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Residential self-selection, reverse causality and residential dissonance. A latent class transition model of interactions between the built environment, travel attitudes and travel behavior

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ABSTRACT

Travel-related attitudes and dissonance between attitudes and the characteristics of the residential built environment are believed to play an important role in the effectiveness of land use policies that aim to influence travel behaviour. To date, research on the nature and directions of causality of the links between these variables has been hindered by the lack of longitudinal approaches. This paper takes such an approach by exploring how people across different population groups adjust their residential environments and attitudes over time. Two latent class transition models are used to segment a population into consonant and dissonant classes to reveal differences in their adjustment process. Interactions between (1) the distance to railway stations and travel-mode-related attitudes and (2) the distance to shopping centres and the importance of satisfaction with these distances are modelled. The models reveal mixed patterns in consonant and dissonant classes at different distances from these destinations. These patterns remain relatively stable over time. People in more dissonant classes generally do not have a higher probability of switching to more consonant classes. People adjust their built environments as well as their attitudes over time and these processes differ between classes. Implications for policies are discussed.

1. Introduction

Governments generally aim for more sustainable travel behaviour (Banister, 2008). One approach to this is to develop built environments that are conducive to the use of alternatives to the car (walking, cycling and public transport). In recent decades, policy measures such as densification and transit-oriented development have been applied for this purpose. While integrated spatial and transport planning is receiving increasing attention in policymaking, the causality and strength of the relationship between the built environment and travel behaviour (the BE-TB link) remains subject to academic debate. The research has been summarised in many reviews (see: Van Wee and Maat, 2003; Boarnet, 2011; Ewing and Cervero, 2010; Gim, 2013; Cao et al., 2009; Mokhtarian and Cao, 2008; Bohte et al., 2009; Chatman, 2014; Næss, 2014).

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1.1. Direction of causality

The causality debate revolves around the residential self-selection hypothesis. It assumes that people self-select in neighbourhoods that are conducive to the use of their preferred travel modes based on their travel abilities, travel-related attitudes, needs, and preferences (Handy et al., 2005; Cao et al., 2009; Bohte et al., 2009; Litman, 2005). For example, people with a favourable attitude towards public transport may choose to live in close proximity to railway stations. Overall, the literature supports the residential self-selection hypothesis, but the outcomes are mixed (Ewing and Cervero, 2010). While some studies, such as Kitamura et al. (1997), Bagley and Mokhtarian (2002) and Lund (2003), concluded that attitudes are more dominant than built environment characteristics, others found a significant influence of the built environment on travel behaviour, even after controlling for residential self-selection (Schwanen and Mokhtarian, 2005; Bohte, 2010; Van de Coevering et al., 2016; De Abreu e Silva, 2014; Lin et al., 2017). For more extensive reviews on this subject, we refer to Cao et al. (2009), Bohte et al. (2009), Ewing and Cervero (2010) and Gim (2013).

People are not always able to fully self-select, as they may be constrained by their income, household circumstances, supply in the housing market or other conflicting residential preferences. Moreover, life course events such as having a child can influence the needs and preferences of households, which may result in the occurrence of residential dissonance over time (Schwanen and Mokhtarian, 2004; De Vos et al., 2012). In addition to moving house (residential self-selection), people can adjust their attitudes towards their current residential neighbourhood in order to reduce residential dissonance. This reverse causality may occur for two reasons. First, according to the theory of cognitive dissonance (Festinger, 1957) people do not only adjust their behaviour but also their attitudes if dissonance occurs. In this case, people may adjust their travel-related attitudes to their residential choices. Second, according to Cullen (1978), people will have positive and negative experiences during their daily routines in their current social and spatial context and consequently adapt their attitudes over time. For example, if they live close to a railway station, people may become more familiar with public transport, start to see it as a good alternative travel option and consequently adjust their attitudes and travel behaviour (Bagley and Mokhtarian, 2002; Bamberg, 2006; Chatman, 2009; Bohte et al., 2009; Van de Coevering et al., 2016).

This reverse direction of influence has received considerable less attention in literature. To the best of our knowledge, only the studies of Bagley and Mokhtarian (2002), Bohte et al. (2009), Van de Coevering et al. (2016) and Lin et al. (2017) explicitly modelled multiple directions of causality, arriving at different conclusions. Bagley and Mokhtarian (2002) found evidence of residential self-selection but not of reverse causality, while Bohte et al. (2009) found that initial residential self-selection effects diminished after controlling for reverse causal influences. Lin et al. (2017) found reciprocal influences and concluded that direction of influence depends on people's ability to self-select. Van de Coevering et al. (2016) found no evidence of residential self-selection, but instead found reverse causality effects between the distance to the railway station and travel-related attitudes.

The dominant direction of causality between travel-related attitudes and the built environment is extremely important for integrated spatial and transport planning. If residential self-selection is dominant, measures such as densification and transit-oriented development environments would primarily benefit people who already have favourable attitudes towards sustainable travel behaviour. It is the combination of a person's attitude and the selection of a conducive neighbourhood that facilitates this behaviour.

This implies that the impact of the built environment on sustainable travel behaviour is influenced by the share of people who already have a positive attitude towards alternatives to the car and their ability to self-select conducive neighbourhoods. If the reverse causal direction is dominant, the built environment not only has a direct effect on travel behaviour but also an additional indirect effect, through its influence on travel-related attitudes. This would mean that controlling for residential self-selection by incorporating travel-related attitudes would lead to an underestimation of the impact of the built environment (Cao et al., 2009; Chatman, 2009; Handy et al., 2005; Næss, 2005; Næss, 2009).

1.2. Approaches to control for residential self-selection

To date, most evidence on residential self-selection is based on variable-centred models such as regression analyses and SEM modelling and most studies apply cross-sectional research designs (see: Mokhtarian and Cao, 2008 for a review). A simple way to control for residential self-selection is to include socio-demographics and travel-related attitudes that influence both travel behaviour and residential location directly in the models (Bhat and Guo, 2007). Kitamura et al. (1997) were the first to explicitly control for attitude induced self-selection in a cross-sectional design study. Since then, many other studies have controlled for the influence of residential self-selection in this way (Bagley and Mokhtarian, 2002; Bohte et al., 2009; Van de Coevering et al., 2016; Lin et al., 2017). A couple of studies use longitudinal or quasi-longitudinal data (Meurs and Haaijer, 2001; Krizek, 2003; Handy et al., 2005; Cao et al., 2007; Cao et al. 2007; Aditjandra et al., 2012; Van de Coevering et al., 2016; Klinger, 2017). To the best of our knowledge, Van de Coevering et al. (2016) were the first to collect attitudinal data at multiple moments in time. They applied linear cross-lagged panel analysis to asses longitudinal directions of influence. In addition to the inclusion of attitudes and socio-demographics, Schwanen and Mokhtarian (2005) introduced the concept of residential neighbourhood dissonance. They distinguished consonant and dissonant groups of urban/suburban residents and residents with a high/low preference for high-density living and compared their travel behaviour. They incorporated these measures of dissonance in their regression models and found that the impact of dissonance on travel behaviour differs between consonant and dissonant groups. Similar measures of dissonance were used by Frank et al. (2007), De Vos et al. (2012), Kamruzzaman et al. (2013) and Cho and Rodríguez (2014). For a more detailed overview we refer to Cao (2015).

