante directe invloed op het verplaatsingsgedrag: personen met meer huishoudelijke verantwoordelijkheid verplaatsen zich minder frequent en over kortere afstanden en tijden. Maar dergelijke personen blijken tevens een hogere sociale status te bezitten, zodat hier toch ook meer complexe verplaatsingspatronen mogelijk zijn. De aanwezigheid van een tegengesteld direct en indirect effect kan wijzen op het bestaan van verschillende groepen respondenten met dezelfde huishoudelijke rol (bijvoorbeeld oudere en minder actieve respondenten tegenover oudere en toch fulltime tewerkgestelde respondenten). Daarenboven is dit indirecte effect van groter belang dan het directe effect. Gewoonlijk gebruikte technieken zoals regressieanalyse schatten enkel het directe effect op verplaatsingsgedrag waardoor het belang van indirecte effecten gedurende lange tijd genegeerd werd in onderzoek naar de interactie tussen ruimtelijke ordening en verplaatsingsgedrag. De volgende hoofdstukken gebruiken stelselmatig structurele vergelijkingsmodellen en besteden telkens aandacht aan het onderscheid tussen directe, indirecte en totale effecten.

Een specifieke analyse van de tweeledige rol van autobezit is beschreven in Hoofdstuk 4, dat is verschenen in het *Journal of Transport Geography*. De meeste studies beschouwen autobezit als één van de vele verklarende variabelen van vervoerswijzekeuze, maar autobezit op zich wordt ook beïnvloed door andere variabelen zoals ruimtelijke ordening en SED kenmerken. Aangezien autobezit fundamenteel gekoppeld is aan langeretermijnbeslissingen met betrekking tot woon- en werkplaats enerzijds en aan kortetermijnbeslissingen over verplaatsingsgedrag anderzijds (Ben-Akiva en Atherton, 1977; Scott en Axhausen, 2006) is het nuttig om beide benaderingen te combineren en om autobezit als een intermediaire variabele te beschouwen die de relatie tussen ruimtelijke ordening en verplaatsingsgedrag intermedieert. Slechts een beperkt aantal studies hebben dit reeds gedaan (vb. Simma en Axhausen, 2003; Scheiner en Holz-Rau, 2007), maar dan eerder vanuit een pragmatisch standpunt waarbij de tweeledige rol van autobezit zonder verdere vragen werd aangenomen. Geen enkele studie bespreekt bijgevolg grondig de gevolgen van het eventueel negeren van deze tweeledige rol. Het vierde hoofdstuk doet dit wel door het vergelijken van de resultaten van een model waarin autobezit de relatie tussen ruimtelijke ordening en autogebruik intermedieert met een model dat hiermee geen rekening houdt. De resultaten van beide modellen bevestigen de invloed van ruimtelijke ordening op zowel autobezit als autogebruik. Een hogere mate van autobezit en meer autogebruik worden geassocieerd met wonen in een suburbane of een landelijke omgeving, in dit hoofdstuk gekenmerkt door lagere dichtheden maar ook door meer ruimtelijke diversiteit, betere autobereikbaarheid en verder afgelegen van het stads- of dorpscentrum. Een vergelijking van beide modellen verduidelijkt echter dat het negeren van de tweeledige rol van autobezit voornamelijk leidt tot een overwaardering van de invloed van de ruimtelijke ordening op het autogebruik. Anderzijds zijn bepaalde ruimtelijke kenmerken van de woonplaats op zich niet significant, terwijl volgens het volledige model wel degelijk een significant maar klein effect bestaat. De tweeledige rol van autobezit wordt daarenboven bevestigd door de interpretatie van de resultaten van de modellen. Bijvoorbeeld, het effect van inkomen op autogebruik gebeurt niet zozeer op een directe manier, zoals nochtans door de meeste studies wordt aangenomen, maar bestaat eerder in de interactie met autobezit. Om al deze redenen beschouwt elk van de volgende vier hoofdstukken de tweeledige rol van autobezit.

Net zoals autobezit kan men ketencomplexiteit als een intermediaire variabele beschouwen die beïnvloed wordt door ruimtelijke ordening en tegelijkertijd zelf het verplaatsingsgedrag beïnvloedt. Hoofdstuk 5, ingediend voor publicatie in *Transportation*, verduidelijkt dat het negeren van de tweeledige rol van ketencomplexiteit echter niet resulteert in een vertekening van de resultaten. Ketencomplexiteit is eerder een variabele die buiten het model staat en de verschillende soorten ketens vooraf definieert. Niettemin blijft het mogelijk dat de invloed van ruimtelijke ordening op woon-werkverkeer significant verschillend is voor diverse soorten ketens. Het vijfde hoofdstuk test daarom de assumptie dat de invloed van ruimtelijke ordening groter is voor pendelverplaatsingen in eenvoudige ketens (thuis-werk-thuis) dan voor complexe ketens waarin de werkverplaatsing gecombineerd wordt met andere verplaatsingen. Het is immers mogelijk dat de beslissing om te pendelen volgens een eenvoudige keten beïnvloed wordt door de ruimtelijke kenmerken van enkel de werkplaats, terwijl voor complexe ketens de ruimtelijke kenmerken van alle stopplaatsen in beschouwing moeten genomen worden. Deze assumptie blijkt gedeeltelijk te kloppen. De ruimtelijke invloed van de werkplaats is inderdaad van grotere invloed op reistijden in eenvoudige woon-werkketens dan in complexe werkketens. Echter, het omgekeerde geldt voor autogebruik: werklocaties in nabijheid van een treinstation, met een slechte autobereikbaarheid en waar het moeilijk parkeren is ontmoedigen het autogebruik voor woon-werkverplaatsingen, zelfs indien deze verplaatsing gecombineerd wordt met andere verplaatsingen. Dergelijke werklocaties zijn mogelijk ook gekenmerkt door hogere dichtheden en een betere functiemenging waardoor andere activiteiten zoals winkelen en recreatie in de nabijheid van de werkplaats uitgevoerd kunnen worden. Het pendelen met de auto is in dergelijke situaties niet altijd noodzakelijk. Daarenboven blijkt dat het negeren van de verschillende soorten ketens leidt tot een onderschatting van de effecten van ruimtelijke ordening op pendelgedrag, en dit vooral voor het pendelen in eenvoudige woon-werkketens.

