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Causal effects of built environment characteristics on travel behaviour: a longitudinal approach

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The influence of the built environment on travel behaviour and the role of intervening variables such as socio-demographics and travel-related attitudes have long been debated in the literature. To date, most empirical studies have applied cross-sectional designs to investigate their bidirectional relationships. However, these designs provide limited evidence for causality. This study represents one of the first attempts to employ a longitudinal design on these relationships. We applied cross lagged panel structural equation models to a two-wave longitudinal dataset to assess the directions and strengths of the relationships between the built environment, travel behaviour and travel-related attitudes. Results show that the residential built environment has a small but significant influence on car use and travel attitudes. In addition, the built environment influenced travel-related attitudes indicating that people tend to adjust their attitudes to their built environment. This provides some support for land use policies that aim to influence travel behaviour.

Keywords: *attitudes, built environment, causality, longitudinal, residential self-selection, travel behaviour*

1. Introduction

Today, cities are facing challenges in terms of accessibility, including car congestion and retail-service accessibility, and in terms of sustainability, such as air pollution and carbon dioxide emissions, decreasing overall quality of life. One approach to sustainable transportation is shaping the built environment to influence travel behaviour (Krizek, 2003a; Van Wee, 2011). Planning concepts have been developed to prevent or at least reduce urban sprawl, by preserving cohesive urban regions, aiming for compact cities (Europe) and promoting transit and pedestrian oriented, mixed neighbourhoods in the US referred to as New Urbanism, Smart Growth and

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Transit Oriented Development. The hypothesis underlying this approach seems rather intuitive: if low-density, single use development patterns are associated with car dependency, promoting compact mixed environments that create proximity to destinations may encourage people to drive less. The question, however, is whether the processes of car dependency and urban sprawl can be so easily reversed (Banister, 2008).

To date, study outcomes generally provide some support for the hypothesis that policies that shape the built environment can be used to influence travel behaviour. Meta analyses reveal that built environment characteristics, in particular the accessibility of destinations, exert an independent but small influence on travel behaviour (Ewing and Cervero, 2010; Gim, 2013). However, discussions about the influence of the built environment on travel behaviour remain. They mainly revolve around issues of causality, research design and methodology. Within the causality debate, the discussion has specifically focused on the role of travel-related attitudes and residential preferences. Two additional hypotheses have been formed that provide an alternative explanation for the associations on the link between the built environment and travel behaviour (hereafter referred to as the BE-TB link).

The first is the residential self-selection hypothesis that entails that households choose their residential neighbourhood based on their travel attitudes. If the majority of people would succeed in finding a neighbourhood that is congruent with these attitudes, these attitudes and the built environment characteristics would be highly correlated. Consequently, if these attitudes are not controlled for in the analysis, they would confound the estimation of the built environment effects which could lead to biased estimations of the impact of the built environment on travel behaviour (Handy et al., 2005; Chatman, 2009). For example, are associations between people's proximity to a railway station and their frequency of public transport use the result of a causal influence of the built environment on travel behaviour? Or do residents with positive attitudes towards using public transport self-select themselves into neighbourhoods in proximity to the railway station and therefore use these modes more often? The existence of self-selection doesn't mean that the built environment is irrelevant as the built environment enables people to self-select into areas that match their travel-related attitudes (Næss, 2009). However, the impact of the built environment on travel behaviour may be limited to people who already have a positive attitude towards public transport (Cao et al., 2009).

The second is the 'reverse causality' hypothesis where the built environment influences travel-related attitudes over time which in turn affect travel behaviour (Bagley and Mokhtarian, 2002; Chatman, 2009). Reverse causality may occur because people adjust their travel-related attitudes to their previous residential choices or because people come to appreciate the convenience of alternative travel modes after living in an area that is supportive to these modes for some time. For example, areas in close proximity to the railway station generally have a good transport provision and less favourable conditions for car use. This may influence people's perceptions of these mobility options and encourage more positive attitudes towards the use of public transport which in turn may encourage the actual use of public transport. Hence, the positive attitudes towards public transport in areas in closer proximity to the railway station may not be (solely) the result of residential self-selection. Instead, the built environment may influence travel behaviour as well as travel-related attitudes which amplifies (rather than weakens) its importance to bring about changes in travel behaviour. These issues will be elaborated on in the next section.

Consequently, the question here is what is the cause and what is the effect, and to what extent? Does the built environment influence travel behaviour directly or is there an indirect influence via attitudes? And if so, do travel-related attitudes primarily influence the built environment as a result of residential self-selection or does the built environment primarily influence travel-related attitudes? This distinction between cause and effect can only be achieved by means of a longitudinal study design. However, to date most studies assess individual behaviour by applying cross-sectional designs and controlling for intervening variables such as socio-demographics and, increasingly, travel-related attitudes and residential preferences (Bohte, 2010). Although these studies provide valuable insights, they cannot identify causal relationships because they (i) do not assess the impact of built environment on travel behaviour over time (ii) are vulnerable to third (confounding) variable influences and (iii) neglect the dynamics involving behavioural change (Handy et al., 2005; Kitamura, 1990; see for an overview Van de Coevering et al., 2015). In the last decade, some progress has been made on this issue by the introduction of (quasi-)longitudinal designs that incorporated travel-related attitudes and residential preferences to control for residential self-selection (e.g. Handy et al., 2005; Cao et al., 2009). However, to the best of our knowledge no previous study has included measurements of travel-related attitudes at two or more moments in time. This precludes the assessment of directions of causality between travel-related attitudes, the built environment and travel behaviour.

To overcome the limitations of previous studies, we conducted a longitudinal study where travel behaviour and its determinants, including attitudes, are measured at two separate moments in time. This study aims to unravel the complex directions of causality between the built environment, travel behaviour and travel-related attitudes. We specifically aim to address the following research questions: (1) To what extent are (changes in) built environment characteristics associated with changes in travel behaviour, after controlling for socio-demographics and the bidirectional relationships with travel-related attitudes? (2) What is the dominant direction of influence between travel-related attitudes and the built environment; does attitude based residential self-selection primarily influence the built environment or does the built environment primarily influence travel-related attitudes over time? (3) How do travel-related attitudes and travel behaviour influence each other over time?

The dataset used in this study builds on previous work of Bohte (2010). Respondents who fully completed the survey in 2005 have been re-invited to participate in a second survey in 2012. To our knowledge, this is the first longitudinal dataset containing all information on travel behaviour, travel-related attitudes and the built environment. A cross-lagged panel structural equation model is applied to this dataset to test the bidirectional relationships over time. Such cross-lagged models make use of the time-ordered nature of panel data to empirically determine which variable is the cause and which variable is the effect. Because the method meets the criterion of time-precedence, it provides a stronger basis for making causal inferences. The modelling approach will be elaborated on in Section 4.

The organization of this paper is as follows: the next section provides an overview of current literature and specifically the role of attitudes in research on the BE-TB link; the third section describes the data collection and the key variables followed by section four that describes the modelling approach; the fifth section describes and discusses the modelling results and the last section summarizes the main findings and discusses policy implications.

2. Literature and conceptual framework

The influence of the built environment on travel behaviour is one of the most researched topics in urban planning and has been discussed in many reviews (see: Van Wee and Maat, 2003; Boarnet, 2011, Ewing and Cervero, 2010, Gim, 2013). A couple of reviews have focused specifically on the role of travel-related attitudes and the issue of residential self-selection (e.g. Cao et al., 2009; Mokhtarian & Cao, 2008; Bohte et al., 2009).