Another less popular approach is based on person-centred analyses, which identify key patterns of values across variables, where the person is the unit of analysis. These analyses – with cluster analysis as a typical example – result in the identification of a small set of segments from a sample by maximising homogeneity within these segments and heterogeneity between segments (Bauer and Shanahan, 2007). In transportation studies, to the best of our knowledge, Anable (2005) was the first to use cluster analysis to define clusters based on attitudinal variables. However, the applications in studies on the interaction between land use and transportation are few. Manaugh and El-Geneidy (2015) used cluster analysis to create segments based on various aspects of housing choice, including financial constraints and preferences related to travel, neighbourhood and housing. Using regression analysis, they demonstrated that the influence of public transport quality on public transport use varies significantly between clusters. Liao et al. (2015) applied a discrete choice model in combination with a latent class analysis and found that preferences for compact walkable and transit-friendly developments are strongly associated with travel-related preferences and travel behaviour.

1.3. Research aim and approach

Previous research has primarily investigated whether attitudes are associated with residential location choice and travel behaviour by performing cross-section analyses. The purpose of this paper is to understand how people adjust their attitudes and their residential location over time, that is to say, in what circumstances do residential self-selection and reverse causal influences from residential choices on attitudes occur.

While determining the dominant direction of causality between these variables is important, it may oversimplify complex underlying adjustment processes. Therefore, we explore how the adjustment process differs across population groups, depending on people's residential dissonance. For example, it is assumed that people who prefer the train but live in suburbs that are not connected to a railway station (referred to as a dissonant situation) are more likely to move house or adapt their attitudes than those with the same preference who live in city centres close to a railway station (referred to as a consonant situation). We also analyse the role of socio-demographic characteristics. Households with children may, for example, have more difficulties finding a sufficiently large house in closer proximity to a railway station to reduce their travel-related dissonance.

In order to identify whether and how adjustment processes differ between various groups we apply latent class transition modelling (LCTM) on a longitudinal dataset. LCTM does not analyse direct lagged relationships between variables over time as in cross-lagged panel models (e.g. Van de Coevering et al., 2016). Instead, it is a segmentation technique – like cluster analysis – that inductively reveals patterns of cases (Collins and Lanza, 2013). We use it to identify consonant and dissonant clusters of people based on their travel-related attitudes and residential built environments and estimating transition probabilities between cluster over time. In other words, LCTM allows us to explore the circumstances and processes through which adjustments in behaviour and attitudes occur over time (Kroesen, 2014).

We estimate two models. The first includes commonly used travel-mode attitudes (related to the use of cars, public transport and bicycles) and their interaction with the distance to the nearest railway station. Schwanen and Mokhtarian (2005) have shown that self-selection is not restricted to attitudes to these specific modes. Therefore, we include a second model concerned with the importance people attach to the distance to shops and services and the actual distance to the nearest neighbourhood shopping centre. The second model also includes people's satisfaction with the current neighbourhood characteristics. This allows us to analyse the extent to which larger objective mismatches between the importance that people attach to the distance and the actual distance are associated with lower levels of satisfaction (i.e. perceived mismatch). We refer to the method section for further details on the models used in this study.

1.4. Paper outline

The remainder of this paper is organised as follows. The following section describes the theoretical background and current knowledge on the relationship between travel-related attitudes, the built environment and travel behaviour. The method section describes the data collection and model specification. The results section describes the findings of the analyses, and the final section presents the conclusions and a discussion, including policy recommendations.

2. Method

2.1. Data collection

Data was collected in three municipalities in the Netherlands in 2005 and 2012: 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. GIS software was used to obtain detailed data on land use, infrastructure and accessibility.

A random sample of households was drawn from the civil registries of each of these areas. It was limited to homeowners because renters in the Dutch housing market have a very limited choice set, which hinders self-selection (Bohte, 2010). An internet questionnaire was conducted in 2005, including 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, 3979 completed the questionnaire – a response rate of 31% (Bohte, 2010).

After this initial data collection round, letters and emails were sent annually to maintain contact with the respondents, and they 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. moved to an unknown destination, changed or unknown contact details, and some had passed away). From these 3300 respondents, 1788 individuals from 1325 different households participated in the second round, a response rate of 54%. Logistic regression was conducted to test whether 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 have dropped out.

For this second wave, we only selected participants that had completed both questionnaires. Due to the selection of homeowners in the first round, the aging of our sample (also called the 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) of the second wave is apparent. Nevertheless, of our panel, 425 people were aged between 33 and 51. To avoid any problems with dependence of observations in the analysis, we randomly selected one of the partners from the 463 households in 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 paper. In addition, new GIS analyses were conducted to obtain data on spatial characteristics in 2005 and 2012 and changes that occurred over this time period.

2.2. Variables

Table 1 provides an overview of the key variables and their descriptive statistics in the first (2005) and second waves (2012). Socio-demographics include gender, the age of the respondents, the number of children in the household and income level. In line with the first wave (Bohte, 2010) we used personal income for the second wave to enable the longitudinal assessment of this indicator. As the personal income does not reflect all resources within the household, results should be interpreted with caution.

Due to the selection of homeowners, the average age and income of the respondents is relatively high; low incomes are due to part-time workers. Travel-related attitudes were determined using confirmatory factor analysis. The importance of the distance to shopping and services is derived from indicator variables which are measured on a 5-point scale ranging from 1 (very unimportant) to 5 (very important). Satisfaction is based on the same indicators and was measured on a 5-point scale ranging from -2 (very unsatisfied) to +2 (very satisfied). Attitudes to car use, cycling and public transport use were measured by asking respondents to rate nine statements on a 5-point 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.

In order to obtain the same factor structure for each transport mode, the responses for these modes were pooled and analysed together. In other words, the factor analysis was conducted on all nine statements, irrespective of mode. The advantage of this approach is that the mean of the latent factor for each mode can be compared to the mean of the other modes. If the factor scores had been conducted for each individual mode, the average for each mode would have been zero, since factor scores are standardised (see Molin et al., 2016).

