UNDERSTANDING NEIGHBOURHOOD DESIGN IMPACT ON TRAVEL BEHAVIOUR: AN APPLICATION OF STRUCTURAL EQUATIONS MODEL TO THE BRITISH MICRO-ANALYSIS DATA

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ABSTRACT

The objective of this study is to explore whether changes in neighbourhood characteristics bring about changes in travel choice. Residential self-selection is a concern in the connections between land-use and travel behaviour. The recent literature suggests that a longitudinal structural equations modelling (SEM) approach can be a powerful tool to assess the importance of neighbourhood characteristics on travel behaviour as opposed to the attitude-induced residential self-selection. However, the evidence to date is limited to particular geographical areas and evidence from one country might not be transferrable to another because of differences in land-use patterns and land-use policies. The paper is to address the gap by extending the evidence using British data. The case study is based on the metropolitan area of Tyne and Wear, North East of England, UK. An SEM is applied to 219 respondents who reported residential relocation within the previous 8 years. We found that neighbourhood characteristics do influence travel behaviour after controlling for self-selection. For instance, the more people are exposed to public transport access, the more likely they drive less. Neighbourhood characteristics also impact through their influence on car ownership. A social environment with vitality also reduces the amount of private car travel. These findings suggest that land-use policies at neighbourhood level can play an important role in reducing driving.

Keywords: longitudinal analysis, neighbourhood characteristics, residential self-selection

INTRODUCTION

There has been a steady increase in studies investigating the relationships between urban form and travel behaviour since the identification of urban sprawl as a problem as a result of a car-dependent lifestyle of many societies. The overarching aim of this study is to contribute to the understanding of the spatial determinants of travel behaviour; so as to support the implementation of spatial policies that reduce driving and car dependence such as the Compact City policy in Europe and the Smart Growth and New Urbanism in the US. Over the past two decades, it has been documented that urban form characteristics, such as density, settlement size, provision and mix of land-use, jobs-housing balance, location, regional structure and accessibility, local street layout and neighbourhood design, are contributively affecting travel behaviour (CfIT, 2009). In relation to many planning studies, the travel behaviour that has been observed are either travel mode choice or (daily) travel distance, although some studies also focus on travel frequency, travel purpose and travel time. The conclusions drawn from these studies show that there are significant associations between urban structure characteristics and travel pattern. The rationale is that by situating residential, employment and service locations closer to each other, trip length will become shorter, and thus individuals will drive less and/or are more likely to travel on foot, by bicycle, and by public transport.

Recently, the understanding of the relationship between urban form and travel behaviour has been reassessed to take into account the issue of residential self-selection. The argument, as first coined by Handy et al. (2005), is that if particular characteristics of a residential neighbourhood area are associated with particular travel behaviour, we have yet to know the direction of causality. Do urban form characteristics influence individuals' travel behaviour? Do individuals' travel behaviour preferences lead individuals to select their residential neighbourhood conducive to particular travel pattern? The latest evidence from the literature shows that both the impacts of urban form characteristics and residential self-selection on travel behaviour may result from the two sources of attitudes and demographics (Cao et al, 2009). Furthermore, Bohte et al. (2009) highlighted that the impacts of attitudinal attributes are as important as those of the socio-economic characteristics. A better understanding of the role of residential self-selection may lead to more sustainable spatial planning, and thus addressing the issue of housing supply as well. Naess (2009) argued that if households were able to self-select their residential neighbourhood, this does not mean the urban structure does not influence travel behaviour, but that the urban structure actually enables households to self-select. Moreover Naess argues that it is possible to persuade households that prefer private car into walking and cycling as the travel behaviour literature indicates. Activity participation, location of activities, choice of travel mode and route choice contribute to a higher amount of motorized travel among outer-area residents than among inner-city dwellers, regardless of any self-selection of residents to particular types of neighbourhoods (Naess, 2009). This is consistent with an activity-based theory of urban travel demand that supports a better understanding of how people actually make decisions derived from the utility based principle. Axhausen and Gärling (1992) observed that travel behaviour models that are solely based on the utility maximisation principle are not sufficient to understand how people make decisions. Travel demand is a derived demand – derived from the desire to reach places, whether work places, parks, shopping centres, town centres or just local amenities. By providing an urban structure that shortens trip lengths this may encourage less motorised travel. Despite the growing interest in activity-based modelling within transportation research, a better understanding of the direction of causality for why people change their travel (driving) behaviour is still intriguing to help shaping sustainable land-use and transport strategic decision making.