In de voorgaande hoofdstukken wordt de relatie tussen ruimtelijke ordening en verplaatsingsgedrag geschat aan de hand van objectieve variabelen. Daarenboven controleert elke analyse of het effect van ruimtelijke ordening wel degelijk een causaal effect is. Het is immers mogelijk dat de zogenaamde relatie tussen ruimtelijke ordening en verplaatsingsgedrag niet zozeer het gevolg is van ruimtelijke kenmerken zoals dichtheid en ruimtelijke diversiteit op zich, maar eerder van de onderliggende voorkeuren om in een dergelijke omgeving te wonen. Elk van de voorgaande hoofdstukken houdt hiermee rekening door het effect van SED kenmerken zoals inkomen of sociale status op de ruimtelijke kenmerken van de woonplaats op te nemen in de modellen. Echter, dit is slechts een gedeeltelijke oplossing. Binnen socio-economisch en demografisch homogene groepen bestaan nog steeds verschillen in gedrag (van Wee, 2002) wat erop wijst dat subjectieve variabelen in rekening gebracht dienen te worden. Een eerste voorbeeld van dergelijke subjectieve variabelen zijn leefstijlen. Leefstijlen worden beschouwd als algemene oriëntaties tegenover thema's zoals vrije tijd, werken, familie, consumptie en wonen (Salomon en Ben-Akiva, 1983; Bootsma *et al*., 1993). Deze oriëntaties zijn eigen aan het individu en bijgevolg moeilijk observeerbaar door een buitenstaander. Echter, de interne oriëntaties komen tot uiting in gedragspatronen die de sociale status van een individu weerspiegelen (Weber, 1972; Bourdieu, 1984; Ganzeboom, 1988; Munters, 1992). Door afnemende sociale controle en toenemende individualisering (Ferge, 1972; Bootsma *et al*., 1993) is men relatief vrij om een eigen leefstijl te ontwikkelen en deze te uiten in de keuze uit bijvoorbeeld diverse recreatieactiviteiten (naar de opera gaan of thuis cocoonen) of woningtypes (traditionele fermette of moderne villa). Hoewel de term leefstijl veelvuldig gebruikt wordt, gebeurt dit eerder op een pragmatische manier dan in overeenstemming met de hiervoor genoemde theoretische beschouwingen. Vaak wordt een clusteranalyse uitgevoerd op een veelvoud van variabelen waarbij elke cluster verwijst naar een andere leefstijl. De resultaten van dergelijke analyses zijn echter zeer afhankelijk van de data-input. Daarenboven combineren sommige studies objectieve SED kenmerken tot variabelen zoals levensfase of gezinssamenstelling welke als benadering van leefstijlen gebruikt worden in verdere analyses. Leefstijlen zijn dan wel gelinkt aan levensfase of gezinssamenstelling, maar het mag duidelijk zijn dat dit totaal verschillende concepten zijn. Hoofdstuk 6, ingediend voor publicatie in *Transportation Research A*, bespreekt bijgevolg de definitie en de invloed van leefstijlen op vervoerswijzekeuze voor vrijetijdsverplaatsingen. Informatie over leefstijlen werd verzameld in een specifieke Internetenquête over mobiliteit en leefstijlen. In overeenstemming met de definitie van leefstijlen bevatte deze enquête vragen over verschillende aspecten van vrijetijdsbesteding en de afweging tussen werk en gezin. Daarenboven waren de antwoorden waaruit de respondent kon kiezen zodanig opgebouwd dat ze de dimensies (zijnde economisch, cultureel, levensfase) weerspiegelden die de onderliggende oriëntaties beïnvloeden (Ganzeboom, 1988). Op basis van een tweedeorde-factoranalyse werden vijf leefstijlen gevonden: (i) cultuurliefhebber, (ii) vrienden en trends, (iii) thuisgeoriënteerde maar actieve familie, (iv) lowbudget en actief/creatief, (v) thuisgeoriënteerd traditionele familie. Het autogebruik blijkt hoger te zijn bij respondenten met een actieve leefstijl. De auto laat immers toe om op een flexibele manier activiteiten zoals sporten en familieactiviteiten te combineren. Het gebruik van openbaar vervoer, wandelen en fietsen is daarentegen geassocieerd met een lowbudget of een niet-traditionele leefstijl. Autogebruik is mogelijks beperkt door budgetbeperkingen of een niet-traditionele levenswijze. De invloed van leefstijlen is echter relatief klein in vergelijking met andere variabele zoals ruimtelijke kenmerken van de woonplaats (vooral voor 'fun shopping') en voornamelijk autobeschikbaarheid. Hun invloed vertoont echter een duidelijk patroon en blijft significant. Dit duidt op het bestaan van belangrijke subjectieve verschillen waardoor studies zich niet enkel mogen focussen op het verklaren van verplaatsingsgedrag aan de hand van objectieve kenmerken zoals geslacht, inkomen en leeftijd.