The aim of this section is to further elaborate on the relationships between travel-related attitudes, built environment and travel behaviour and on the need for applying longitudinal designs to determine causality in these relationships.

2.1 Attitudes and behaviour

Attitude-based research in transportation studies is often based on attitude theories derived from social psychology such as the Theory of Planned Behaviour (TPB) (Ajzen, 1991) and Swartz's Norm Activation Model (Schwartz, 1977). It is beyond the scope of this article to discuss these theories in depth; however, in the context of the current article two notions are of paramount importance.

First, various definitions of attitude exist. In general terms an attitude is a favourable or unfavourable elevation of an attitude object (e.g. place, situation or behaviour) based on a person's beliefs about that object (Ajzen & Fishbein, 1977). Attitudes are typically considered to be relatively enduring dispositions which exert pervasive influence on behaviour (Ajzen, 1987). Attitudes in this article are based on the multidimensional definition of attitudes by Eagley and Chaiken (1993) which recognizes three components: (i) the affective component; the degree that people enjoy or like a particular behaviour (e.g. I enjoy travelling by bike) (ii) the cognitive component; the perceived likelihood that performance of a behaviour will lead to a particular outcome (driving a car is environmental unfriendly) and (iii) the conative component; the actual actions of people related to the behaviour in question (I would use the bike for commuting).

Second, it is acknowledged that there are other psychological determinants of behaviour beside attitudes. Although attitudes are believed to be important determinants of behaviour, the actual correspondence between attitudes and behaviour is sometimes reported to be low, leading to the expression of attitude-behaviour inconsistency (Gärling et al., 1998). The TPB provides two explanations for this inconsistency. First, attitudes do not influence behaviour directly but indirectly through their influence on intentions, which represent a person's motivation to actually enact the behaviour. Second, attitudes are not the only determinants of importance. The TPB identifies two additional determinants: subjective norms (perceived social pressure) and perceived behavioural control (perceived ability to perform behaviour) (Arjzen, 1991). This study does not incorporate these additional psychological determinants. However, past behaviour is taken into account as human behaviour is (at least partly) habitual and as past behaviour is sometimes considered the best predictor for current behaviour, especially if circumstances remain relatively stable (Thøgersen, 2006; Bamberg et al., 2003).

2.2 Attitudes in research on the BE-TB link

Figure 1 conceptualises the relationships between the built environment, travel behaviour and third variables: individual and household characteristics, travel-related attitudes (TA) and preferences. At the start of the causality debate, most studies hypothesized the direct relationship between the built environment and travel behaviour (link 8). The studies done by Newman and Kenworthy (1988, 1999), which assessed the influence of urban densities on per capita energy use in a large range of world cities, are famous examples. During the 1990s more cross-sectional studies appeared on the BE-TB link, most of them controlling for the influence of sociodemographics (link 3) and latterly attitudes (link 7) on travel behaviour. Cervero and Kockelman (1997) provided additional evidence for the influence of built environment on travel behaviour and coined the idea of the 3Ds, density, diversity and design, later extended to include destination accessibility and distance to public transport (Ewing & Cervero, 2001; Ewing and Cervero, 2010).

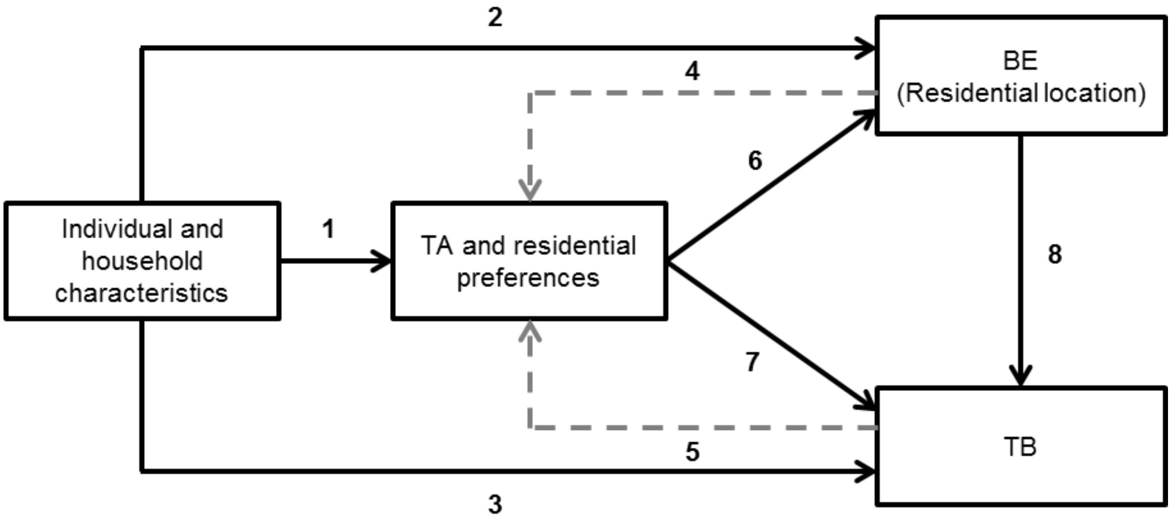

Figure 1. Conceptual model of relationships between BE-TB and intervening variables. Adjusted from Bohte (2010)

Policy concepts like New Urbanism, Smart Growth, Transit Oriented Development and Compact City policies include these principles and aim at reducing car use and travel distances while simultaneously enhancing accessibility. The underlying hypothesis is that compact mixed use environments provide proximity between destinations which enhances opportunities of slow modes such as walking and biking. In addition, these more compact mixed developments spatially concentrate travel demand making the provision of public transport easier and more profitable which in turn enables a higher level of service. Furthermore, the amount of vehicle kilometres driven may decline because the distances that need to be covered between destinations are smaller (Van Wee, 2011). Most studies have provided support for this hypothesis, ceteris paribus: residents of higher density, mixed-use developments with good facilities for public transport, cycling and pedestrians and with short distances to destinations tend to drive less and make more use of alternative transportation modes. The built environment seems to have small but significant associations with travel behaviour at different levels of aggregation ranging from regional accessibility to local street designs (Krizek, 2003b). Destination accessibility, the ease of access to trip attractions, appears to be most strongly associated with travel behaviour (Ewing and Cervero, 2010; Gim, 2013).

Since the end of the 1990s, the residential self-selection hypothesis has become one of the prime topics in the discussion about causality. The general definition of residential self-selection is "the tendency of people to choose locations based on their travel abilities, needs and preferences" (Litman, 2005: p6). Residential self-selection generally results from two sources: individual and household characteristics (e.g. socio-demographics) and attitudes (link 2 and 6). In the last decade the importance of attitude-induced residential self-selection has increasingly been recognized. An example of attitude induced self-selection occurs when someone who prefers to walk settles in a neighbourhood that is conducive to walking and consequently walks more. In this case, it is not the built environment alone that causes someone to walk. Rather it is the combination of a person's pre-existing positive attitude and the selection of a neighbourhood conducive to walking that makes more walking possible. Then, the impact of the built environment on travel behaviour may be limited to people who already favour walking and effects on people who are for instance car oriented may be limited.

