# Causale invloed van ruimte op mobiliteit?

# een longitudinale benadering

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**Samenvatting**

Een groot deel van de kennis op de relatie tussen mobiliteit en ruimte is gebaseerd op cross-sectie onderzoek waarbij op één moment in de tijd data wordt verzameld. Met deze onderzoeken zijn statistische verbanden aangetoond tussen mobiliteit en ruimte. Alhoewel deze onderzoeken inzicht kunnen geven in deze samenhang, leveren ze niet afdoende bewijs voor het bestaan van een causale relatie. Hiervoor moet onder meer een oorzaak-gevolg relatie worden vastgesteld: een verandering in mobiliteit (gevolg) moet dan optreden *nadat* er zich veranderingen in de ruimte hebben voorgedaan (oorzaak). Om dit aan te tonen is het gebruik van een longitudinaal onderzoeksdesign, waarbij op meerdere momenten in de tijd wordt gemeten, noodzakelijk.

Deze paper beschrijft de resultaten van een van de eerste longitudinale studies op de relatie tussen mobiliteit en ruimte. De studie bouwt voort op een eerdere studie van Bohte (2010). Omdat tijdens en na deze studie contact is onderhouden met de respondenten was het mogelijk om een groot deel van deze groep opnieuw uit te nodigen voor een tweede onderzoek. In beide ronden hebben respondenten een online vragenlijst ingevuld waarbij is gevraagd naar hun huishoudenskenmerken (o.a. huishoudenstype, inkomen, werkzaamheden), hun mobiliteitsgedrag (gebruik modaliteiten) en hun attitudes (houding ten aanzien van deze modaliteiten). De beschikbaarheid van attitudes op meerdere tijdsmomenten is uniek in dit type onderzoek. De ruimtelijke kenmerken van de woonomgeving zijn in kaart gebracht met behulp van GIS. Hiermee is een longitudinale dataset gecreëerd met twee meetmomenten: 2005 en 2012.

Het onderzoek had tot doel om de richting en kracht van de relaties tussen ruimte, mobiliteit en attitudes te analyseren. Tevens is gekeken naar de rol van autobezit. Voor de analyse is gebruik gemaakt Structural Equation Modeling (SEM). Specifiek hebben we een cross-lagged panel model geschat waarbij is gekeken in hoeverre basiswaarden van attitudes, modaliteitskeuzes en de woonomgeving in 2005 invloed hebben op deze zelfde variabelen in 2012. Daarnaast is gekeken naar de invloed van veranderingen in deze variabelen tussen de tijdsmomenten. De resultaten laten zien dat de afstand tot een treinstation, een kleine maar significante invloed heeft op zowel autogebruik als op attitudes voor vervoerwijzen. Dit impliceert dat vormen van ruimtelijk mobiliteitsbeleid zoals het compacte stadsbeleid, het VINEX-beleid en knooppuntontwikkeling een kleine bijdrage kunnen leveren aan het veranderen van de mobiliteit én de mobiliteitsvoorkeuren van mensen.

## 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 (BE) to influence travel behaviour (TB) (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. 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 BE can be used to influence TB. Meta analyses reveal that BE characteristics, in particular the accessibility of destinations, exert an independent but small influence on TB (Ewing and Cervero, 2010). However, discussions about the influence of the BE on TB 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 (TA) and residential preferences. Two additional hypotheses have been formed that provide an alternative explanation for the associations on the BE-TB link: (1) the residential self-selection (RSS) hypothesis and (2) the 'reverse causality' hypothesis. Both will be elaborated on in the next section.
The primary question is if the BE influence TB directly or if there is an indirect influence via attitudes. To date, relationships between these variables have been assessed by appying cross-sectional designs but these are not best suited to identify causal relationships because they do not assess the impact of the BE on TB over time and are unable to identify cause-effect relationships (see for an overview Van de Coevering et al., 2015). To overcome the limitations of previous studies, we conducted a longitudinal study where TB 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 BE, TB and TA. 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 TB, TA and the BE.