De voorgaande vier hoofdstukken beschouwen telkens een beslissingshiërarchie van verplaatsingen en activiteiten op korte termijn, woonplaatskeuze en autobezit op middellange termijn, en eventueel leefstijlen op lange termijn. Tot dusver zijn de onderliggende invloeden, zoals opgenomen in het conceptueel model van het tweede hoofdstuk, niet beschouwd. Attitudes zijn een eerste voorbeeld van dergelijke onderliggende invloeden. Binnen de sociale psychologie bestaat een onderzoekstraditie op het gebied van attitudes (voor een overzicht, zie vb. Fishbein, 1967; Kraus, 1995), maar ook binnen mobiliteitsstudies wordt het onderzoek naar attitudes alsmaar belangrijker (Parkany *et al*., 2004). De meeste mobiliteitsstudies onderzoeken attitudes direct in relatie tot verplaatsingsgedrag. Zo tracht men bijvoorbeeld te achterhalen wat de perceptie van het openbaar vervoer bepaalt of hoe men aspecten zoals tijdsbesparing, flexibiliteit en milieu-impact evalueert voor verschillende vervoerswijzen. Men vergeet echter de link met beslissingen op middellange termijn over woonplaatskeuze en autobezit, en de onderliggende residentiële attitudes en mobiliteitsattitudes. Hoofdstuk 7, ingediend voor publicatie in *Transport Policy*, beschouwt daarom de invloed van attitudes op deze middellangetermijnbeslissingen. Door de combinatie met andere kenmerken zoals bezit van een rijbewijs of een openbaarvervoer abonnement werd de term 'autobezit' op een iets ruimere manier gedefinieerd als 'autobeschikbaarheid'. Een positieve attitude tegenover de auto doet de autobeschikbaarheid toenemen, terwijl het omgekeerde geldt voor een pro-milieu attitude. Samen met de objectieve levensfase zijn deze attitudes de voornaamste variabelen die de autobeschikbaarheid beïnvloeden. Autobeschikbaarheid kan op zijn beurt attitudes beïnvloeden. Zo blijkt het beschikbaar zijn van verschillende auto's de attitude van frequent autogebruiker te versterken en een gefrustreerde mobiliteitsattitude te verminderen. De invloed van de objectieve ruimtelijke variabelen blijft significant aanwezig. Auto's zijn minder beschikbaar in buurten met een hoge dichtheid en een goede lokale bereikbaarheid, alsook in buurten dichtbij een regionaal centrum gelegen. Niettemin wordt de beslissing om in een dergelijke buurt te wonen tevens beïnvloed door onderliggende residentiële attitudes en mobiliteitsattitudes. Wonen in een suburbane of landelijke omgeving is vooral geassocieerd met een positieve waardering van de open ruimte en stilte. Respondenten met een pro-milieu attitude en een voorkeur voor alternatieven voor de auto alsook voor verscheidene voorzieningen op buurtniveau blijken eerder in een stedelijke omgeving te wonen. Dit wijst tevens op het voorkomen van residentiële zelfselectie. In stedelijke omgevingen gebruikt men minder de auto maar dit is niet zozeer omwille van de ruimtelijke kenmerken an sich maar eerder wegens de voorkeur om te wonen in een dergelijke omgeving die toegang biedt tot alternatieven voor de auto. Net zoals bij autobeschikbaarheid zijn deze subjectieve attitudes belangrijke invloedsvariabelen voor de woonplaatskeuze. Deze bevindingen illustreren dat residentiële attitudes en mobiliteitsattitudes belangrijke verklarende variabelen zijn voor zowel woonplaatskeuze als autobeschikbaarheid.

Hoofdstuk 8, ingediend in publicatie in *Environment and Planning A*, bouwt verder op de bevindingen uit het vorige hoofdstuk en beschouwt de invloed van objectieve en subjectieve variabelen op vervoerswijzekeuze voor vrijetijdsverplaatsingen. Modellen die enkel objectieve variabelen gebruiken hebben een goede model fit, maar de verklaarde variantie in vervoerswijzekeuze is aanzienlijk lager. Subjectieve variabelen zoals leefstijlen en attitudes verklaren een belangrijk deel van deze variantie. Daarenboven leidt het negeren van dergelijke subjectieve variabelen tot een onderschatting van de ruimtelijke effecten op vervoerswijzekeuze. Het blijft echter moeilijk om te achterhalen of eerder objectieve dan wel subjectieve variabelen van belang zijn. Bijvoorbeeld, op het eerste zicht lijkt vervoerswijzekeuze vooral beïnvloed door objectieve ruimtelijke kenmerken. Maar het voorgaande hoofdstuk verduidelijkte dat in de eerste plaats subjectieve residentiële attitudes een belangrijke rol spelen in de keuze van een woonplaats, wat tevens wijst op het voorkomen van residentiële zelfselectie. De afweging van de effecten van objectieve autobeschikbaarheid tegenover subjectieve mobiliteitsattitudes leidt tot gelijkaardige conclusies. Het beschikbaar hebben van een auto is een belangrijke verklaring voor het al dan niet gebruiken van deze auto terwijl de mobiliteitsattitudes slechts een klein indirect effect hebben op vervoerswijzekeuze. Echter, autobeschikbaarheid op zich is grotendeels bepaald door deze mobiliteitsattitudes. Zelfselectie bestaat dus niet alleen ten opzichte van woonplaatskeuze maar ook ten opzichte van andere aspecten zoals autobezit (van Wee, 2009). De relatie tussen ruimtelijke ordening en verplaatsingsgedrag is bijgevolg niet zo eenvoudig en eenduidig. Onderzoek naar de interactie tussen ruimtelijke ordening en verplaatsingsgedrag dient rekening te houden met verschillende aspecten zoals (residentiële of mobiliteitsgerelateerde) zelfselectie, de afweging tussen objectieve en subjectieve invloeden, en het onderscheid tussen directe, indirecte en totale effecten als gevolg van de complexe interrelaties tussen de verschillende variabelen.

Aanbevelingen voor verder onderzoek

Hoewel dit doctoraatsonderzoek enkele nieuwe inzichten verschaft in de relatie tussen ruimtelijke ordening en verplaatsingsgedrag, kunnen tevens een aantal suggesties voor toekomstig onderzoek worden gegeven. Hieronder worden slechts enkele suggesties beschreven.

De resultaten van de empirische analyses binnen dit doctoraatsonderzoek lijken de assumptie te bevestigen dat ruimtelijke ordening kan bijdragen tot een duurzaam verplaatsingsgedrag, en vooral tot een reductie van het autogebruik ten voordele van het openbaar vervoer, wandelen en fietsen. Ruimtelijke ordening heeft steeds een directe invloed op vervoerswijzekeuze, zelfs indien men controleert voor zelfselectie en intermediaire variabelen zoals autobezit. Andere aspecten van verplaatsingsgedrag zoals verplaatsingsafstand en reistijd zijn in vergelijking niet even grondig onderzocht. Daarenboven komen niet alle aspecten van het conceptueel model, zoals beschreven in het tweede hoofdstuk, even uitgebreid aan bod. De analyses focussen vooral op de beslissingshiërarchie en de onderliggende beredeneerde invloeden, terwijl het effect van niet-beredeneerde invloeden zoals gewoonten en impulsiviteit alsook de sociale context waarbinnen verplaatsingsgedrag plaatsvindt niet belicht werden. Interdependenties zijn niet enkel het gevolg van het simultaan optreden van relaties tussen verscheidene aspecten, maar tevens van een genestelde datastructuur. Zo maken individuen deel uit van een gezin, een gezin woont in een bepaalde buurt, enzovoort. Een multilevel-analyse kan een dergelijke genestelde datastructuur bestuderen. Bovendien kan deze gecombineerd worden met structurele vergelijkingsmodellen zodat rekening gehouden wordt met beide soorten interdependenties.