A comprehensive review on the methodological aspect to understand the impact of residential self-selection on travel behaviour concludes that longitudinal structural equations modelling is recommended against other methodological approaches (Cao et al, 2009). Structural Equations Modelling (SEM) integrates path analysis and factor analysis (latent variable modelling) (Jöreskog, 1973). Using SEM, we can analyse direct relationships and indirect relationships through mediating variables, such as the influence of attitudes on travel behaviour through the residential choice. Unlike most standard statistical methods, SEM is not limited to the analysis of explanatory variables on a single dependent variable; it can deal with several endogenous variables with interdependent relationships (Byrne, 2001). The use of longitudinal analysis with the collection of travel related attitudinal data before and after a residential move, provides the best way for changes in attitudes to be measured (Mokhtarian and Cao 2008). The most recent study that uses such approach (or at least the closest approach) is Cao et al. (2007). They used Northern California data collected in 2003. Apart from this, there is no such comparable study until the work in Tyne and Wear, UK was carried out by Aditjandra et al. (2007) although this is at a smaller scale than Cao et al. (2007). Whilst the cross sectional analysis of the UK study is documented elsewhere (see: Aditjandra et al. 2009), this paper offers the analysis of quasi-longitudinal data using SEM and aims to better understand how changes in neighbourhood characteristics lead to changes in travel behaviour after accounting for residential self-selection.

In the current debate of the development of the Eco-Town in Britain, one of the arguments for their promotion has been the opening of new land for living as a result of housing market pressure. A number of Eco-Town projects are currently under discussion between the UK government and local authorities but it is still unclear how this housing is to be planned to meet the objectives. Although land-use changes in Britain have not been particularly environmentally unfriendly (Bibby, 2009), it is nevertheless true that a better understanding of the impact of urban structure on travel behaviour provides evidence on how to better meet future sustainable travel behaviour. This paper directly addresses this issue.

The next section briefly reviews recent SEM applications in travel behaviour research. This is followed by a description of the data description, the methodology and the results. The last section draws together key findings and conclusions in relation to the contribution that urban structure and therefore planning can make to more sustainable travel behaviour in the future.

LITERATURE REVIEW

The use of SEM in travel behaviour research has a long track record that dates back to the 1980s (Golob, 2003). It is a modelling technique that can handle a large number of endogenous and exogenous variables, as well as latent (unobserved) variables specified as linear combinations of the observed variables. It is a confirmatory, rather than exploratory method because the modeller is required to construct a model in terms of a system of unidirectional effects of one variable on another.

Application of SEM studies that focus on the urban form impact on travel behaviour can be traced back from the work of Golob (2000). Using data from Portland in the US, he incorporated a residential accessibility index (as an exogenous variable) to explain time use and trip generation. The work of Simma and Axhausen (2003), based in Austria, incorporated measures of residential accessibility and local land-use (as exogenous factors) to explain travel distance differences and personal household characteristics (endogenous variables). In the cross sectional data, they concluded that local accessibility measures were found to be more influential than regional measures developed from gravity models and land-use characteristics.

Recently, de Abreu e Silva et al. (2006) applied SEM to model land-use characteristics for the work and residential location to predict commuting distance and other travel variables. They concluded that land-use and urban design strongly influence car ownership and mode choice after controlling for socio-economic and demographic characteristics. Using Flemish (Belgian) regional travel survey, van Acker et al. (2007) found that socio-economic characteristics played a greater role than land-use characteristics in predicting trip frequency, distance and time. Moreover, Maat and Timmermans (2009) concluded that indirect effects can steer a total effect in another direction, thus the apparent effects of one variable on another variable can be the trade off of opposite effects. For example, the effects of residential density on travel distance suggest that people in dense residential environment travel a little less, although this effect is partly cancelled out by extra trip activities. Workplace density/mix increases total daily travel distances but decreases distances by car. The studies reviewed above are based on the activity-based theory that improves our understanding of travel behaviour decision making alongside other studies that are based on the traditional utility-maximisation theory as discussed below. The arguments used to support activity-based theory are that travel distance and the urban form relationship are a statistical association, as distances are not travel choices in itself but the consequence of other decisions (Maat and Timmermans, 2009).