Kitamura et al. (1997) were one of the first to discuss the role of travel-related attitudes. They concluded that attitudes are more strongly associated with travel behaviour than are characteristics of the built environment and noted that lifestyle choices and attitudes are probably relevant to both the selection of a residential neighbourhood and travel behaviour. If the associations between attitudes and residential choice would indeed be dominant, the observed associations on the BE-TB link may be attributed to residential self-selection.

After the study of Kitamura et al. (1997) more studies appeared which assessed the influence of residential self-selection. The research outcomes are mixed (Ewing & Cervero, 2010). Using the dataset of Kitamura et al. (1997), Bagley and Mokhtarian (2002) explicitly controlled for residential self-selection based on travel-related attitudes and the built environment. They found that attitudinal and lifestyle variables were most strongly associated with travel behaviour and that built environment characteristics had little influence. Lund (2003) came to comparable results in a study on the frequency of walking trips. Conversely, Schwanen and Mokhtarian (2005) found that even after controlling for attitudes and mismatches, the built environment still exerts a significant influence on travel behaviour. They assessed the role of attitudes by incorporating an attitudinal-based measure of dissonance between one's preferred and actual neighbourhood types. Bohte (2010) also found a significant influence of the built environment after controlling for attitudes. For a more extensive insight we refer to reviews that focused on the role of attitudes and the issue of residential self-selection (e.g. Cao et al., 2009; Mokhtarian & Cao, 2008; Bohte et al., 2009).

The 'reverse causality' hypothesis, where the built environment influences travel-related attitudes [link 4], has received considerably less attention in studies on the BE-TB link. The same holds for reverse causal relationships between travel-related attitudes and travel behaviour (link 5). Reverse causality may occur for two reasons. First, according to the well-known theory of cognitive dissonance (Festinger, 1957) people may not only adjust their behaviour but also their attitudes if dissonance occurs between the two. In this case, people may adjust their travel-related attitudes to their previous residential choices. Second, according to Cullen's model (1978) people will have positive and negative experiences during their daily routines in their current social and spatial context (for instance a lack of public transport provision). Consequently, they will develop and adjust certain attitudes and preferences towards their daily routines (less favourable towards public transport use) but also towards longer term life choice decisions (residential and job location choices).

The earlier mentioned study of Bagley and Mokhtarian (2002) was also one of the first to take into account the reverse influences of the built environment and travel behaviour on travel-related attitudes. This study found no reverse effects of the built environment on travel-related attitudes but the number of vehicle miles driven had a small but significant influence on pro-driving attitudes. More recently, findings of Bohte (2009) did suggest reverse causal influences on these relationships: the distance to the railway station appeared to have a relatively strong negative effect on respondents' attitudes towards using public transport and the share of car trips negatively influenced attitudes towards cycling and positively influenced their attitude towards car use. A few transportation studies specifically explored reverse causality between travel-related attitudes and travel behaviour and provided support for this reverse causal hypothesis (Tardiff, 1977; Golob, 1979; Tertoolen (1998) Thøgersen (2006).

Recently, the question was raised whether it is possible to convincingly test the bidirectional causal effects between the built environment, travel behaviour and travel-related attitudes, using cross-sectional research designs (Krizek, 2003; Handy et al., 2005). To identify a causal relationship on the BE-TB link four conditions should be met (Singleton and Straits, 2009; Shadish et al., 2002): (1) association; the built environment and travel behaviour are statistically associated, (2) non-spuriousness; relationship between the built environment and travel behaviour cannot be attributed to another confounding variable (3) time precedence; the influence of the built environment (the cause) precedes a change in travel behaviour (the effect) in time and (4) plausibility; there should be a logical causal mechanism for the cause and effect relationship. Previous cross sectional studies have met the first condition but hardly the other three (Handy et al., 2005).

The application of more rigorous (quasi-)longitudinal approaches is still limited on the BE-TB link. A couple of studies used prospective longitudinal designs and found a significant influence of the built environment (Krizek, 2003a; Meurs and Hajer, 2001) but these did not include travel-related attitudes. Bamberg (2006) did incorporate attitudinal questions before and after a residential move but did not explicitly assess the impact of changes in the built environment on travel behaviour. The studies of Handy et al. (2005) and Cao et al. (2007) used a quasi-longitudinal research design based on retrospective questioning. However, as retrospective questioning on attitudes is generally considered unreliable, these studies only controlled for current attitudes. They concluded that residential self-selection influences the relationship between built environment and travel behaviour but that the built environment still exerts an independent but small influence on travel behaviour.

To the authors knowledge there have been no studies on the BE-TB link that have applied a prospective longitudinal design and have included the measurement of travel-related attitudes on two or more moments in time. Furthermore, reverse causal effects from travel-related attitudes to behaviour have been scarcely studied. This article builds on the current literature and aims to reduce this gap by evaluating the bidirectional relationships between (changes in) the built environment, travel-related attitudes and travel behaviour over time.

3. Data and methods

3.1 Data collection

This study builds on previous work and the previous data collection of Bohte (2010) who also studied the role of attitudes in residential self-selection. For this purpose data was collected in three municipalities in the Netherlands in 2005: Amersfoort, a medium-sized city, Veenendaal, a small town with good bicycle facilities and Zeewolde, a remote town. Within these municipalities, different types of residential areas were selected ranging from historical centres to suburban areas, and representing a wide variety of built environment characteristics, including car-friendly, bicycle friendly and public transportation friendly areas (see Figure 2). GIS-software was used to obtain detailed data on land use, infrastructure and accessibility.

From each of these areas a random sample of households was drawn from the civil registries, limited to homeowners because renters have a very limited choice set which hinders self-selection on the Dutch housing market (Bohte, 2010). An internet questionnaire was conducted in 2005 with questions about demographic, socioeconomic, attitudinal and travel related characteristics. Both partners in a household were asked to participate. From the 12.836 people who were approached, 3.979 completed the questionnaires – a baseline response rate of 31% (Bohte, 2010). After this initial data collection round, annual postcards and emails were sent to maintain contact with the respondents and respondents were invited to provide information regarding house moves and changes in contact details. We were able to contact approximately 3300 respondents (83%) again for a second-round questionnaire in 2012. The other respondents dropped out for a variety of reasons (e.g. house moves to an unknown destination, changed and unknown contact details, and some had passed away). From these 3300 respondents, 1788 participants from 1325 different households participated again in the second round, a response rate of 54%. Logistic regression was conducted to test whether a systematic drop-out had occurred between the research rounds. Results revealed that younger and less educated respondents, females and respondents from households with young children were more likely to drop out.

For this second wave, we only selected participants that had participated in both questionnaires. Due to the selection of homeowners at baseline, the aging of our sample (also called stagnation effect), and the selective drop out, older people with a higher education level and higher incomes are overrepresented in our sample compared to population statistics of the neighbourhoods. The relatively high average age (57 years) in the second wave is apparent. Still, our panel encompasses 425 people aged between 33 and 51. To avoid any problems with dependency of observations in the analysis, we randomly selected one of the partners from the 463 households of which both partners participated. Furthermore, a couple of cases were removed because their data was incomplete on important variables. As a result, 1322 respondents were included in analyses for this article. In addition, new GIS analyses were conducted to obtain data on the spatial characteristics in 2012 and 2005 and changes that occurred over this time period.