Ruimtelijke kenmerken zoals dichtheid en ruimtelijke diversiteit zijn verzameld op het niveau van statistische sectoren, wat overeenkomt met het niveau waarop de meest gedetailleerde ruimtelijke data momenteel beschikbaar is in België en Vlaanderen. Men kan veronderstellen dat dergelijke zones kenmerken van de onmiddellijke woonomgeving kunnen voorstellen. Echter, er is weinig geweten over wat personen percipiëren als hun 'buurt'. Voor sommige mensen is dit de straat waarin ze wonen, voor andere het bouwblok of een groter stadsdeel. Hierbij aansluitend lijkt het interessant om in één enkele analyse ruimtelijke informatie te verzamelen op verschillende schaalniveaus. Zo is het mogelijk dat woon-werkverkeer, dat doorgaans over een grotere afstand gebeurt dan het dagelijkse boodschappen doen, beïnvloed wordt door ruimtelijke kenmerken van een hoger schaalniveau dan de onmiddellijke en directe woonomgeving. Dezelfde opmerking geldt voor vervoerswijzen met een verschillende radius (vb. fiets en te voet versus trein en auto). Afhankelijk van verplaatsingsmotief of vervoerswijze lijkt het belangrijk om de ruimtelijke informatie op het juiste schaalniveau te verzamelen. Daarenboven hebben de verschillen in schaalniveaus mogelijk belangrijke gevolgen voor de interpretatie van de resultaten. Het is immers een gekend probleem binnen de geografie dat statistische resultaten veranderen naargelang de schaal waarop de data verzameld wordt. Dit schaaleffect is bekend als een aspect van het 'modifiable areal unit problem' (MAUP) (Openshaw, 1984; Fotheringham en Wong, 1991). Daarnaast bestaat ook het zoneringeffect dat verwijst naar de statistische gevolgen van het groeperen van data volgens verschillende zoneringschema's op eenzelfde schaalniveau. MAUP is intrinsiek aan elke kwantitatieve analyse van ruimtelijk geaggregeerde data, maar desondanks wordt het weinig bestudeerd binnen het onderzoek naar de relatie tussen ruimtelijke ordening en verplaatsingsgedrag.

Naast de voorgaande ruimtelijke opmerkingen kunnen tevens enkele suggesties gemaakt worden voor verder onderzoek volgend uit de sociale component van dit doctoraatsonderzoek. In feite verwijzen de residentiële attitudes in de huidige analyses naar de woonomgeving die respondenten verkiezen indien ze op zoek zouden gaan naar een nieuwe woonplaats. Echter, deze residentiële voorkeuren zijn niet afgewogen tegenover de ruimtelijke kenmerken van de huidige woonomgeving. De resultaten duiden wel aan dat iemand met een voorkeur voor open ruimte en stilte meer geneigd is om in een minder dicht bebouwde omgeving te wonen, maar in feite is niet nagegaan of de residentiële voorkeuren werkelijk overeenkomen met de huidige woonomgeving. Het blijft mogelijk dat bepaalde respondenten in een omgeving wonen die niet overeenstemt met hun residentiële voorkeur, wat belangrijke gevolgen kan hebben voor hun verplaatsingsgedrag (Schwanen en Mokhtarian, 2005a, b). Daarenboven biedt de internetenquête informatie over hoe respondenten hun huidige woonplaats percipiëren. Het lijkt interessant om de overeenstemming na te gaan tussen deze percepties en de objectieve ruimtelijke kenmerken van de huidige woonplaats. Dit kan een indicatie zijn van iemands kennis over zijn of haar directe woonomgeving. In dit doctoraatsonderzoek worden subjectieve invloeden zoals attitudes op een kwantitatieve manier benaderd. Deze eerste kwantitatieve analyses dienen aangevuld te worden met meer kwalitatief onderzoek om een diepgaand inzicht te verwerven in de werkelijke gedragsmechanismen. Kwalitatief onderzoek kan zinvol zijn voor het achterhalen van de ruimtelijke kenmerken die werkelijk belangrijk zijn voor verplaatsingsgedrag (Handy *et al*., 2002).

Beleidsaanbevelingen

Beleidsinitiatieven zoals het 'New Urbanism' in de VS en het 'Compacte Stad' beleid in Europa baseren zich op de idee dat wonen in een traditionele en stedelijke omgeving samen gaat met minder autogebruik en kortere verplaatsingen. De bevindingen van dit doctoraatsonderzoek lijken dit te onderbouwen. Een dichtbebouwde omgeving waarin wonen gecombineerd wordt met andere activiteiten en die dicht bij een stads- of dorpscentrum gelegen is, is geassocieerd met minder autogebruik, meer gebruik van het openbaar vervoer en een groter aandeel wandelen en fietsen. Tevens lijkt de vervoerswijzekeuze eerder een afweging tussen de auto en alternatieve vervoerswijzen, en bijgevolg niet zozeer tussen gemotoriseerd en niet-gemotoriseerd vervoer of tussen individueel en collectief vervoer. Om autogebruik te ontmoedigen kan het ruimtelijke ordeningsbeleid zich focussen op (i) de ontwikkeling van residentiële buurten die niet losstaan van stads- en dorpscentra, (ii) verdichting, en (iii) het verstrekken van diverse voorzieningen op buurtniveau. Deze drie ruimtelijke principes dienen vertaald te worden naar meer specifieke en geavanceerde stads- en buurtontwerpen (Grava, 2003; Marshall, 2005).