In the confirmatory factor analysis, one factor labelled ‘pleasant’ was identified, on which the variables pleasant, comfortable, flexible and privacy loaded strongly in both 2005 and 2012. The other indicators did not lead to the identification of a strong second factor or to an acceptable model fit, and were therefore discarded. To gain reliable and stable factor scores, only indicators with a loading of over 0.60 were included (see Kline, 2010, for further discussion). Furthermore, measurement invariance was assessed for all factors by constraining the factor loadings to be equal for both years. This constraint did not result in a significant decrease in model fit. The equal form and equal loadings invariance suggest that the indicators have a comparable influence on the factor in both years, which is a prerequisite for a longitudinal assessment of change in this factor (Newsom, 2015). The factor scores were saved and added to the database as mode-specific variables.

The built environment was operationalised by measures of accessibility. Shortest routes between respondents’ homes to the neighbourhood shopping centre and the nearest railway station were calculated based on the network (source of road network: Dutch National Roads Database, NWB, 2013). The coordinates of the destinations were derived from a retail database (Locatus, 2013) and the national employment database (LISA, 2013). Travel behaviour was assessed by 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-point Likert scale ranging from 1: ‘(Almost) never with the car and (almost) always with alternatives’ to 7 ‘(Almost) always with the car and (almost) never with alternatives’. The dynamics in the panel show that approximately 1 in 5 respondents moved house and 1 in 4 experienced changes in their job location. A significant share of respondents (39%) experienced an increase in income category.

The distribution of the continuous indicator variables, the travel-mode attitudes, importance and satisfaction and the distances to destinations deviated strongly from normality. Therefore, the attitudes were recoded into 5-point ordinal scales, which corresponded with the 5-point scales of the underlying indicators. The distances to destinations were recoded into 10-point ordinal scales. For each variable, thresholds were chosen that divided the sample into more or less even proportions.

2.3. Model specification

An important assumption in this paper is that differences in the nature and degree of dissonance will lead to different adjustment processes. To date, many studies used a priori classifications of dissonance and ‘variable-centered’ approaches such as regression modeling to identify the role of dissonance (see Cao, 2015 for an overview). An advantage of ‘variable-centered’ approaches is that they enable to estimate an easy to interpret main effect for a dissonance variable in the model controlling for other variables. A disadvantage is that these main effects could mask differences in adaption processes between subgroups in the population and

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

Variables	Description	2005 %/Mean (st.dev)	2012 %/Mean (st.dev)
Socio-demographics			
Age	Average	50.4 (10.6)	57.4 (10.6)
Gender	Female	42.7%	42.7%
	Male	57.3%	57.3%
Children	Number of children in household	1.18	0.98
Net personal income (monthly)	Low (< €1000)	19.0%	12.2%
	Middle (≥€1000 to < €2000)	39.4%	33.1%
	High (> €2000)	42.6%	54.7%
Importance & satisfaction with distance			
Importance distance to shops and services		0 (0.26)	0 (0.27)
– Importance dist. to non-daily shops		3.12 (0.81)	3.30 (0.78)
– Importance dist. to restaurants, pubs, etc.		2.62 (0.87)	2.68 (0.88)
– Importance dist. to cultural and other services		2.78 (0.88)	2.93 (0.89)
Satisfaction with distance to shops and services		0 (0.40)	0 (0.28)
– Satisfaction dist. to non-daily shops		0.98 (0.75)	1.13 (0.60)
– Satisfaction dist. to restaurants, pubs, etc.		0.71 (0.72)	0.80 (0.64)
– Satisfaction dist. to cultural and other services		0.70 (0.73)	0.74 (0.71)
Travel-mode-related attitudes			
Car attitude		0.57 (0.35)	0.54 (0.35)
– Travelling by car is comfortable (loading = 0.69)		1.30	1.31
– Travelling by car is flexible (loading = 0.90)		1.35	1.36
– Travelling by car is fun (loading = 0.73)		0.89	0.94
– Travelling by car is private (loading = 0.89)		1.16	1.13
Public transport attitude		−0.85 (0.41)	−0.81 (0.42)
– Travelling by PT is comfortable (loading = 0.69)		−0.21	−0.10
– Travelling by PT is flexible (loading = 0.90)		−1.10	−0.91
– Travelling by PT is fun (loading = 0.73)		−0.27	−0.13
– Travelling by PT is private (loading = 0.89)		−1.04	0.98
Bicycle attitude		0.29 (0.41)	0.28 (0.40)
– Travelling by bicycle is comfortable (loading = 0.69)		0.39	0.43
– Travelling by bicycle is flexible (loading = 0.90)		1.00	1.06
– Travelling by bicycle is fun (loading = 0.73)		1.21	1.16
– Travelling by bicycle is private (loading = 0.89)		0.63	0.62
Built environment variables			
Average distances	To neighbourhood shopping centre	*1123 (778) m*	*1161 (819) m*
	To nearest railway station	*6150 (5458) m*	*5627 (5721) m*
Travel behaviour variables			
Car share	Frequency of car use compared to other modes	4.8 / (1.9)	4.7 (1.9)
Car availability	% always access to a car	73%	73%
Car ownership	# of cars in household	1.48 (0.64)	1.47 (0.66)
Company cars	# of company cars in household	0.24 (0.44)	0.20 (0.42)
Public transport card	% of public transport card owners	23.1%	32.5%
Dynamics in panel		*Change*	
Residential relocation	Number of movers in database	250 (19%)	
Job changes	Number of job changes	238 (18%)	
Children	Arrival of newborns/adopted children	100 (8%)	
Changes in Income	Decrease	180 (14%)	
	Stable	511 (48%)	
	Increase	631 (39%)	

nonlinear effects and interactions effects have to be specifically controlled for. This paper presents a ‘person-centered’ approach, as an alternative by applying LCTM. It groups a set of respondents in subgroups by maximising homogeneity within groups and heterogeneity between groups. In LCTM, these groups are assumed to explain associations between the indicators including nonlinear effects and interaction effects. The advantage is that these groups are inductively derived from the data which enables a more thorough understanding of adjustments in behaviour and attitudes over time under different circumstances. A disadvantage of LCTM is that they require more parameters and may produce less accurate and stable results compared to variable/centered methods when sample sizes are small and when nonlinear and interaction effects are not present (Bauer and Shanahan, 2007).