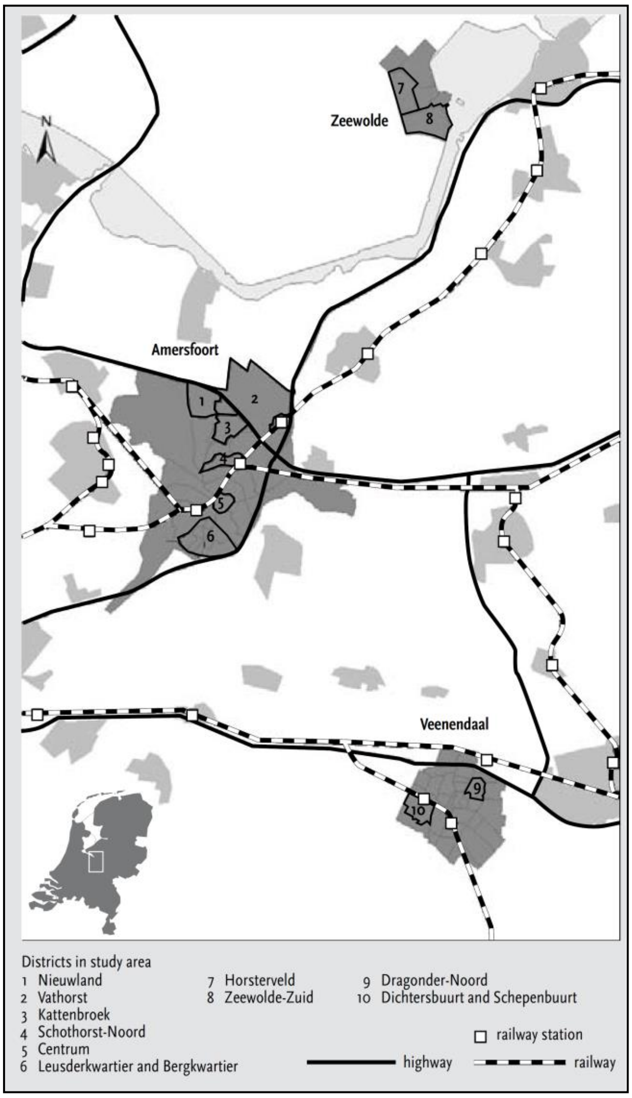

Figure 2. Study area. Source: Bohte, 2010.

3.2 *Variables*

Table 1 provides an overview of the key variables and their descriptive statistics in the first (2005) and second wave (2012). Travel behaviour was assessed with the question: "How often do you use the car compared to other modes such as public transport, bicycling and walking". Responses were provided on a 7-level Likert scale ranging from 1: "Almost never with the car and almost always with alternatives" to 7 "Almost always with the car and never with alternatives". On average, respondents used their cars quite often. A single question is not a very precise measure to assess the various (sub)dimensions of an individual's travel behaviour such as distances or travel times travelled and split by mode. However, deriving the mode split by asking people for their travel distances or travel times per mode, may offer pseudo-accuracy, while this simple measure directly reflects how people assess their mode split. Moreover, another benefit is that the full complexity of a person's travel behaviour can be parsimoniously captured.

Attitudes towards car use, cycling and public transport use were measured by asking respondents to rate 9 statements on a 5-level Likert scale, ranging from –2 'strongly disagree' to +2 'strongly agree'. These statements included affective (e.g. "driving a car is pleasurable") as well as cognitive (e.g. "bicycling is environmentally friendly") aspects. The 9 responses were then summed up to determine a person's travel-related attitudes. An additional attitude variable was weighted by the importance, measured on a 5-level scale, to reflect that people do not always attach the same importance to each of these aspects, which can lead to an overvaluation of non-salient and unimportant beliefs. As the weighted and unweighted TA yielded highly similar results, we used the unweighted one. The mean values in Table 1 indicate that cycling attitudes are most positive, whereas public transport attitudes are negative.

The built environment was operationalized by measures of accessibility. Shortest routes between respondents' homes to a variety of destinations were calculated along the network (source of road network: Dutch National Roads Database (NWB, 2013). Destinations included, amongst others, the municipal centre, the neighbourhood shopping centre, the nearest railway station and

Table 1. Key variables in 2005 and 2012 (N=1322)

Variables	Description	2005 Mean (st.dev)	2012 Mean (st.dev)
Travel behaviour variables			
Modal choice	Amount of car use compared to other modes	4.8 / (1.9)	4.7 (1.9)
Attitudinal variables			
Travel-related attitudes	Car attitude	2.8 (4.9)	3.5 (4.7)
	Public transport attitude	-4.8 (5.8)	-3.8 (6.1)
	Bicycle attitude	9.0 (4.9)	9.3 (5.1)
Built environment variables			
Residential location	Amersfoort	41.2%	39.7%
	Veenendaal	27.0%	26.8%
	Zeewolde	31.8%	28.7%
	Other	0%	4%
Average distances	To municipal centre	1949 (775) m	1955 (870) m
	To nearest shopping centre	1123 (778) m	1161 (819) m
	To nearest railway station	6150 (5458) m	5627 (5721) m
	To nearest bus stop	604 (566) m	495 (483) m
	To nearest highway ramp	5491 (5001) m	5255 (5048) m
Socio-demographics			
Age	Average	50.4 (10.6)	57.4 (10.6)
Gender	Female	42.7%	42.7%
	Male	57.3%	57.3%
Household composition	Single household:	7.1%	9.3%
	Single parent	1.7%	2.6%
	Partners without children	34.2%	44.3%
	Partners with children	56.4%	42.7%
	Other	0.6%	1.1%
Education	Low:	9.9%	9.6%
	Medium	37.6%	36.5%
	High	52.5%	53.9%
Net personal income (monthly)	Low (< € 1.000)	19.0%	12.2%
	Middle (>=€1.000,-< €2000,-)	39.4%	33.1%
	High (>€2000,-)	42.6%	54.7%
Paid work	No job	20.3%	31.3%
	Part-time job (< 30 hours)	24.9%	21.3%
	Fulltime job (>= 30 hours)	54.8%	47.4%
Car ownership	No car	2.5%	3.0%
	One car	51.9%	52.3%
	Two cars	41.4%	40.9%
	More than two cars	4.2%	3.9%
Dynamics in panel		*Change*	
Residential location and work location	Number of movers in database	250 (19%)	
	Number of changes in job location	315 (24%)	
Car ownership	Decrease	14.1%	
	No change	72.7%	
	Increase	13.2%	
Modal choice (car use compared to other modes)	Decrease	31.8%	
	No change	39.0%	
	Increase	29.0%	

bus stops (with different levels of service) and highway ramps. Also, distances to services such as supermarkets, restaurants and pubs were measured. The coordinates of the destinations were derived from a retail database (Locatus, 2013) and the national employment database (LISA, 2013). Two types of accessibility measures were included in the analyses: (i) the distance to the nearest occurrence of each type and (ii) the number of locations of each type within 400, 3000 and 10.000m.

The average decline in distance to the nearest railway station can be attributed to the opening of a new railway station in Amersfoort (Vathorst) which opened in May 2006.

Socio-demographic variables included gender, age, household income, household composition, educational level and economic status. The majority of homeowners in our sample live together with a partner and have a relatively high education level and income. Most households own one or two cars (with an average of 1.5 cars per household). The table shows a couple of apparent changes in the panel; the amount of partners without children has increased as children left the house and the amount of people without a job increased due to people reaching pension age and due to job losses related to the economic crisis. However, the overall statistics cover underlying dynamics in the sample. Almost 1 in 5 respondents moved house and 1 in 4 experienced changes in their job location. Also, considerable changes occurred in car ownership levels and travel behaviour.