De effectiviteit van het ruimtelijke ordeningsbeleid kan echter enkel correct begrepen worden indien men rekening houdt met de complexiteit van de relatie tussen ruimtelijke ordening en verplaatsingsgedrag. Ten gevolge van intermediaire variabelen zoals autobezit is deze relatie niet zo eenvoudig en eenduidig als aanvankelijk gedacht. Zo heeft de ruimtelijke ordening in de eerste plaats een invloed op autobezit en vervolgens pas op vervoerswijzekeuze. Dit heeft als gevolg dat maatregelen zoals verdichting zowel een directe als een indirecte invloed hebben op vervoerswijzekeuze aangezien deze tevens autobezit ontmoedigen. Indien men dit negeert, dan bestaat het gevaar dat de effecten van dergelijke ruimtelijke maatregelen verkeerd ingeschat worden. Daarenboven mag het ruimtelijke ordeningsbeleid zich niet beperken tot de ruimtelijke ontwikkeling van woonplaatsen als zijnde een belangrijk vertrekpunt van vele verplaatsingen, maar moet het tevens aandacht bieden aan belangrijke bestemmingslocaties van deze verplaatsingen zoals werklocaties.

Tenslotte, indien geen rekening wordt gehouden met verschillen in persoonlijke leefstijlen en attitudes zal eender welk ruimtelijk ordeningsbeleid niet zomaar het gewenste effect hebben op ieders verplaatsingsgedrag. Maatregelen zoals verdichting zijn immers nuttig voor een welbepaalde bevolkingsgroep die er werkelijk voor opteren om in dergelijke buurten te wonen. De analyses in dit doctoraatsonderzoek illustreren dat personen ervoor opteren om in een stedelijke omgeving te wonen indien dit past binnen hun eerder niet-traditionele leefstijl of indien deze woonomgeving toegang verschaft tot diverse diensten, winkels, jobs, … Andere bevolkingsgroepen verkiezen eerder een suburbane of landelijke woonomgeving, ondanks alle initiatieven om steden te herwaarderen en alle inspanningen van ruimtelijke planners. Dit geldt zeker voor personen met een actieve of een familiegerichte leefstijl, of voor personen die de open ruimte en de stilte van het platteland verkiezen. Dergelijke bevolkingsgroepen zijn geneigd om vaker de auto te gebruiken, en dit autogebruik wordt nogmaals aangemoedigd door een positieve attitude ten opzichte van de auto. Niettemin bestaan er andere mogelijkheden om het autogebruik te verminderen, die vooral te zoeken zijn in transportplanning. Door het benadrukken van aspecten zoals tijdsbesparing en het positieve effect op milieu en gezondheid kan men het imago van openbaar vervoer, fietsen en wandelen verbeteren. Een dergelijke positieve attitude kan op zijn beurt het gebruik van deze vervoerswijzen stimuleren. Bijgevolg wordt het duidelijk dat het beleid zich niet enkel mag richten op het ontwerpen en ontwikkelen van objectieve plannen (vb., een duurzame lay-out van residentiële omgevingen) maar zich tevens bewust moet zijn van de subjectieve implicaties (vb., imagovorming van vervoerswijzen).

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"Erger je niet aan de slechte weg,
maar geniet van de reis."

Barbara Hoffman

Internet survey on mobility and lifestyles

DEEL 1: LEEFSTIJL

▪

Dit eerste deel peilt naar uw ***leefstijl***. Er volgen enkele vragen over:
− uw reisgewoonten
− uw literaire interesses
− uw vrijetijdsbesteding
− uw opinies over werk en relaties

A. Reizen

1. Voor welke logiesvorm kiest u gewoonlijk op reis (exclusief zakenreizen) ?

□ ik ga niet op reis (➔ ga verder met vraag 7)
□ hotel
□ huurwoning
□ vakantiedorp (Club Med, Center Parcs)
□ camping
□ bij particulieren
□ eigen tweede verblijf
□ ander: __________

2. Met welk transportmiddel bereikt u uw hoofdreisbestemming (exclusief zakenreizen) ?

□ wagen
□ vliegtuig
□ trein
□ touringcar
□ ander: __________

3. Wie organiseert uw reis (exclusief zakenreizen) ?

□ een reisbureau organiseert alles (transport, logies, activiteiten)
□ een reisbureau organiseert het transport en de logies, maar ikzelf bepaal de activiteiten ter plaatse
□ een reisbureau organiseert het transport, maar ikzelf bepaal de logies en de activiteiten ter plaatse
□ een reisbureau organiseert de logies, maar ikzelf bepaal het transport en de activiteiten ter plaatse
□ ik organiseer alles zelf (transport, logies, activiteiten)

4. Welke aspecten vindt u belangrijk op reis (exclusief zakenreizen) ? (meerdere antwoorden mogelijk)

□ natuur
□ rust, relaxen
□ vertrouwde omgeving
□ luxueuze verblijfplaats
□ lekker eten
□ cultuur
□ dichtbij huis
□ goedkoop
□ sportmogelijkheden
□ zonnig klimaat
□ geen taalproblemen
□ ongekende oorden
□ animatie voor kinderen
□ ander:__________

5. Hoeveel keer bent u het voorbije jaar op reis geweest (exclusief zakenreizen) ? __________

6. Hoeveel van deze reizen duurden één week of langer ? __________

B. Literatuur

7. Over welke onderwerpen leest u gewoonlijk een boek of tijdschrift ? (meerdere antwoorden mogelijk)

□ roman
□ vrouwentijdschrift (Flair, Libelle)
□ wetenschap
□ gezondheid
□ huisdieren
□ fantasy/science fiction
□ wonen/decoratie
□ financiën/zaken/handel
□ mode
□ humor/komedie
□ computer/ICT
□ horror
□ milieu/natuur
□ tuin
□ sport
□ stripverhalen
□ geschiedenis
□ religie/godsdienst
□ thriller/avontuur
□ mannentijdschrift (P-magazine, Ché)
□ koken
□ doe-het-zelf/klussen
□ kinderverhalen/sprookjes
□ actualiteit/politiek
□ kunst/architectuur
□ detective
□ entertainment/showbizz-nieuws
□ ander: __________