Using cross-sectional data from San Francisco Bay Area, California, US, Bagley and Mokhtarian (2002) developed the first SEM in addressing residential self-selection resulting from attitudes. The SEM includes urban structure characteristics such as traditional and suburban neighbourhood and various travel attitudes as endogenous variables – this is in contrast with the aforementioned studies that treated urban structure as exogenous. Demographic, lifestyle and other additional attitudes were included as exogenous variables in this study. They concluded that residential location type had little separate impact on travel behaviour; attitudes and lifestyles were the most important predictors of travel behaviour.

Scheiner and Holz-Rau (2007) used data collected in Cologne, Germany to analyse the relationships between life situation (socio-economic and demographic characteristics), lifestyle (preferences and location attitudes measures), choice of residential location (density of supply, quality of public transport and mixed land-use) and travel mode. Their findings show that life situation is influencing mode choice more than lifestyle. But lifestyle plays an important role by affecting location attitudes and residential location type that in turn influence mode choice. The effect of location attitudes on travel behaviour (travel mode choice and distance) are found to be equal or even stronger than the effects of residential location attributes on travel behaviour in this cross sectional data, thus indicating the importance of residential self-selection issue.

In the field of travel behaviour and urban form, the superiority of SEM over linear regression is becoming more apparent (Bohte et al, 2009). This is especially true when attitudinal variables are accounted for in the joint models for travel behaviour and urban form characteristics. Using a linear regression on a cross sectional data set only shows that attitudinal characteristics are influencing travel behaviour at higher magnitude (coefficient) level than the urban form characteristics (see for example: Kitamura et al., 1997; Handy et al., 2005; Aditjandra et al., 2007). In a regression model using cross sectional data, the direction of causality can not be identified and any indirect relationships between attitudes and built environment are not clearly explained as compared to SEM. Furthermore, the collection of attitudinal data before and after a residential move is the only method of actually measuring whether attitudes have changed after relocation and have adjusted to the current built environment of the new residential location (Mokhtarian and Cao, 2008). However, the application of SEM with longitudinal data is a gap in the literature.

Handy et al. (2005) used quasi-longitudinal data from a survey of 8 neighbourhoods in Northern California. The data include residents who moved within the previous year and those who did not move during the same period. They developed an ordered probit model to investigate the unidirectional causal link from changes in the urban form (built environment) to changes in driving behaviour. However, the model has been criticised because, by design, it did not separately identify exogenous and endogenous influences (Cao et al., 2007). Cao et al. (2007) conducted a longitudinal SEM analysis using the movers in the same data. They found that neighbourhood preferences and travel related attitudes indirectly influence travel behaviour through residential choice and directly influence car ownership and driving behaviour and walking behaviour to a lesser extent. The accessibility factor (that has high associations with access to shopping mall and town centre) is the most influencing factor in explaining changes in driving behaviour.

Aditjandra et al. (2007, 2009), using a similar analysis to Handy et al. (2005), investigated the relationships of urban form and travel behaviour in British context and showed that there are significant differences between US and British data. To go in depth and to establish the direction of causation, the same data are analysed here using a SEM approach. The rationale underlying this study is the recognition of the planning activities that are heavily influenced by past experience. Whilst the problem of car dependency through the urban sprawl effect is well known worldwide, the implication of different planning and policies apply to different countries in land-use terms are different from one to another. This means evidence from one country might not be transferable to another (Aditjandra, 2008). This SEM approach will help to establish the strength and direction of the relationships among changes in the built environment, changes in travel behaviour and changes in car ownership in British context. This study enables a comparison between different countries.