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

Figure 1 conceptualises the relationships between BE–TB and third variables: individual and household characteristics and attitudes and preferences. At the start of the causality debate, most studies hypothesized the direct relationship between the BE and TB (link 8). The study done by Newman and Kenworthy (1988), which found a significant relationship between urban densities and per capita energy use in a large range of world cities, is a famous example. 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 TB.

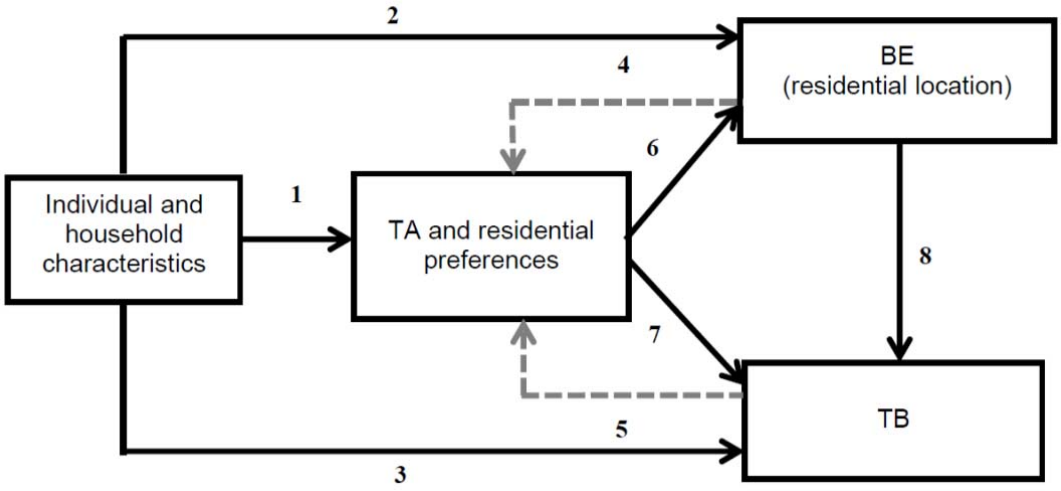


*Figure 1. Conceptual model of relationships between BE-TB and third variables. Adjusted from Bohte (2010)*

Policy concepts like New Urbanism, Smart Growth, Transit Oriented Development and Compact City policies 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. The BE seems to have small but significant associations with TB at different levels of aggregation ranging from regional accessibility to local street designs. Destination accessibility, the ease of access to trip attractions, appears to be most strongly associated with TB (Ewing and Cervero, 2010).
Since the end of the 1990s, the residential self-selection hypothesis (RSS) has become one of the prime topics in the discussion about causality. The general definition of RSS 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 RSS 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 BE 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 BE on TB may be limited to people who already favour walking and effects on people who are for instance car oriented may be limited. Numerous studies have appeared which assessed the influence of RSS. The research outcomes are mixed (Ewing & Cervero, 2010). For a more extensive insight we refer to reviews that focused on the role of attitudes and the issue of RSS (e.g. Cao et al., 2009; Bohte, 2010).
The 'reverse causality' hypothesis, where the BE influences TA [link 4], has received considerably less attention in studies on the BE-TB link. The same holds for reverse causal relationships between TA and TB (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 TA 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). Studies which assesed the reverse influences of the BE and TB found mixed outcomes (Bohte, 2010) A few transportation studies specifically explored reverse causality between TA and TB and provided support for this reverse causal hypothesis (e.g. Thøgersen, 2006).

Recently, the question was raised whether it is possible to convincingly test the bidirectional causal effects between the BE, TB and TA, using cross-sectional research designs (Handy et al., 2005). To identify a causal relationship on the BE-TB link four conditions should be met (Singleton and Straits, 2009): (1) association; the BE and TB are statistically associated, (2) non-spuriousness; relationship between the BE and TB cannot be attributed to another confounding variable (3) time precedence; the influence of the BE (the cause) precedes a change in TB (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. The handfull of (quasi-)longitudinal studies available (e.g. Cao *et al*., 2007), did not incorporate TA on two moments in time.
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 TA on two or more moments in time. Furthermore, reverse causal effects from TA 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 BE, TA and TB 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 RSS. 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 BE-characteristics, including car-friendly, bicycle friendly and public transportation friendly areas.
An internet questionnaire was conducted in 2005 and 2012 with questions about demographic, socioeconomic, attitudinal and travel related characteristics. Both partners in a household were asked to participate. At baseline, 3979 people completed the questionnaires, a response rate of 31% (Bohte, 2010). At follow up, 1788 people (out of 3300 that could be contacted) participated, a response rate of 54%. 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. As a result, 1322 respondents were included in analyses for this article.