The major benefits of LCTM compared to k-means cluster analyses are that it involves a model-based clustering technique that probabilistically assigns individuals to a class (or cluster), which reduces misclassification biases, and this statistical criteria can be used to determine the optimal number of classes (Collins and Lanza, 2013; Vermunt and Magidson, 2013). Furthermore, it is a transition model, which means that it enables the identification of these classes at multiple moments in time and estimation of

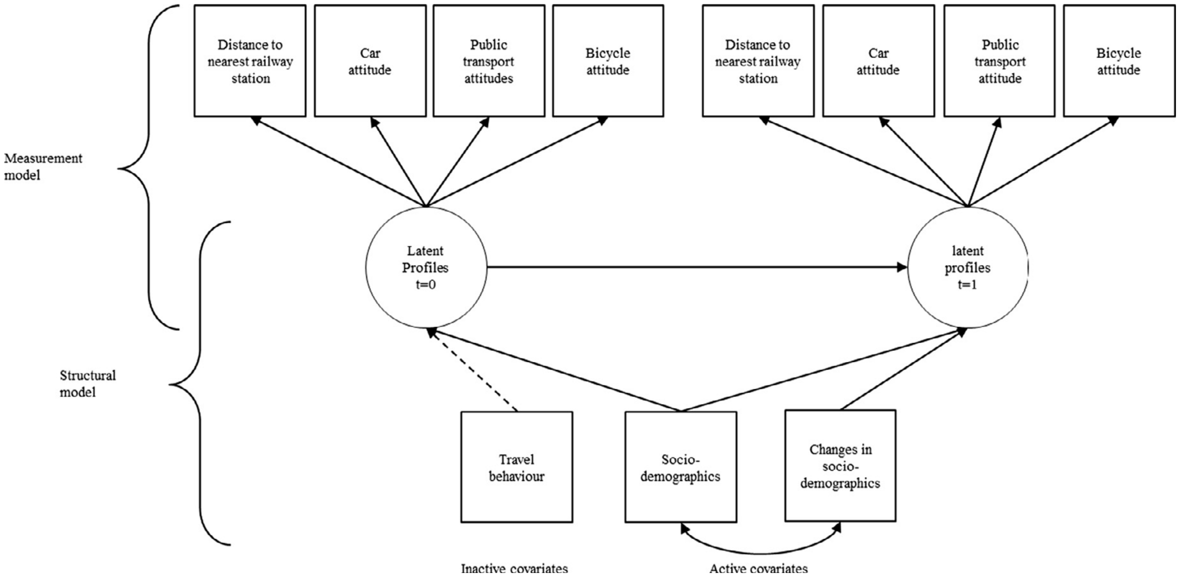

Fig. 1. Model I: LCTM for travel-mode attitudes and distance to the railway station.

transition probabilities between these classes (Collins and Lanza, 2013).

Two models are estimated below. Model I clusters travel-mode attitudes and their interaction with the distance to the nearest railway station. Model II clusters the importance that people attach to the distance to shops and services and the actual distance to the nearest neighbourhood shopping centre. The model specifications are presented in Figs. 1 and 2. They show that LCTMs consist of a measurement, a structural and a longitudinal part. Below, the model conceptualisations and related assumptions of both models are described.

The measurement model in Model I is specified by four indicators: three travel-mode-related attitudes, for car, public transport and the bicycle, respectively, and one built environment characteristic, the distance to the railway station (Fig. 1). In the measurement part, latent profiles (a set of latent classes) are assumed to explain associations between these indicators (Vermunt and Magidson, 2013). The latent classes represent different combinations of travel-related attitudes and distances to the nearest railway

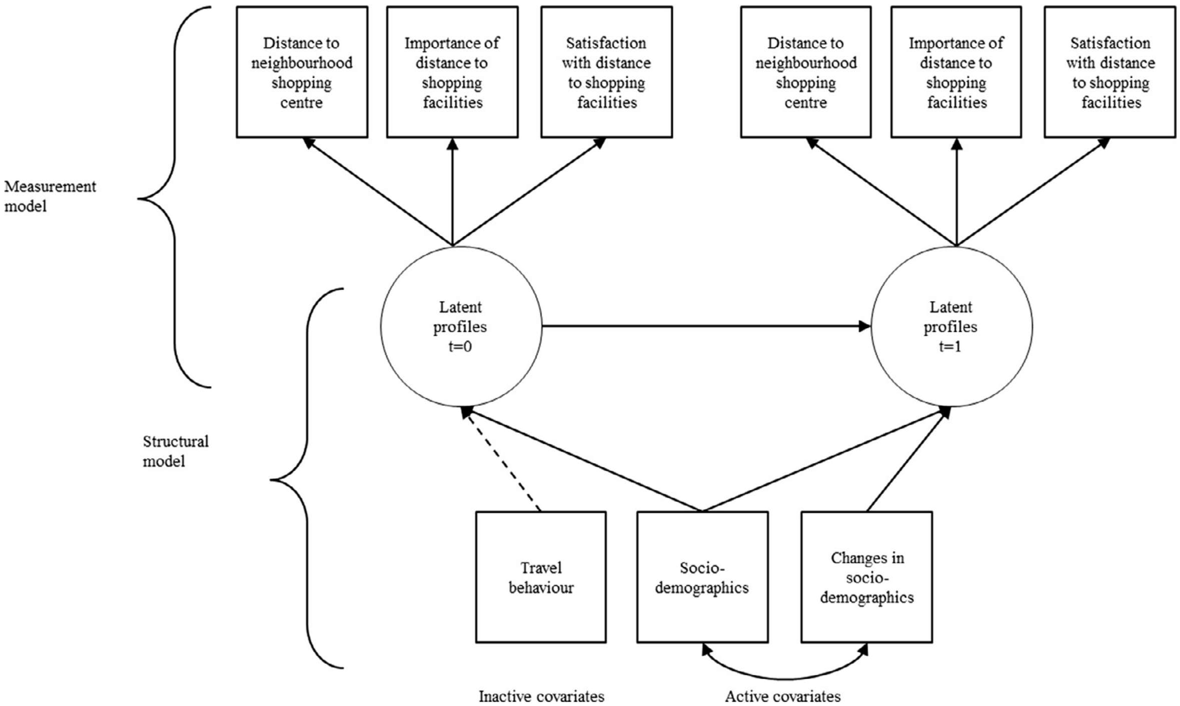

Fig. 2. Model II: LCTM for importance, satisfaction and distance to shopping centre.

station. The assumption here is that, due to the processes of residential self-selection and reverse causality, the majority of people will have travel-mode attitudes which are aligned to the characteristics of their residential environment. Thus, people living in areas in closer proximity to railway stations will have more positive attitudes to alternatives to the car (public transport and cycling), while people who have positive attitudes to the car would live further away.