4. Modelling approach and specification

4.1 Modelling approach

As mentioned in the introduction, in this paper we apply the Cross-Lagged Panel Model (CLPM) within a framework of structural equation modelling (SEM). The CLPM is well suited to assess the causal dominance among the variables of interest. In this model, each variable is regressed on its own values and on the values of other variable(s) of interest at a previous point in time. The autoregressive effect from each variable on itself at a later time reflects its stability. A small effect indicates that a substantial change has occurred over time whereas a large effect reflects a high stability and little change over time. The remaining variance, after controlling for the autoregressive effects, can be ascribed to changes in the period between the measurement occasions. This variance may be (partially) explained by the cross-lagged effects from other variables at a previous point in time. If another variable has a significant cross-lagged effect, while accounting for the initial overlap between the variables at the first point in time, this variable can effectively predict 'change' in the first variable from the first point in time to the next (Selig & Little, 2012). Hence, in contrast to cross-sectional analyses, CLPMs are able to satisfy the criterion of time-precedence empirically (Finkel, 1995). It thus provides a stronger basis for making causal inferences.

4.2 Specification

Figure 3 shows the specification of the relationships between the built environment, travel behaviour, travel-related attitudes and household characteristics (as depicted in Figure 1) in the CLPM. The built environment is reflected by the built environment characteristics of the residential location, respondents' travel behaviour is reflected by mode use and travel-related attitudes are reflected by mode attitudes. In addition, baseline values as well as changes in socio-demographics are included.

In this model, correlations C1, C2 and C3 account for the initial overlap between the variables (due to previous causal influences vice-versa or possible shared causes), S1, S2 and S3 represent the stability coefficients, and L1 – L6 represent the over-time (cross-)lagged influences between mode use, travel-related attitudes and the built environment. In addition, D1 – D3 represent the influences of socio-demographic variables (and changes in these variables) that were included as control variables. It is assumed that the baseline values of the socio-demographic characteristics may influence travel behaviour and travel-related attitudes both at the first point in time (reflecting cross-sectional relationships) and at the second point in time (reflecting longitudinal relationships). The changes in the socio-demographics are only assumed to affect mode use and travel-related attitudes at the second point in time. Hence, it is assumed that travellers only respond to changes in these variables (lagged effects) and do not change their mode use or attitudes in anticipation of these changes (lead effects). Correlations C4, C5 and C6 account for the association that remains after accounting for the stability (S1, S2 and S3) and cross-lagged effects (L1-L6) and the included covariates (D1-D3). The significance and strength of the parameters L1-L6 indicate the primary direction of causality and allows us to answer the questions: does this relationship primarily run from travel-related attitudes to travel behaviour; is the reverse influence of travel behaviour on attitudes stronger or do effects run in both directions?

Synchronous effects, e.g. from travel-related attitudes to mode use at the second point in time and/or vice versa, are not modelled. A synchronous effect should be understood as a change in one variable at the second occasion resulting from a change in the other variable at some time after the first occasion. While it is certainly theoretically justifiable to include such synchronous effects in the present application (because of the long-time interval between measurement occasions), inclusion of these effects will lead to problems with endogeneity (explanatory variables will be correlated with error terms) and possibly also identification problems (when it is not possible to uniquely estimate all of the model's parameters (see Kline, 2010)). We therefore decided not to include these effects in the model. It should be noted, however, that while the model is not able to provide direct evidence in favour of synchronous effects, the strength and significance of the C4-C6 correlations will inform us whether synchronous effects are likely present or not.

Finally, measurement errors of attitudes have been accounted for in the analyses. This feature is especially relevant with respect to the travel-related attitudes, as they (unlike the other variables in the model) can be conceptualized as latent constructs. To indicate that the travel-related attitudes are treated as such, they are represented as circles in the model.

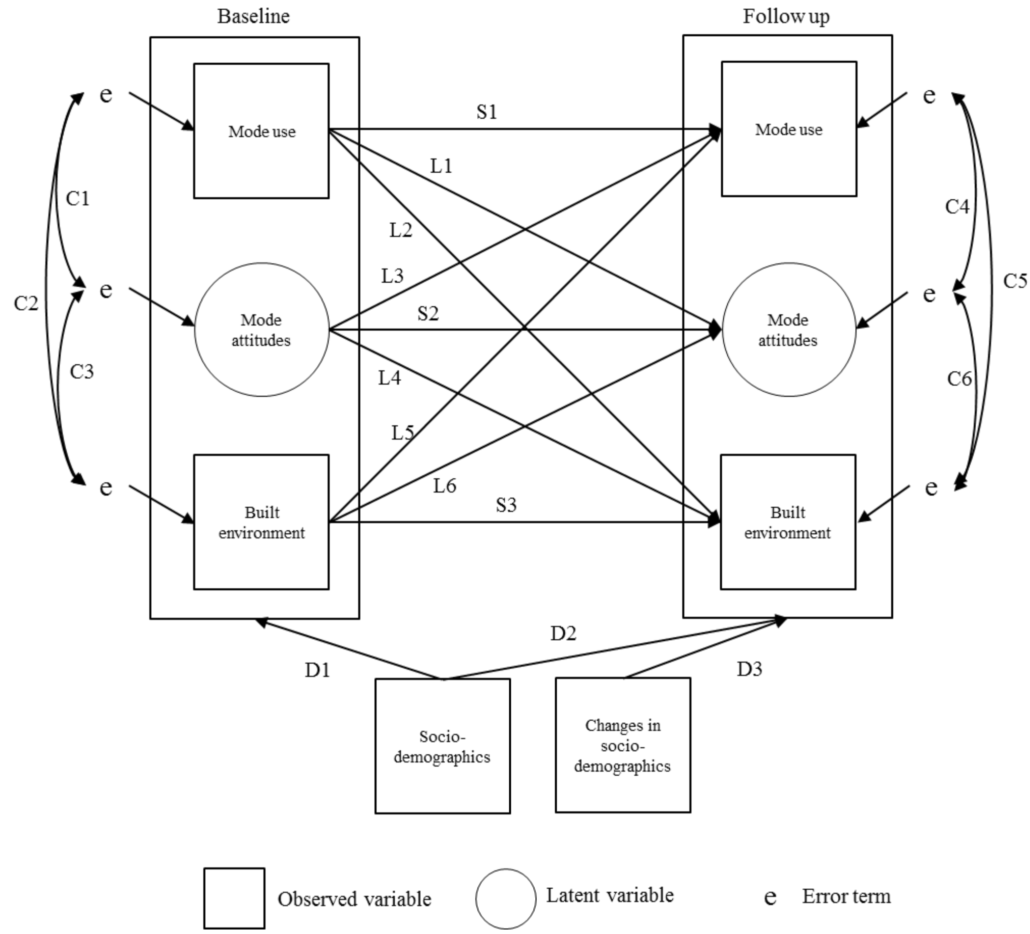

Figure 3. Specification of the cross-lagged panel model

4.3 Specification issues

The maximum likelihood (ML) estimation, the most often used method in SEM, was applied. In ML, the multivariate normality is assumed for the distribution of the endogenous variables. In practice, many studies fail to meet this condition. Even though ML parameter estimates seem relatively accurate in large samples, the estimated standard errors tend to be too low which results in type I errors (a 'false' significant effect). Statistical test of model fit also tend to be too high which results in a rejection of a 'correct' model (Kline, 2010).