C. Vrijetijd

8. Welke vrijetijdsactviteiten beoefent u gewoonlijk tijdens het weekend ? (meerdere antwoorden mogelijk)

□ onderhouden van tuin
□ bezoeken van familie/vrienden
□ winkelen/shoppen
□ godsdienstige activiteiten
□ culturele activiteiten
□ kokerellen
□ radio/muziek luisteren
□ familie/vrienden ontvangen
□ sporten
□ vrijwilligerswerk
□ uiteten gaan
□ thuis blijven en relaxen
□ lezen
□ bioscoop
□ karweitjes doen
□ TV/video/DVD kijken
□ discotheek/fuif
□ ander: __________

9. Welke sporten beoefent u regelmatig ? (meerdere antwoorden mogelijk)

□ voetballen
□ tennis, golf
□ motorcrossen
□ parachutespringen, basejumping
□ wielrennen, mountainbiken
□ wandelen
□ waterskiën, zeilen
□ joggen, lopen
□ skiën, snowboarden
□ diepzeeduiken
□ atletiek
□ rafting, kano- of kajakvaren
□ paardrijden
□ zwemmen
□ yoga
□ fitness

10. Welke culturele evenementen heeft u het voorbije jaar bijgewoond ? (meerdere antwoorden mogelijk)

□ bioscoop
□ paardenkoers
□ auto tuning, autoshow
□ concert
□ rommelmarkt, jaarmarkt
□ balletvoorstelling
□ fuif
□ stoet, parade
□ handelsbeurs
□ casino
□ bibliotheek
□ discotheek
□ theatervoorstelling
□ ander: __________

11. Wat zijn uw hobby's ? (meerdere antwoorden mogelijk)

□ klusjes uitvoeren (aan het huis)
□ naaien, borduren, breien
□ schilderen
□ sporten
□ theater spelen
□ meubels maken, herstellen
□ PC, webdesign
□ onderhoud van (moes)tuin
□ vrijwilligerswerk
□ muziek spelen (instrument bespelen, DJ, …)
□ autoherstelling uitvoeren
□ fotografie
□ lezen
□ ander: __________

12. Beoefent u bepaalde hobby's uit in verenigingsverband (sportvereniging, culturele vereniging, ...) ?

□ ja
□ nee

D. Opinies over werk en relaties

13. In welke mate bent u akkoord met onderstaande stellingen over werk en relaties ?

	helemaal akkoord	akkoord	neutraal	niet akkoord	helemaal niet akkoord
Ik vind carrière maken belangrijk	□	□	□	□	□
Ik vind het soort werk niet belangrijk, zolang ik maar voldoende verdien	□	□	□	□	□
Ik vind een interessante en boeiende job belangrijk	□	□	□	□	□
Ik vind een succesvol(le) huwelijk/vaste relatie belangrijk	□	□	□	□	□
Ik vind het krijgen en opvoeden van kinderen heel belangrijk	□	□	□	□	□
Ik hecht veel belang aan de mening van mijn gezinsleden	□	□	□	□	□
Ik maak gemakkelijk vrienden	□	□	□	□	□
Ik vind het belangrijk om vrienden regelmatig te zien	□	□	□	□	□
Ik ken veel mensen, maar slechts enkelen zijn échte vrienden	□	□	□	□	□

DEEL 2: OPINIES EN GEWOONTEN OVER VRIJETIJD EN MOBILITEIT

Dit tweede deel peilt naar uw ***opinies*** en ***gewoonten*** over vrijetijd en mobiliteit.

A. Opinies over vrijetijdsactiviteiten

14. In welke mate bent u akkoord met onderstaande stellingen over vrijetijdsactiviteiten ?

	helemaal akkoord/helemaal juist	akkoord/juist	neutraal	niet akkoord/niet juist	helemaal niet akkoord/helemaal niet juist
Ik vind het belangrijk om vrijetijdsactiviteiten ***buitenshuis*** te kunnen uitoefenen	☐	☐	☐	☐	☐
Ik kan voldoende tijd vrijmaken voor vrijetijdsactiviteiten ***buitenshuis***	☐	☐	☐	☐	☐
Ik vind het belangrijk om mensen te ontmoeten tijdens de vrijetijdsactiviteiten die ik ***buitenshuis*** uitoefen	☐	☐	☐	☐	☐
Door mijn vrijetijdsactiviteiten ***buitenshuis*** heb ik enkele vrienden leren kennen	☐	☐	☐	☐	☐
Ik vind het belangrijk om vrijetijdsactiviteiten ***thuis*** te kunnen uitoefenen	☐	☐	☐	☐	☐
Ik kan voldoende tijd vrijmaken voor vrijetijdsactiviteiten ***thuis***	☐	☐	☐	☐	☐
Ik ben een bezige bij	☐	☐	☐	☐	☐

B. Vrijetijdslocaties

15. Duid aan welke aspecten u belangrijk vindt voor de verschillende vrijetijdslocaties. Eenzelfde aspect kan voor verschillende locaties van belang zijn.

	uitgaan	bezoek aan bos, park, natuurgebied	sport- of culturele voorziening als toeschouwer	sport- of culturele activiteit als deelnemer	shoppen
voldoende parkeerplaats	☐	☐	☐	☐	☐
gratis parkeerplaats	☐	☐	☐	☐	☐
goede bereikbaarheid met de auto	☐	☐	☐	☐	☐
goede bereikbaarheid met openbaar vervoer	☐	☐	☐	☐	☐
goede bereikbaarheid met fiets	☐	☐	☐	☐	☐
goede bereikbaarheid te voet	☐	☐	☐	☐	☐
nabij mijn woning	☐	☐	☐	☐	☐
nabij winkels, cafés, ... zodat de vrijetijdsactiviteit gecombineerd kan worden met andere activiteiten	☐	☐	☐	☐	☐
aantrekkelijke inrichting van de locatie (mooi ontwerp, vormgeving, design)	☐	☐	☐	☐	☐

C. Vrijetijdsgewoonten

16. Welke vrijetijdsactiviteiten beoefent u maandelijks ?

□ bezoek aan familie of vrienden
□ uitgaan
□ bezoek aan bos, park, natuurgebied
□ deelnemen aan sport- of culturele activiteit als toeschouwer
□ actief deelnemen aan sport- of culturel activiteit
□ shoppen