### *3.2 Variables*

Table 1 provides an overview of the key variables and their descriptive statistics in the first (2005) and second wave (2012). TB 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. While a single self-report question is not a very precise measure to assess the various (sub)dimensions of an individual’s TB, a main benefit of using a single aggregate measure is that the full complexity of a person’s TB 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 TA. An additional TA-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 BE was operationalized by measures of accessibility. Shortest routes between respondents’ homes to a variety of destinations were calculated along the network. Destinations included, amongst others, the municipal centre, the neighbourhood shopping centre, the nearest railway station and bus stops (with different levels of

service) and highway ramps. Also, distances to services such as supermarkets, restaurants and pubs were measured. 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 TB.

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

| Variables | Description | 2005 Mean (st.dev) | 2012 Mean (st.dev) |
|---|---|---|---|
| *TB 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) |
| *BE 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 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% |
| 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% |

**Table 1 (continued)**

| Variables | Description | 2005 Mean (st.dev) | 2012 Mean (st.dev) |
|---|---|---|---|
| Paid work | No job | 20.3% | 31.3% |
| | Parttime 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%) | |
| | | 14.1% | |
| Car ownership | Decrease | 72.7% | |
| | No change | 13.2% | |
| | Increase | | |
| Model choice (car use compared to other modes) | Decrease | 31.8% | |
| | No change | 39.0% | |
| | Increase | 29.0% | |

## 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 effects 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).

### *4.2 Specification*

Figure 2 shows the specification of the relationships between the BE, TB, TA and household characteristics (as depicted in Figure 1) in the CLPM. The BE is reflected by the BE characteristics of the residential location, respondents' TB is reflected by mode use and TA is 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, TA and the BE. 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 TB and TA 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 TA 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 TA to TB; is the reverse influence of TB on attitudes stronger or do effects run in both directions? Finally, measurement errors of attitudes have been accounted for in the analyses.