Distances to destinations and car ownership were non-normally distributed (which is a common characteristic of these variables). Transformations to meet the normality assumption were considered but this did not result in a more normal distribution. To assess the impact of non-normality, a mean- and variance-adjusted weighted least square parameter estimator (WLSMV) was also applied on the same CLPM as an alternative estimator. WLSMV is a robust estimator which does not require normal distributions (Kline, 2010). Both estimation methods led to a comparable result which suggests that the non-normal distributions did not significantly affect the model outcomes. However, in some models the WLSMV estimator did not converge, which may be due to the fact that this estimator typically requires a larger sample size than the ML estimator. Therefore, in the next section, only the results of the ML estimation are discussed.

In addition, it is argued that the impact of non-normality is reduced in larger samples. Following Cao et al. (2007), the ratio between sample size and the number of observed variables and the power for hypotheses testing in our sample was assessed. The ratio between our sample size and the number of observed variables is relatively large (1322/24=55) compared to the suggested minimum ratio of 15 (Stevens, 1996). In addition, with 59 degrees of freedom the power for hypotheses testing is 0,99 for sample sizes larger than 500 (MacCallum et al. 1996). Due to the large sample and high power, the impact of non-normal distributions in this research is reduced.

Previous studies on the BE-TB link have often resulted in mixed outcomes (see literature review). This can be attributed to a variety of reasons including different estimation methods and the type of control variables that are included in the analyses. To enrich the understanding regarding the impact of control variables on the research outcomes, multiple SEM models were built and differences in outcomes were assessed. The outcomes of two models will be described in detail in the following section. In the first model, effects were estimated for the endogenous variables, namely mode use, mode attitudes and built environment characteristics. In the second model we first added socio-demographic control variables (considered exogenous) and then car ownership (considered endogenous). The influence of car ownership has been estimated separately because most of the households in our sample own one or two cars. Consequently, its distribution is non-normal which does not comply with the data distribution requirements of endogenous variables in SEM. By including car ownership in a separate model we have been able to assess its impact on the relationships between other variables in the model. This impact proved to be very limited. Therefore, it was decided to include the effects of car ownership in the description of the outcomes of the second model. Nevertheless, the results with regard to car ownership should be interpreted with considerable caution.

5. Results

Tables 2 and 3 present the unstandardized and standardised estimates of the two models; Model 1 includes only endogenous variables, while in Model 2 also sociodemographic variables (considered exogenous) and car-ownership (considered endogenous) were added. The relationships between the baseline socio-demographics and the built environment, mode use and mode attitudes in 2005 (link D1 in figure 3) are included in the continued part of Table 3.The results will be discussed according to our research questions and a number between brackets (#) will be used to refer to the links in the model conceptualisation in Figure 3.

The final models were constructed through model trimming, that is, that all non-significant relationships were removed from the models. Variables that were left with no path were removed from the model. It is important to note that these included the dummies for job changes (yes/no) and residential relocation (yes/no) because they yielded no significant results.

The overall fit statistics of the models are included in the tables. All models appear to have good fits. Chi-square statistics indicate that the models could not be rejected at the 1 per cent probability level ($p<0.01$). RMSEA (values of less than 0.05 indicate good fit); TLI and CFI (closer to one indicate better fit) also indicate good fit. This is not surprising since we removed non-significant results from a saturated model.

5.1 The influence of the built environment on travel behaviour

The results of the Model 1 indicate one significant effect of the built environment on travel behaviour: those living further away from the railway station in 2005 have a higher share of car use in 2012 [L5]. Hence, 'continued exposure' to low PT access induces higher car use over time. This outcome corroborates earlier findings of Bohte (2010) based on the cross sectional dataset of 2005 and provide stronger evidence for causality in this relationship as the influence of built environment characteristics precede the change in car use in time, thereby meeting the time precedence criterion for causality. Surprisingly, this lagged influence of the built environment is relatively strong; the standardized effect is stronger than the standardized effects of the individual travel-related attitudes, socio-demographics and car ownership. Other determinants of the built environment (such as distances to local shopping areas and other destinations and the proximity to activity places) do not seem to exert a significant influence on the share of car use.

Model 2 shows that the inclusion of the socio-demographic control variables only marginally affects the influence of the distance to the railway station on travel behaviour. Interestingly, there are no significant lagged effects of baseline socio-demographics or 'change' variables such as residential moves, job changes or changes in household composition on travel behaviour in 2012 [D2-D3]. Nevertheless, the baseline socio-demographic variables significantly add to the explanation of the initial travel behaviour in 2005 [D1]. This confirms the adage, "association does not prove causation". Apparently, a large portion of the influence of the baseline socio-demographic variables on travel behaviour in 2012 is captured by the stability effect of travel behaviour from 2005 [S1] and changes in socio-demographics cannot explain the changes in travel behaviour in 2012. Compared to travel behaviour, the distance to the railway station is clearly more stable over time [S3]. Nevertheless, socio-demographic variables exert small but significant influences on this variable [D2]. Older respondents and those living together in households with children (compared to single person households) in 2005 tend to increase their distance from the railway station in 2012 while the opposite applies to respondents that worked fulltime in 2005.

Car ownership is significantly influenced by the built environment over time: people living further away from the railway station in 2005 not only have a higher share of car use, but also higher car ownership rates in 2012. In turn, car ownership significantly influences travel behaviour: people who own more cars in 2005 have a higher share of car use in 2012. In addition car ownership not only influences travel behaviour but the reverse is also true: higher car use in 2005 has a positive effect on car ownership in 2012. Hence, these findings support earlier findings that car ownership (partly) mediates the link between the built environment and travel behaviour (Handy et al., 2005; Cao et al., 2007).

5.2 *Influences between attitudes and the built environment*

Model 1 does not reveal any significant influences of the lagged travel-related attitudes (2005) on the distance to the railway station in 2012 (or any other built environment determinant). Note that this may partially be related to the high stability of this variable over time [S3]. Conversely, significant longitudinal effects are found in the opposite direction: people living further away from the railway station not only increase their car use over time but also develop a more favourable attitude towards the car and a less favourable attitude towards PT [L6]. Hence, the 'continued exposure' to low PT access not only induces car use but also affects attitudes providing support for the reverse causality hypotheses on this link as suggested by Handy et al. (2005), Bohte (2010) and Chatman (2009).

The inclusion of the socio-demographics and car ownership in Model 2 (Table 3) only slightly affects the reverse influence of the built environment on travel-related attitudes which supports the robustness of these parameter estimates. Without discussing the effects of the socio-demographic characteristics in too much detail, it can be observed that, overall, the signs of the baseline effects in 2005 and lagged effects are in expected directions [D1-D2]. For example, men have a more favourable attitude towards the car (compared to women) and, over time, develop an even more favourable attitude towards the car. Highly educated people, on the other hand, have a more positive PT attitude (compared to people with a medium education level) and over time develop a more negative attitude towards the car. Another interesting finding is that, people who are older at baseline tend to develop a more positive attitude towards PT over time.

Car ownership is significantly related to the distance to the railway station and also effects travel-related attitudes: people with higher car ownership in 2005 tend to develop a more positive attitude towards the car and a more negative attitude towards public transport.