▪

17. Wat is de geschatte afstand en reistijd (alleen heenreis) van uw woning tot de locatie waar u gewoonlijk ... ?

	afstand (in kilometers)	reistijd (in minuten)
1	☐	☐
2	☐	☐
3	☐	☐
4	☐	☐
5	☐	☐
6	☐	☐

18 Met welk transportmiddel bereikt u gewoonlijk de locatie waar u ... ?

	auto	trein	bus, tram, metro	fiets	te voet	ander
1	☐	☐	☐	☐	☐	☐
2	☐	☐	☐	☐	☐	☐
3	☐	☐	☐	☐	☐	☐
4	☐	☐	☐	☐	☐	☐
5	☐	☐	☐	☐	☐	☐
6	☐	☐	☐	☐	☐	☐

D. Opinies over mobiliteit

19. Welke aspecten zijn typisch voor onderstaande transportmiddelen ? Eenzelfde aspect kan verschillende transportmiddelen typeren.

	auto	openbaar vervoer	fiets	te voet
goed voor mijn imago	☐	☐	☐	☐
milieuvriendelijk	☐	☐	☐	☐
ontspannend	☐	☐	☐	☐
comfortabel	☐	☐	☐	☐
tijdsbesparend	☐	☐	☐	☐
flexibel	☐	☐	☐	☐
goedkoop	☐	☐	☐	☐
privacy biedend	☐	☐	☐	☐
gezond	☐	☐	☐	☐
veilig	☐	☐	☐	☐
betrouwbaar	☐	☐	☐	☐
activiteiten uitoefenen tijdens verplaatsing (werken, lezen, muziek beluisteren, ...)	☐	☐	☐	☐

20. Welke aspecten vindt u belangrijk bij de keuze van transportmiddel ?

	heel belangrijk	belangrijk	neutraal	niet belangrijk	helemaal niet belangrijk
goed voor mijn imago	☐	☐	☐	☐	☐
milieuvriendelijk	☐	☐	☐	☐	☐
ontspannend	☐	☐	☐	☐	☐
comfortabel	☐	☐	☐	☐	☐
tijdsbesparend	☐	☐	☐	☐	☐
flexibel	☐	☐	☐	☐	☐
goedkoop	☐	☐	☐	☐	☐
privacy biedend	☐	☐	☐	☐	☐
gezond	☐	☐	☐	☐	☐
veilig	☐	☐	☐	☐	☐
betrouwbaar	☐	☐	☐	☐	☐
activiteiten uitoefenen tijdens verplaatsing (werken, lezen, muziek beluisteren, ...)	☐	☐	☐	☐	☐

21. In welke mate gaat u akkoord met onderstaande stellingen over mobiliteit ?

	helemaal akkoord/helemaal juist	akkoord/juist	neutraal	niet akkoord/niet juist	helemaal niet akkoord/helemaal niet juist
Ik ontdek graag nieuwe, onbekende plaatsen	☐	☐	☐	☐	☐
Mijn bestemming bereiken, is het enige goede aan verplaatsingen	☐	☐	☐	☐	☐
Het verkeer maakt me nerveus	☐	☐	☐	☐	☐
Ik ben graag onderweg	☐	☐	☐	☐	☐
Ik vind verplaatsingen vervelend	☐	☐	☐	☐	☐
Reistijd is per definitie verloren tijd	☐	☐	☐	☐	☐
Volgens mijn huisgenoten/vrienden worden	☐	☐	☐	☐	☐

DEEL 3: PERSOONLIJKE EN HUISHOUDELIJKE VRAGEN

In dit laatste deel worden enkele algemene achtergrondvragen gesteld. Deze vragen hebben betrekking op enkele persoonlijke en huishoudelijke eigenschappen.

A. Persoonlijke vragen

22. Geboortejaar ? __________

23. Geslacht

□ man
□ vrouw

24. Heeft u een rijbewijs ?

□ ja
□ nee

25. Heeft u een abonnement voor het openbaar vervoer ?

□ ja
□ nee

26. Wat is uw hoogst behaalde diploma of getuigschrift ?

□ geen
□ lager onderwijs
□ buitengewoon onderwijs (BUSO)
□ lager beroeps- of technisch onderwijs (BSO, TSO)
□ hoger beroeps- of technisch onderwijs (BSO, TSO)
□ lager middelbaar onderwijs (ASO)
□ hoger middelbaar onderwijs
□ hoger niet-universitair onderwijs, korte type (bachelor)
□ hoger niet-universitair onderwijs, lange type (master)
□ universitair onderwijs (master, licentiaat)
□ postuniversitair onderwijs

27. Werkt of studeert u aan de Universiteit Gent ?

□ ja
□ nee (➔ ga verder met vraag 30)

28. Onder welk statuut bent u verbonden aan de Universiteit Gent ?

□ student (➔ ga verder met vraag 32)
□ ATP
□ WP
□ AAP
□ ZAP

29. Werkt u voltijds of deeltijds (uw tewerkstelling aan Universiteit Gent en eventueel andere bedrijven/instellingen meegerekend) ? indien u deeltijds werkt, gelieve het percentage op te geven.