In the structural part of the model, the transition probabilities are conditional on exogenous covariates to control for differences in socio-demographic characteristics. Socio-demographic characteristics in 2005 ($t = 0$) are assumed to influence membership of the profiles in 2005. For example, males may have a higher probability of being assigned to classes with stronger car attitudes. The following covariates are considered: gender, age, the number of children in the household and personal income. Travel behaviour variables are included as inactive covariates. This means that they do not actively contribute to the model, but their average values are included for the respective classes. This enables us to describe the travel behaviour of the different classes and to also profile them. They are not specified as indicators, as this would lead to identifying attitude and travel behaviour patterns, while the focus of this study is on the interaction between travel-related attitudes and the built environment. Including them as active covariates would lead to endogeneity issues, as travel behaviour is generally considered to be affected by characteristics of the built environment and not the other way around.

In the longitudinal part of the model, the same latent profiles are estimated for two separate moments in time (2005 and 2012), which results in an LCTM. Change is represented by transitions between latent classes over time. These transitions are based on a model that estimates the probability of class membership in 2012 ($t = 1$), conditional on class membership in 2005. They can be translated into a matrix of transition probabilities. In accordance with the theory of cognitive dissonance (Festinger, 1957), we expect that the influence of residential self-selection and reverse causality will depend on the level of initial dissonance in 2005. For example, it is expected that car lovers living in close proximity to the railway station have a higher probability of moving house and self-select to a more conducive neighbourhood than their counterparts who already live in a suburban area. The above-mentioned covariates (socio-demographics) are assumed to influence class membership in 2012. For example, older people may have a higher probability of transitioning to classes with more positive attitudes to public transport. In addition, changes in socio-demographics and two dummy variables indicating whether a person moved house or changed jobs, respectively, in between the two waves, are assumed to influence class membership in 2012.

Model II is specified with three indicators: the distance to the nearest shopping centre, the importance which people attach to the distance to shopping facilities and satisfaction with the current distance (Fig. 2). We expect people who attach more importance to the distance to shopping facilities will live in closer proximity to shopping centres. If they live further away from these facilities, we expect them to be less satisfied. In other words, we assume that a higher level of objective dissonance is reflected in lower satisfaction levels (perceived dissonance).

The structural and longitudinal parts are identical to the previous model. In accordance with the assumptions of the previous model, we expect that the influence of residential self-selection and reverse causality will depend on the initial level of dissonance in 2005. For example, people who consider proximity to shopping facilities to be important but currently live far from them will have a higher probability of moving house or will adjust the level of importance attributed to the distance to reduce cognitive dissonance.

2.4. Model estimation

Since the indicators of the latent classes are ordinal variables in both models, ordinal logit models were used to estimate the relationships of the latent class variables to the indicators. The latent class variables are nominal variables. Therefore, the influence of background variables on the latent class variables as well as the probability of transitions over time were modelled using multinomial logistic regression models.

Multiple measurement models with one to seven classes that only included the indicators were estimated and compared to determine the optimal number of latent classes. Their ability to account for the associations between the indicators and their BIC values were compared to determine the best model. Subsequently, the best model was selected and the covariates added. The six class solutions showed the lowest BIC values and the chi-square of all bivariate residuals was below 3.84 for both models, indicating that there was no significant covariation between the indicators. These were selected and are described in the following section. The models in this study were estimated with Latent Gold 5.0 (Vermunt and Magidson, 2013), a dedicated software package for LCTMs.

3. Results

This section considers the results of both models, which are presented in two separate tables each. The first table presents the results of the measurement and structural part of a model. This includes the unconditional probability of belonging to a certain class and the conditional probability of having a certain response pattern dependent on class membership. In addition, it describes the influence of the covariates on these latent classes. For ease of interpretation, we translated these probabilities into the profile of class membership in 2005. This reveals people's level of dissonance and their average socio-demographic characteristics. The second table presents the results of the longitudinal part of a model, which includes transition probabilities and the effect of the covariates on these transition probabilities. This reveals how people adjusted their residential environment and attitudes between 2005 and 2012.

3.1. Travel-mode attitudes and distance to the railway station

Table 2 presents the profile of latent class membership in 2005 of the first model, which includes: (1) the class sizes based on

Table 2
Profile of class membership in 2005: mode attitude and distance to railway station.

Mode attitudes and distance to train station N = 1322								
	Class	1N-D	2N-PT/B	3R-MM	4R-C	5S-C	6S-C/B	Overall
Indicators	Class size (%)	26	18	16	16	12	12	100
Distance to train station ((Wald = 95, p < 0.01)	Avg.[meters]	2282	2253	13,918	14,045	3248	2629	6150
Car attitude (Wald = 188, p < 0.01)	Factor score	0.40	0.34	0.43	0.82	0.87	0.79	0.57
Public transport attitude (Wald = 307, p < 0.01)	Factor score	−0.87	−0.34	−0.70	−1.21	−1.22	−0.92	−0.85
Bicycle attitude (Wald = 223, p < 0.01)	Factor score	0.17	0.44	0.30	0.24	−0.01	0.69	0.29
Active covariates								
Age (Wald = 52, p < 0.01)	Avg.[years]	49	50	45	44	46	48	47
Children in household(Wald = 15, p < 0.01)	% hh with children	53	49	62	70	49	66	58
Gender (Wald = 10, p < 0.1)	% males	48	58	47	63	82	58	57
Income (Wald = 12, p < 0.05)								
% < avg. income (< €20,000 net personal income)		43	34	48	30	12	37	36
% avg. income − 2x average income (€20,000–30,000)		37	42	34	44	53	3	41
% > 2x avg. income (> 30,000)		20	24	18	26	36	23	24
Inactive covariates								
Car availability	% car always access to car	69	54	80	83	88	72	73
Car share	1 = always alternatives, 7 = always car	4.48	3.56	5.30	5.83	5.83	4.23	4.79
Public transport card	% of PT card owners	23	53	12	10	14	21	23
# cars per household	% 0 cars	2	9	0	0	0	1	2
	% 1 car	57	72	38	37	47	54	52
	% 2 cars	38	18	57	56	44	42	42
	% 3 + cars	4	1	4	6	10	3	4
Company cars	% hh with company car	23	11	25	31	31	23	23

unconditional class membership probabilities, (2) the Wald statistics and average values of the indicators and covariates conditional on class membership and (3) the inactive covariates and their average values.