5.3 *Influences between attitudes and travel behaviour*

In model 1, car use in 2012 is positively influenced by the car attitude in 2005 and negatively by the cycling attitude in 2005 (Table 2). Hence, the baseline travel-related attitudes are able to predict changes in people's car use over time [L3]. It seems that the direction of influence primarily runs from attitudes to travel behaviour. However, reverse causality is also found on this link: higher car use in 2005 has a positive effect on car related attitudes in 2012 [L1]. Furthermore, it is apparent that the autoregressive relationships are strong. The dictum, "past behaviour is the best predictor of future behaviour" seems to apply: higher car use in 2005 has a strong positive effect on car use in 2012 [S1]. The stability of travel-related attitudes is noticeably higher than stability of travel behaviour; the car attitude is most stable [S2]. This is in line with expectations since behaviour is assumed to be more volatile than attitudes. Aside from the autoregressive effects, a more positive PT attitude in 2005 has a small but significant negative influence on the bicycle attitude in 2012. This is also the only significant interaction between attitudes which implies that attitudes towards a certain transport mode generally do not influence the attitudes towards the other modes over time.

The inclusion of socio-demographics and car ownership (Model 2) results in an important finding: the reverse influence from car use (2005) on car related attitudes in 2012 is no longer significant while the influence of car attitudes (2005) on car use (2012) is strengthened. This suggests that the reverse causality from car use on car related attitudes in the previous model was a spurious result related to the omission of the socio-demographic control variables.

Table 2. Model 1 with endogenous variables only (N=1322)

Endogenous variables 2012	Travel behaviour		Attitudes towards transport modes						Built environment	
Variables 2005	Car use 2012		Att. car 2012		Att. PT 2012		Att. bicycle 2012		Distance to railway station 2012	
	b	β	b	β	b	β	b	β	b	β
Travel behaviour										
Car use 2005	0.490**	0.490	0.164**	0.077						
Attitudes										
Att. car 2005	0.056**	0.125	0.707**	0.745						
Att. PT 2005					0.739**	0.696	-0.058**	-0.066		
Att. bicycle 2005	-0.054**	-0.121					0.693**	0.648		
Built environment characteristics										
Distance railway station 2005 (km)	0.048**	0.135	0.047**	0.063	-0.157**	-0.153			0.975**	0.931
	R^2= 0.44		R^2= 0.76		R^2= 0.85		R^2= 0.81		R^2= 0.87	

Chi-square: 14.140 , 13 df, p: 0.3640, RMSEA: 0.008 , Prob. RMSEA <= .05: 1.000, TLI: 1,000, CFI: 0.999

Table 3. Model 2 with car ownership and controls for socio-demographics (N=1322)

Endogenous variables	Travel behaviour		Attitudes towards transport modes						Built environment		Car ownership	
Exogenous variables	Car use 2012		Att. car 2012		Att. PT 2012		Att. bicycle 2012		Distance to railway station 2012		# cars in hh. 2012	
	b	β	b	β	b	β	b	β	b	β	b	β
Travel behaviour												
Car use 2005	0.468**	0.468									0.025*	0.071
Attitudes												
Att. car 2005	0.055**	0.123	0.711**	0.748							0.014**	0.090
Att. PT 2005					0.723**	0.679	-0.059*	-0.067				
Att. bicycle 2005	-0.054**	-0.121					0.708**	0.660				
Built environment												
Distance railway station 2005	0.046**	0.132	0.051*	0.068	-0.138**	-0.135			0.981**	0.936	0.011**	0.093
Car ownership												
# cars in HH 2005	0.141*	0.047	0.405*	0.064	-0.454*	-0.052					0.462**	0.442
Socio demographics												
Gender (ref=female) 2005			0.590**	0.071								
Age 2005					0.026*	0.049			0.020**	0.037	-0.010**	-0.160
High education level (ref=middle) 2005			-0.513*	-0.063							0.071*	0.052
Low income (ref=middle) 2005											0.150**	0.073
Work_fulltime_2005							1.012**	0.109	-0.328**	-0.029		
Family with children (ref= single-person hh) 2005									0.333**	0.029		
	R^2= 0.44		R^2= 0.76		R^2= 0.85		R^2= 0.81		R^2= 0.87		R^2= 0.35	

Table 3. Model 2 with car ownership and controls for socio-demographics (continued)

Endogenous variables	Travel behaviour		Attitudes towards transport modes						Built environment		Car ownership	
Exogenous variables	Car use 2005		Att. car 2005		Att. PT 2005		Att. bicycle 2005		Distance to railway station 2005		# cars in hh. 2005	
	b	β	b	β	b	β	b	β	b	β	b	β
Socio demographics												
Gender (ref=female) 2005	0.850**	0.219	2.226**	0.256			-0.926**	-0.106	0.673	0.061		
Age 2005	-0.025**	-0.139	-0.046**	-0.113	0.064**	0.129			-0.132**	-0.257	-0.004*	-0.066
High education level (ref=middle) 2005	-0.179	-0.047	-0.590*	-0.068	0.914**	0.087			-0.942**	-0.086		
Low income (ref=middle) 2005	-0.548**	-0.094	-0.951*	-0.072								
Work_fulltime_2005									-0.920*	-0.084		
Family with children (ref= single-person hh.) 2005	-0.564**	-0.146	-0.706*	-0.081	-0.578	-0.054	0.824**	0.095			0.210**	0.162
	R^2= 0.090		R^2= 0.089		R^2= 0.029		R^2= 0.021		R^2= 0.058		R^2= 0.038	

Chi-square: 52.748, 59 df, p: 0.7038 , , RMSEA: 0.000 , Prob. RMSEA <= .05: 1.000, TLI: 1,00, CFI: 1,00

5.4 Correlations between error terms

The results of the three models above show that the autoregressive effects [S1-S3] are (very) strong, but that the cross-lagged relationships between the endogenous variables [L1-L6] are rather weak. Two possible explanations can be offered. One is that the relationships between the endogenous variables are simply not that strong. The other explanation is that the time-lag (7 years) is probably rather long compared to the true lags with which the endogenous variables influence each other. In attitude theory, influences between attitudes and behaviour are assumed to be rather direct. However, the influence of positive and negative daily experiences on attitudes as described in Cullen's (1978) model, evolve more slowly (Thøgersen, 2006). Research of Chen and Chen (2009) indicates that behavioural effects of built environment changes could take up to 3 years to materialize. The long time-lag in the panel increases the likelihood that additional changes occur in one of the endogenous variables or in other (unobserved) variables after the first measurement point in 2005 that affect the values in 2012. The correlations between the error terms of the travel-related attitudes and car use (C1-C3 in 2005 and C3-C6 in 2012) indicate that this could indeed be the case here (see Table 4).