□ voltijds (➔ ga verder met vraag 32)
□ deeltijds: __________ (➔ ga verder met vraag 32)

30. Wat is uw huidige statuut van tewerkstelling ?

□ student (➔ ga verder met vraag 32)
□ huisvrouw, huisman (➔ ga verder met vraag 32)
□ gepensioneerd (➔ ga verder met vraag 32)
□ arbeidsongeschikt (➔ ga verder met vraag 32)
□ werkzoekende (➔ ga verder met vraag 32)
□ arbeider
□ bediende
□ kaderpersoneel
□ zelfstandige
□ vrij beroep

31. Werkt u voltijds of deeltijds ? Indien u deeltijds werkt, gelieve het percentage op te geven.

□ voltijds
□ deeltijds: __________

32. Wat is het maandelijks netto-inkomen van uw huishouden ?

□ 0 – 499 €
□ 500 – 999 €
□ 1000 – 1499 €
□ 1500 – 1999 €
□ 2000 – 2499 €
□ 2500 – 2999 €
□ 3000 – 3499 €
□ 3500 – 3999 €
□ 4000 – 4499 €
□ 4500 – 4999 €
□ +5000 €

33. Heeft u een mentale of fysieke handicap die u verhinderd om te …

	ja	nee
autorijden	□	□
wandelen buitenshuis	□	□
fietsen	□	□
openbaar vervoer gebruiken	□	□

B. Huishoudelijke vragen

34. Tot welk type huishouden behoort uw huishouden ?

□ alleenstaand zonder (thuiswonende) kinderen (➔ Ga verder met vraag 36)
□ alleenstaand met thuiswonende kinderen
□ gehuwd/samenwonend zonder (thuiswonende) kinderen (➔ Ga verder met vraag 36)
□ gehuwd/samenwonend met thuiswonende kinderen
□ andere

35. Hoeveel thuiswonende kinderen heeft u en welke leeftijden hebben zij ?

	Aantal
Kinderen onder de 6 jaar:	
Kinderen van 6 tot 12 jaar:	
Kinderen van 12 tot 18 jaar:	
Kinderen van 18 jaar en ouder:	

36. Over welke transportmiddelen beschikt uw huishouden ?

□ geen
□ auto's, het aantal is __________
□ motoren, het aantal is __________
□ bromfietsen/scooters, het aantal is __________
□ fietsen, het aantal is __________

37. Kan u altijd over een auto beschikken ?

□ ja, wanneer ik maar wil
□ nee, dat gaat in overleg met mensen binnen mijn huishouden
□ nee, dat gaat in overleg met mensen buiten mijn huishouden
□ nee, (vrijwel) nooit

38. Beschikt u over een bedrijfswagen ?

□ ja, het aantal is __________
□ nee

39. Beschikt u voor uw transportmiddelen over stallingsmogelijkheden nabij de woning (een garage, schuur, carport en/of oprit) ?

□ ja
□ nee

40. Woont u in een…

□ huurwoning
□ koopwoning

41. In welk type woning woont u ?

□ een open bebouwing, vrijstaande woning
□ een halfopen bebouwing
□ een gesloten bebouwing, rijhuis
□ een flat met 3 of minder bouwlagen
□ een flat met meer dan 3 bouwlagen

42. Beschikt u over een tuin, balkon en/of terras ?

□ ja
□ nee

43. Wat is de geschatte afstand tussen uw woning en …

	afstand (in kilometers)
bus/tram/metro-halte	□
treinstation	□

▪

44. In welke mate bent u tevreden met onderstaande aspecten van de buurt waar u woont ?

	heel tevreden	tevreden	neutraal	niet tevreden	helemaal niet tevreden
sociaal veilig (geen criminaliteit, vandalisme, ...)	☐	☐	☐	☐	☐
verkeersveilig	☐	☐	☐	☐	☐
fietspaden	☐	☐	☐	☐	☐
voetpaden	☐	☐	☐	☐	☐
voldoende parkeerplaatsen	☐	☐	☐	☐	☐
nabijheid openbaar vervoer	☐	☐	☐	☐	☐
nabijheid winkels	☐	☐	☐	☐	☐
nabijheid vrijetijdsvoorzieningen	☐	☐	☐	☐	☐
nabijheid familie, vrienden	☐	☐	☐	☐	☐
nabijheid van mijn werkplaats	☐	☐	☐	☐	☐
rust	☐	☐	☐	☐	☐
groen	☐	☐	☐	☐	☐
netheid	☐	☐	☐	☐	☐
uitzicht van de gebouwen	☐	☐	☐	☐	☐
goed contact met de buren	☐	☐	☐	☐	☐
bevolkingssamenstelling	☐	☐	☐	☐	☐
bebouwingsdichtheid, afstand tussen huizen	☐	☐	☐	☐	☐

45. Wat is uw postcode en straatnaam ?

Postcode:	
Straatnaam:	

TOT SLOT

46. Als dank voor uw medewerking worden één Fnac-bon ter waarde van 100€ en vijf Fnac-bons ter waarde van 25€ verloot onder de volledig ingevulde vragenlijsten. Indien u hierop kans wenst te maken, gelieve dan uw e-mailadres te noteren. Op deze manier kunnen we u contacteren indien u tot de gelukkige winnaars behoort. Deze gegevens zullen enkel gebruikt worden voor het versturen van de Fnac waardebonnen. Wenst u deel te nemen ?

□ ja, mijn e-mail is ____
□ nee

47. De resultaten van dit onderzoek zullen neergeschreven worden in een verslag. Een exemplaar van de onderzoeksresultaten kan u digitaal bezorgd worden. Wenst u een exemplaar van de onderzoeksresultaten ? De onderzoeksresultaten zullen tevens beschikbaar zijn op http://geoweb.ugent.be

□ ja, mijn e-mail is ____
□ nee

CURRICULUM VITAE

Veronique Van Acker was born on the 20th of March in 1981 in Ghent. In 1999 she started her education in Geography at Ghent University, where she received a Master's degree in 2003, specializing in social and economic geography. After graduating as a geographer, she continued her studies with an additional education in Spatial Planning (also at Ghent University) in 2004. Her Master's thesis received the prize for best thesis in spatial planning, organized by the Flemish Association for Environment and Planning (VRP). Immediately afterwards, she became a research assistant at the Department of Geography at Ghent University. In the meantime, she also obtained a doctoral training degree (2006) and a teacher's training degree (2008). During her PhD research, she stayed as a visiting research fellow at Delft University of Technology in the Netherlands (with Professor Bert van Wee, autumn 2006) and at the University of California, Davis, in the USA (with Professor Patricia L. Mokhtarian, spring 2008). Important research initiatives were undertaken during these two research stays. Results of her PhD research have been published in or are submitted to internationally peer-reviewed journals, and have been presented at various national and international conferences. She also serves as a member of the editorial board of AGORA, a popularizing scientific magazine on current social and spatial issues, and as an expert member of GECORO Lochristi, the commission on spatial planning of the municipality Lochristi.