Class size shows that people have a relatively high probability of being in first class, while the remainder are distributed quite evenly over the other classes. The Wald indices reveal that all indicators have a significant influence on the latent class variable. Thus, the indicators significantly discriminate between the clusters. With regard to the active covariates, age, the presence of children in the household and income have a significant influence on class membership in 2005. Gender is significant at the 10% level. Note that no coefficients were calculated for the inactive covariates since they are not part of the model. However, below they are used to characterise the classes.

The latent profiles uncover six classes at, on average, 2, 3 and 14 km from the railway station. For the ease of interpretation we added labels to the classes. Please note that these labels do not cover the full heterogeneity within each class:

- Class 1: nearby discontented (N-D)
- Class 2: nearby PT/bike (N-PT/B)
- Class 3: remote multimodal (R-MM)
- Class 4: remote car (R-C)
- Class 5: suburban car (S-C)
- Class 6: suburban car /bike (S-C/B)

Differences in attitude profiles vary strongly between – and interestingly also within – these distance categories. Overall, the patterns of attitudes and distance to the railway station do not completely support our assumption that people living in closer proximity to the railway station have more favourable attitudes towards public transport and the bicycle. Two classes are aligned with this expectation and show consonant profiles:

- Class 2: nearby PT/bike (18%): people who live, on average, closest to the railway station and have favourable attitudes towards public transport and the bicycle and the least favourable attitude towards car use.
- Class 4: remote car (16%): people who live furthest from the railway station and have more favourable car use attitudes and less favourable attitudes towards the bicycle and, in particular, public transport.

Other classes show less consonant patterns.

- Class 1: nearby discontented (26%): people in this largest class live close to the railway station but do not show favourable attitudes towards public transport, the bicycle or, interestingly, car use.
- Class 3: remote multimodal (16%): people live far from the station but their car attitude is below average and their public

Table 3
Matrix of transition probabilities: mode attitude and distance to railway station*.

State [t = 1](%)	1N-D	2N-PT/B	3R-MM	4R-C	5S-C	6S-C/B
State [t = 0] (%)(Wald = 43, P < 0.05)						
1 (N-D)	100	0	0	0	0	0
2 (N-PT/B)	1	99	0	0	0	0
3 (R-MM)	5	1	92	1	2	0
4 (R-C)	2	0	1	87	6	3
5 (S-C)	0	0	0	0	96	4
6 (S-C/B)	4	10	0	0	0	86
Covariates 2005						
Age (Wald = 11, P < 0.05)	−0.07	0.09	0.08	−0.09	0.05	−0.05
Gender, ref. = female (Wald = 13, P < 0.05)	**3.74**	−1.94	−2.92	2.02	**−2.88**	1.98
Income (Wald = 12, P < 0.05)	**−1.58**	**1.23**	−0.58	−0.32	0.20	**1.04**
Children in hh, ref = no. (Wald = 16, P < 0.01)	**3.61**	−1.63	**4.66**	−2.46	0.74	**−4.91**
Changes in covariates 2005–2012						
Arrival children (Wald = 11, P < 0.05)	**4.06**	−4.92	2.62	−2.47	0.39	0.32
Change in income (Wald = 12, P < 0.05)	**−1.72**	0.74	0.27	−0.23	0.37	0.57
House move (Wald = 15, P < 0.01)	**5.56**	0.17	**−6.77**	**−6.75**	2.62	**5.18**
Job change (Wald = 7, n.s.)	**2.03**	−0.82	1.69	−1.07	−1.97	0.13

* Estimates in bold are significant at $p < 0.05$.

transport and bicycle attitudes slightly above average.

- Class 5: suburban car (12%): people are clearly oriented towards car use and less towards the other modes, while the average distance from the railway station is not great.
- Class 6: suburban car/bike (12%): people with favourable bicycle attitudes close to the railway station (in line with our assumption) but also favourable car attitudes and somewhat less favourable attitudes towards public transport.

Somewhat surprisingly, it can also be observed that there are no distinct classes with more favourable attitudes towards the bicycle or public transport in closer proximity to the railway station. Instead, these more favourable attitudes appear in the nearby PT/bike and suburban car/bike classes at approximately 2.5 km from the station, on average. This suggests that people living in areas in closer proximity to stations do not have distinct attitude profiles and, consequently, there is no gradual relationship between this distance and attitudes.

The profile of the covariates shows that people in the nearby PT/bike class are, on average, a little older and clearly have low car availability and car use and there is a high share of public transport card holders. This suggests that public transport is used in combination with the car to cope with the single car in many households. The nearby discontented class contains more females than males and income levels are lower than average. The lack of sufficient financial resources may be a cause of the less favourable attitudes towards all transport modes. The suburban car class has a very large share of males, a high income level and high car availability and use. This suggests that males are more car-oriented and, in combination with sufficient financial opportunities, use the car very often, even if they live relatively close to the railway station.

Table 3 presents the transition probabilities between 2005 and 2012 and parameter estimates for the influence of the covariates on these probabilities. The rows represent initial cluster membership in 2005 and the columns represent cluster membership in 2012. The greatest probabilities are on the diagonal, which means that people have the highest probability of remaining in the same class over time. Contrary to our expectations, people in more dissonant classes (1, 3, 5 and 6) generally do not have a higher probability of switching to more consonant classes (2 and 4).

People in the first two classes remained almost completely inert. For people in the consonant nearby PT/bike class, this was more or less expected. However, for people in the nearby discontented class, living in relatively close proximity to the railway station for seven years apparently did not result in more positive bicycle or public transport attitudes, nor did the dissonance increase the probability of moving house. As expected, the most important transitions indicate that the built environment and mode-related attitudes mutually influence each other over time and that the direction of influence differs across the classes. People in the suburban car/bike class showed the strongest tendency to move to the second nearby PT/bike class. This indicates that people's attitudes towards public transport use shifted upwards, which may be due to their relatively close proximity to the railway station. The transition of people from the remote car class to the suburban car class implies a move to a residential area closer to the railway station, without adjusting their car or public transport attitudes. This may be people moving from remote areas to suburban areas in cities that are still conducive to car use for reasons that we do not control for in this model. Interestingly, attitudes to the bicycle became less favourable after the move.

A similar unexpected negative influence of proximity on attitudes appeared in the transition from the remote multimodal to the nearby discontented class. This involved people who move from an area far from the railway station to a residential area in closer proximity, while their attitudes towards public transport and the bicycle become less favourable.

The parameters of the covariates show that, apart from job changes, all covariates significantly influence the transition probabilities. A higher income in 2005 increases the probability of being in the nearby PT/bike and the suburban car/bike classes in 2012,

Table 4
Profile of class membership in 2005: Importance of and satisfaction with distance to shopping facilities.