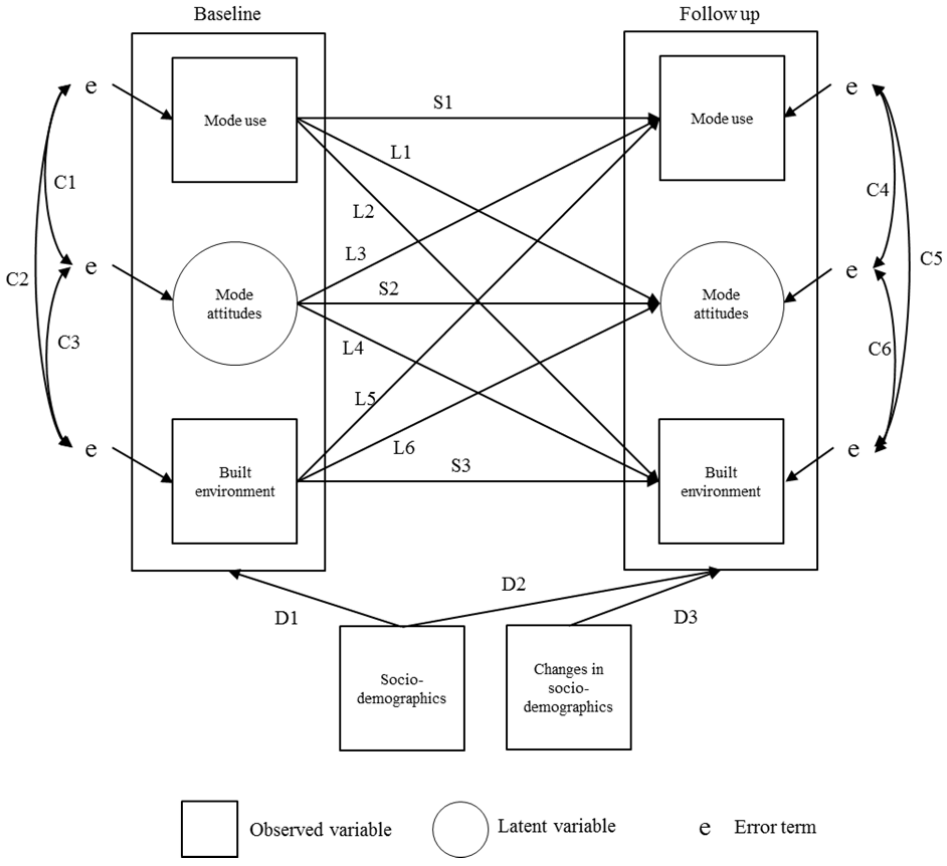


*Figure 2. Specification of the cross-lagged panel model*

## 5. Results

Tables 2 present the unstandardized and standardised estimates of the model. The results will be discussed according to our research questions and brackets (#) will be used to refer to the links in the model conceptualisation in Figure 2. In this paper, stability effects, cross-lagged effects and the effects of (changes in) sociodemographics are discussed. A complete desciption of the model results including correlations (C1-C6) and effects of sociodempgraphics on the baseline variables (D1) is available in (Coevering *et al.*, *submitted*).

### *5.1 The influence of the BE on TB*

The results indicate one significant effect of the BE: 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. These outcomes corroborate 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 BE characteristics precede the change in car use in time, thereby meeting the time precedence criterion for causality. Surprisingly, this lagged influence of the BE is relatively strong; the standardized effect is stronger than the standardized effects of the individual TA, socio-demographics and car ownership.

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 TB in 2012 [D2-D3].

Compared to TB, 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 BE 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 TB: people who own more cars in 2005 have a higher share of car use in 2012. In addition car ownership not only influences TB 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 BE and TB (e.g. Cao et al., 2007).

### *5.2 Influences between attitudes and the BE*

The model does not reveal any significant influences of the lagged TA (2005) on the distance to the railway station in 2012 (or any other BE determinant). Note that this may partially be related to the high stability of this distance over time [S3]. Conversely, significant longitudinal results 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 Bohte (2010) and Chatman (2009).
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 TA: 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 the BE*

Car use in 2012 is positively influenced by the car attitude in 2005 and negatively by the cycling attitude in 2005. Hence, the baseline TA 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 TB. 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 TA is noticeably higher than stability of TB; 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.

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

| Endogenous variables<br>Exogenous variables | Travel behaviour<br>Car use 2012 | | Attitudes towards transport modes<br>Att car 2012 | | Att PT 2012 | | Att bicy 2012 | | BE<br>Distance to railway station 2012 | | Car ownership<br># cars in hh 2012 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b | β | b | B | 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 | |

## 6. Conclusions and discussion

Building on cross-sectional studies about the impacts of the BE on TB, 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 BE on TB and the directions of causality on the links between the BE, TB and TA. The value of each of these variables in 2012 was regressed on its own value in 2005 and on the values of other variable(s) of interest in 2005.

Our results suggest that there is a causal influence from the BE on TB: 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 BE (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 BE 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 kilometers. In contrast, differences in distances to the nearest shopping centers and municipality centers 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 BE characteristics have to be quite large to exert a significant influence on TB.

In contrast to earlier studies in this field, we found no effects from TA on the BE, indicating that attitude-induced RSS 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 attitudes affect 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 (BE, TB 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 ones towards other transport modes.

Finally, the findings point to a significant and intermediate role of car ownership on the link between the BE and TB, 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 modeling 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 values in 2012. One or more intermediate measurements points would have given better insights. Second, a more precise measurement of TB than the qualitative measure used in this study, based on travel dairies or GPS, would be preferable to assess the links between the transport modes and their related attitudes.

Taken together, findings from this study provide some support for land use policies that aim to influence TB. The significant influences of the distance to the railway station on TB and TA 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 BE is by itself not sufficient for realizing large changes, the BE 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 TA and TB.

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