Table 4. Correlations between error terms of endogenous variables in 2005 and 2012

	Car use	Car attitude	PT attitude	Bicycle attitude	Distance railway station
Car use	-	0.199**	-0.138**	-0.127**	0.096**
Car attitude	0.425**	-	-0.109*	0.155**	0.037
PT attitude	-0.296**	-0.379**	-	0.150**	-0.019
Bicycle attitude	-0.344**	-0.241**	0.344**	-	0.073*
Distance railway station	0.306*	0.150**	-0.175**	-0.049	-

*p<0.05, **p<0.01

The correlations in the lower left triangle represent the initial overlap between the travel-related attitudes, car use and the built environment in 2005. It can be observed that significant and moderately strong correlations exist and that the signs are all in the expected directions. The correlations in the upper left triangle represent the correlations between the endogenous variables that remain in 2012 (after accounting for the stability, autoregressive and the covariate effects). These are generally lower (as expected). The correlations between travel-related attitudes and car use all remain significant. This indicates that either synchronous effects between travel-related attitudes and car use exist *or* that 'third variables' (not included in the model) have both influenced travel-related attitudes and car use in the period between the two measurements (see paragraph 4.2). An example of the first is an increase in car use after the baseline measurement in 2005 after which people started appreciating the flexibility of the car, leading to a more positive attitude. An example of the latter is a decline in oil prices after the baseline measurement in 2005 which makes car use cheaper, positively influencing car attitudes as well as car use. Given the relatively strong initial correlations (in 2005), it seems likely that these correlations can (at least partly) be ascribed to synchronous effects. Interestingly, the remaining correlations between the error terms of the distance to the railway station and the other variables are considerably smaller. Correlations with attitudes towards the car and public transport are no longer significant. This indicates that synchronous or 'third variable' effects do not play a major role here and that the estimates of the lagged effect of the distance to the railway system on the attitudes towards the car and public transport reflect its long term influence.

5.5 Multi-group analyses

In the previous models all respondents have been incorporated. As described in Table 1, our total sample is relatively old. This may have led to a relative higher stability (autoregressive effects) over time as older people become set in their ways. Furthermore, 81% of the households have not moved during the seven year period between the research rounds. This may have attributed to the absence of a significant residential self-selection effect. To explore the effects of the sample composition we conducted two additional multiple group analyses on the sample: 1) a group analysis between people aged 30-51 and people aged 51+ in 2005 and (2) a multi-group analysis between movers and non-movers.

The analysis with different age groups revealed that the stability of both groups with regard to their attitudes, travel behaviour and built environment are rather comparable. The older age group appears to be even more dynamic as their attitude towards bicycling is less stable (standardized autoregressive effects are 0.588 versus 0.767; >0.01). This might be related to health issues of older people that affect their opportunities for bicycling. The small difference between the age groups may be related to the fact that most dynamics with regard to changes in residence, employment and travel behaviour take place early in life. After reaching the age of 30 years, the propensity for change drop rapidly, only to slightly rise again when people reach pension and/or old age (Beige and Axhausen, 2012). The second multi-group analysis, between movers and non-movers, did not reveal any significant residential self-selection effects within the group of movers. This may be related to the fact that most households moved locally, within a short distance from their old residence. Therefore, changes in distances to the railway station do occur but remain small. This is supported by the autoregressive effects for both groups (0.705 for movers versus 1.00 for non-movers; >0.01). Furthermore, the year of move may have influenced the effects of the built environment on travel behaviour as these effects can take years to materialize (Coevering *et al.*, 2015). To control for the different time lags, the variable 'year of move' was included in the analysis for the movers. However, this variable did not have a significant effect on travel behaviour indicating that differences in the amount of time that movers were 'exposed' to their new residential environment did not significantly affect their travel behaviour above and beyond the effect of the new environment itself.

6. Conclusions and discussion

Building on cross-sectional studies about the impacts of the built environment on travel behaviour, this study departed from the assumption that longitudinal studies can provide stronger evidence for causal relationships. A cross-lagged panel structural equation model was developed based on a two-wave longitudinal dataset to analyse the impact of the built environment on travel behaviour and the directions of causality on the links between the built environment, travel behaviour and travel-related attitudes. The variables in 2012 were regressed on their 2005 counterparts and cross-lagged effects between all variables of interest were included.

Our results suggest that there is a causal influence from the built environment on travel behaviour: the distance to railway stations in 2005 has a significant and (compared to the other determinants) relatively strong influence on the share of car use in 2012. Presumably, people living in areas in closer proximity to the railway station, which generally provides better conditions for alternative transport modes, are more inclined to start using these alternatives. However, other determinants of the built environment (such as distances to local shopping areas and other destinations and the proximity to activity places) do not seem to exert a significant influence on the share of car us. The question is why this particular dimension of the built environment stands out. In this case it might be related to the large variety in the distances to railway station in the sample, which is in Veenendaal 1,5 km on average, in Amersfoort 3,1 km and in Zeewolde 13,9 kilometres. In contrast, differences in distances to the nearest shopping centres and municipality centres are relatively small which is partly due to the strong land-use and retail planning traditions in the Netherlands (Van Wee & Maat, 2003). Hence, it seems that differences in built environment characteristics have to be quite large to exert a significant influence on travel behaviour.

In contrast to earlier studies in this field, we found no effects from travel-related attitudes on the built environment, indicating that attitude-induced residential self-selection did not significantly affect residential location choices. Importantly, we did find significant effects in the other direction, i.e., after living closer to a railway station people tend to adjust their attitudes in favour of public transport. These results are in line with Bamberg's findings (2006) who reported more positive attitudes towards alternative transportation modes after moving to areas with better public transport provision.

In line with attitude theory, it appears that travel-related attitudes affect travel behaviour, rather than the other way around. From a methodological point of view it is important that reverse causality was found in the model that only included the endogenous variables (built environment, travel behaviour and attitudes). However, after controlling for socio-demographics this influence was no longer significant. This might indicate that this relationship was spurious in the model that included the endogenous variables only.

A remarkable finding was the high temporal stability of attitudes. We were surprised that even after 7 years, people's attitudes hardly changed. In addition, the attitude's interrelationships were weak meaning that even if people did change their attitude towards for instance car use, it does not imply that they have necessarily developed more positive (or negative) ones towards other transport modes.

Finally, the findings point to a significant and intermediate role of car ownership on the link between the built environment and travel behaviour, as suggested in literature. However, as the car ownership variable does not fully comply with the normality assumption of the ML estimation method, these results should be interpreted with considerable caution.

Even though the longitudinal modelling approach in this study provides additional opportunities for causal research on the BE-TB link, some remarks should be made. First of all, the time lag of 7 years between the research rounds is relatively long. During this period, unobserved changes may have taken place in the endogenous variables and in exogenous variables that affect the variables in 2012. One or more intermediate measurements points would have given better insights. The correlations between the error terms of the endogenous variables in 2012 indicate that the effects of unobserved changes are most profound on the bidirectional relations between attitudes and travel behaviour. The relations between attitudes and the distance to the railway station do not seem to be affected. This makes sense as changes in the built environment do not occur very often and as it may take relatively long before people adapt to changes in their environment. Second, a more precise measurement of travel behaviour than share of car use, measured using a Likert scale would be preferable to assess the links between the transport modes and their related attitudes. Including more detailed indicators derived from travel dairies or GPS based research such as distances travelled or travel times will provide a more comprehensive picture of the way in which the built environment affects different dimensions of travel behaviour.

Taken together, findings from this study provide some support for land use policies that aim to influence travel behaviour. The significant influences of the distance to the railway station on travel behaviour and travel-related attitudes are promising. It implies that urban planning concepts such as the compact city, New Urbanism and Transit Oriented Development, may not only provide opportunities for segments of the population who already favour living in more compact transit-accessible environments with alternatives to car use. In addition, these concepts may encourage other segments of the population to start appreciating such an environment and increase their use of car alternatives after living there for a while. Even though net effect of the built environment is by itself not sufficient for realizing large changes, the built environment may play an important role in comprehensive packages of policies and programs (e.g. pricing policies, promotional campaigns) which aim to bring about substantial changes in travel-related attitudes and travel behaviour.

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