	Class	1N-I	2N-C	3R-I	4C-I	5C-C	6R-C	Overall
Indicators	Class size (%)	21	19	16	16	14	14	100
Distance neighbourhood shopping centre (Wald = 360, p < 0.01)	Avg. distance [meters]	878	899	2126	414	432	2153	1123
Importance distance to shopping facilities (Wald = 242, p < 0.01)	Factor score distance	−0.19	0.20	−0.19	−0.17	0.24	0.19	0.00
Satisfaction distance to shopping facilities (Wald = 144, p < 0.01)	Factor score distance	0.01	0.10	−0.13	0.01	0.21	−0.22	0.00
Active covariates								
Age (Wald = 61, p < 0.01)	Avg. [years]	47	49	43	49	52	45	47
Children in household (Wald = 27, p < 0.01)	% HH with children	67	58	70	55	35	56	58
Gender (Wald = 32, p < 0.01)	% males	64	53	62	64	48	49	57
Income (Wald = 11, p < 0.1)								
% < avg. income (< €20,000 net personal income)		33	36	37	34	36	40	36
% avg. income − 2x average income (€20,000–30,000)		43	40	41	44	39	35	40
% > 2x avg. income (> 30,000)		24	24	22	21	26	25	24
Inactive covariates								
Car availability	% car always access to car	70	64	80	75	68	85	73
Car share	1 = always alternatives, 7 = always car	4.45	4.44	5.51	4.71	4.44	5.40	4.79
Public transport card	% of PT card owners	24	28	11	23	35	18	23
# cars per household	% 0 cars	2	4	1	2	4	1	2
	% 1 car	54	58	43	53	63	38	52
	% 2 cars	42	33	52	37	30	56	41
	% 3 + cars	3	5	4	8	2	4	4
Company cars	% hh with company car	20	26	30	21	17	26	23

with favourable attitudes towards public transport and the bicycle, respectively. It also reduces the probability of being in the nearby discontented class in 2012, with less favourable attitudes towards all modes. An increase in income between 2005 and 2012 also reduces the probability of being in the nearby discontented class in 2012. Households with children find themselves more often in the nearby discontented and remote multimodal classes in 2012, with less favourable car attitudes, and less often in the suburban car/bike class, which has a more favourable attitude towards the car and the bicycle. People who moved house had a higher probability of living in closer proximity to the railway station. In other words, there was an overall tendency to move to areas in closer proximity to railway stations.

3.2. Importance, satisfaction and distance to the shopping centre

Table 4 presents the profile of the latent class membership in 2005 for Model II. The class sizes reveal that people are distributed quite evenly over them and the Wald indices reveal that all indicators are significant. With regard to the active covariates, age, presence of children in the household and gender have a significant influence on class membership in 2005. Income only just fails to be statistically significant at the 5% level ($p = 0.052$).

The profile roughly reveals three distance categories, within 450, 900 or 2200 m from the nearest neighbourhood shopping centre. We labelled them as follows:

- Class 1: nearby indifferent (N-I)
- Class 2: nearby caring (N-C)
- Class 3: remote indifferent (R-I)
- Class 4: closest indifferent (C-I)
- Class 5: closest caring (C-C)
- Class 6: remote caring (R-C)

In each of these classes, there are people who do and people who do not attach importance to this distance. Contrary to expectations, there is no clear-cut relationship between the importance that people attach to the distance to shopping facilities and the actual distance to the nearest neighbourhood shopping centre. In line with expectations, people who live closer to the neighbourhood shopping centre are more satisfied. This particularly applies to people who attach importance to this distance. For them, a higher level of dissonance due to larger distances to shopping facilities is related to lower satisfaction levels. These differences are smaller for classes of people who do not attach much importance to this distance. Nevertheless, people in the remote indifferent class, who live furthest away, are unsatisfied despite the fact that they do not attach much importance to this distance.

With regard to the covariates, people living in closer proximity to the nearest neighbourhood shopping centre are on average a little older. In particular, the closest caring class consists of older people with fewer children in the household and a stronger

Table 5
Matrix of transition probabilities: Importance of and satisfaction with distance to shopping facilities*.

State [t = 1] (%)	1N-I	2N-C	3R-I	4C-I	5C-C	6R-C
State [t = 0] (%) (Wald = 103, p < 0.01)						
1 (N-I)	92	4	4	0	0	0
2 (N-C)	0	98	1	0	0	1
3 (R-I)	9	0	91	0	0	0
4 (C-I)	8	0	4	86	1	0
5 (C-C)	1	4	0	5	87	4
6 (R-C)	0	12	7	0	0	80
Covariates 2005						
Age (Wald = 7, n.s.)	−0.04	0.04	−0.05	0.05	−0.09	*0.09*
Gender (Wald = 8, n.s.)	0.10	−1.00	−0.22	**3.52**	−2.54	0.14
Income (Wald = 20, P < 0.01.)	−0.55	−0.40	−0.31	**3.46**	−2.37	0.16
Children in hh, ref = no. (Wald = 9, n.s.)	**−1.00**	0.66	−0.41	**−1.59**	*1.08*	**1.27**
Changes in covariates 2005–2012						
Arrival children (Wald = 6, n.s.)	*2.25*	*2.45*	1.89	−1.32	**−8.26**	*2.99*
Change in income (Wald = 19, P < 0.01)	**−1.66**	*0.82*	**−1.19**	**−1.43**	**2.03**	**1.44**
House move (Wald = 37, p < 0.01)	**7.64**	**12.31**	**3.73**	**−7.65**	**−12.96**	**−3.07**
Job change (Wald = 4, n.s.)	−0.83	−1.00	−1.35	−0.66	*4.02*	−0.18

* Estimates in bold are significant at $p < 0.05$.

orientation to alternatives to the car. They appear to be satisfied with the current distance to shopping facilities. More generally, the distance classes seem to be related to people's mobility profiles. People in the remote indifferent and remote caring classes, are clearly more car-oriented. Furthermore, within each distance class, people who attach more importance to this distance are less car-oriented and use alternatives more often.

Table 5 presents the probabilities of transitioning between classes between 2005 and 2012 and the parameter estimates for the influence of the covariates on these probabilities. It shows that people are most likely to remain in the same class over time. Contrary to expectations, dissonant groups in general do not appear to clearly have higher probabilities of transitioning compared to consonant groups. However, dissonant individuals in the remote caring class, the least satisfied, do have the highest probability of transitioning to another class over time.

The largest share of people transitioned from the remote caring class to the nearby caring class. This indicates residential self-selection, where people who attach importance to and are currently unsatisfied with the distance to shopping facilities move to an area in closer proximity and become more satisfied. In other classes, higher levels of dissonance (or lower satisfaction) do not seem to be related to larger transition probabilities. A smaller group of people transitioned from the remote caring class to remote indifferent class. This may be due to cognitive dissonance reduction, where dissonant people reduce the importance that they attach to the distance and reduce their dissatisfaction level over time.

The other transitions show that most people remain more or less stable with regard to the importance that they attach to the distance to shopping facilities. Transitions from the closest caring class to the nearby caring class 2 the remote caring class show that consonant individuals living in close proximity to shopping facilities may transition to classes with larger distances and lower levels of satisfaction. Transitions between the closest caring class and the closest indifferent class, where people who live in close proximity to the neighbourhood shopping centre reduce their importance and satisfaction levels over time, seem counterintuitive. Perhaps changes in household circumstances that were not controlled for explain these changes.

The parameter estimates of the covariates show that people who moved house more often joined one of the first three classes in 2012. This is in line with the overall pattern in the transition matrix, where more people transitioned to these classes. People who experienced a rise in income had a higher probability of transitioning to classes that attach more importance to the distance to shopping facilities.

4. Conclusions

How are people's travel-related attitudes aligned with the characteristics of their residential built environment, and do people adjust one or the other over time to bring them more in line with each other? This paper aimed to enhance our understanding of interactions between the characteristics of the residential built environment, travel-related attitudes and travel behaviour. We identified consonant and dissonant subgroups based on travel-related attitudes and residential environment characteristics and we explored how people in these groups adjust their travel-related attitudes and residential environments over time. Two separate LCTMs were developed based on a two-wave longitudinal dataset from the Netherlands. Model I addressed the interaction between the distance to the train station and travel-mode attitudes. Model II addressed the distance to shopping facilities and the importance and satisfaction that people attach to this distance.

Contrary to our expectations, we did not find clear-cut relationships between travel-mode attitudes and characteristics of the built environment. The profile of latent class membership in 2005 showed no overall tendency for people to live closer to a railway station if they liked public transport or cycling. Nor was there an overall tendency for people who preferred close proximity to shops and services to live closer to shopping areas. Instead, people with supportive and non-supportive attitudes were distributed across the distance ranges, revealing consonant and dissonant population groups. For Model II, we analysed the impact of this residential dissonance on people's satisfaction. The results indicate that higher levels of dissonance negatively affect people's satisfaction with the distance to shopping facilities. This mainly applies to people who attach importance to the distance to shopping centres. Others do not seem to care much until the distances become very large.

The latent class profiles remained relatively stable over time in both models. Again, contrary to our expectations, people in more dissonant classes generally did not show a greater likelihood of switching to more consonant classes. In the first model the public transport attitudes of the dissonant suburban car/bike class shifted upward after living in proximity to a railway station thereby reducing the dissonance. However, people the nearby discontented class remained almost inert, despite living relatively close to the railway station and having less favourable attitudes towards all travel modes. In Model II, only people who were very unsatisfied with the distance to shops showed higher transition probabilities. Thus, it appears that dissonance and dissatisfaction levels have to reach a certain threshold before people adjust their behaviour or their attitudes.

As expected, both models reveal adjustments in people's attitudes as well as adjustments in the residential environment, and both adjustments differ across population groups. This suggests that processes of residential self-selection and reverse causality both occur and depend on initial residential dissonance.

Furthermore, people's socio-demographics significantly influenced transition probabilities. One example is the role of income in the nearby discontented class from the first model. People with lower incomes are overrepresented in this group and also had a higher probability of being in this group in 2012. This suggests that at least for a share of people in this group, their lower income reduced the opportunity to lower their dissonance by moving to a more conducive environment. This result should be interpreted with caution as we were only able to include respondent's personal income while household income would provide a more complete picture of the resources in the household.

Some methodological remarks should be made. Despite the long time lapse of seven years, the number of changes in the dataset were limited. Although this is, in itself, an interesting research finding, it limits the data on the number of transitions over time and consequently the ability to reveal patterns of reverse causality and, especially, self-selection. Moreover, due to the long time lapse, unobserved events may have taken place that affect the 2012 values. Furthermore, more measurement points would enhance the ability to determine causal directions and the time that processes of residential self-selection and reverse causality take to fully materialise.

5. Policy implications

What do the findings of this study mean from a policy perspective? Residential developments in accessible distance to railway stations benefit people with positive public transport and bicycle attitudes. It does not seem necessary to densify within close proximity as groups with significantly more favourable attitudes towards these modes are identified no closer than 2.5 km, on average, from the railway station. The strong bicycle culture in the Netherlands probably allows for longer distances to the railway station. Developing bicycle-friendly neighbourhoods at longer distances from a railway station, and providing good connections by public transport and bicycle, is also effective and provides more opportunities for densification policies.

Campaigns that actively promote the favourable conditions for cycling and/or public transport in these neighbourhoods may encourage self-selection. A higher share of people with positive attitudes living within three kilometres of the station will increase the effectiveness of densification policies. In addition, for certain groups, attitudes also seem to be influenced by the built environment itself. This suggests that densification could encourage more sustainable travel behaviour, not only directly but for certain groups also indirectly through its effect on attitudes.

But how do we address the relatively large group of people with no positive attitudes towards travel modes within this 2.5 km distance range? Apparently, they do not consider the use of any of these modes as comfortable, flexible or fun, which may be related to their lower income levels. This calls for the identification of the specific needs of this group and research into better ways to accommodate them in a sustainable manner. However, it also makes sense to be realistic: a share of these households will not be sensitive to these policies, as they do not have positive attitudes towards sustainable travel modes. They could be encouraged to move to more remote areas, as their car use disturbs areas which have the potential for more sustainable travel behaviour.

Finally, about half of the sample attached importance to the distance to shopping facilities. Their satisfaction levels clearly dropped between one and two kilometres to these destinations. Thus, it is important that they are given the opportunity to live closer to these facilities. Policies to preserve small-scale retail in close proximity to residential areas could contribute to higher shopping satisfaction levels, as well as higher levels of sustainable transportation. However, after decades of protective national retail policy, such policies in the Netherlands have become more deregulated and decentralised since 2004. Consequently, large-scale peripheral retail developments and hypermarkets are starting to appear, which will probably increase average distances to shopping areas. The impact of these developments will also depend on the current e-shopping trend. This may lead people to become less sensitive to the distance to shops.

Overall, this study provides some support for land use policies that aim to influence travel behaviour. Given the importance of supportive attitudes, the combination of land use policies and promotional campaigns which enhance residential self-selection could be key for the effectiveness of these policies.

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