METHODOLOGY

Data and variables

Since the objective of the study is to examine British case, the selection of neighbourhood hotspots to depict the typical British residential neighbourhoods was important. Ten neighbourhoods were selected to represent five Districts of Tyne and Wear metropolitan area in the North East of England. The neighbourhoods were selected to vary systematically on neighbourhood type, the Districts of the metropolitan conurbation and size of neighbourhoods. The neighbourhoods types were characterised by various street pattern layouts based on typo-morphology classification advocated by Marshal (2005) (Figure 1).

The neighbourhood unit was captured by reference to the lowest administration area used in the latest British Census (2001), the Lower Layer Super Output Area (LSOA). Tyne and Wear metropolitan area contains 719 different LSOA in total and on average, a LSOA consist of 1500 household with 7500 individual persons. The potential neighbourhoods for survey were screened District by District to ensure that income and other characteristics were above average for the area using Index of Multiple Deprivation 2004 to control for these characteristics. The purpose of this screening was to find neighbourhoods where people would choose to live rather than areas where housing might be allocated on the basis of need as it is preferences in the choice in the built environment that is being considered. The Index of Multiple Deprivation (IMD) 2004 is a UK measure of the deprivation of an area. This is available at the LSOA level and where the lower the number, the higher the level of deprivation. In Tyne and Wear, 32,482 is the least deprived area. The IMD is a weighted index, constructed by 7 aspects: income, employment, health, education, barriers to housing and services, crime and living environment.

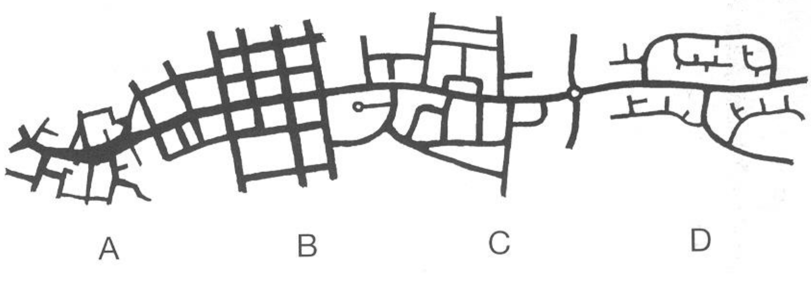

Figure 1 ABCD Typology as transect (Source: Marshall, 2005)

To combine the census screening and neighbourhood design screening, Google Earth™ was then used to capture the aerial view of a shortlist of potential neighbourhood 'hotspots' as well as to identify the homogeneity of street lay out within the LSOA. A total of 190 LSOAs from the 38 highest IMD of each district were image captured and analysed in this way. After filtering the potential 'hotspots' through controlling for income (high IMD) and the sustainability of travel exhibited (percentage of high and low of car travel to work as well as the percentage of walking, cycling and public transport use), the most representative residential neighbourhood according to ABCD typology street layout were selected as the areas for the case-study approach.

Table 1 shows how the chosen areas are classified according to the ABCD typology, as well as the characteristics of high vs low percentages of sustainable travel to work attributes derived from the British Census 2001 data which includes the modes of walk, cycle, metro and bus. It is noticeable that the A type is missing as it was not possible to find this within Tyne and Wear.

Table 1 Case-Study areas classified by ABCD typology, Census 2001 percentage of sustainable travel to work and neighbourhood housing types

ABCD typology sorting	*% Sustainable travel to work (walk, cycle, metro and bus)*	
	High	*Low*
B prone to C type	South Shields, South Tyneside (terraced)	
	Low Fell, Gateshead (terraced)	
C type	Lemington, Newcastle (semi-detached)	Cleadon Park, South Tyneside (semi detached and detached)
	Fulwell, Sunderland (terraced and semi-detached)	Tynemouth, North Tyneside (semi detached and detached)
D type	Pelaw - Wardley, Gateshead (detached)	Chapel Park, Newcastle (semi detached and detached)
		Preston Grange, North Tyneside (detached)
		Washington, Sunderland (detached)

Note: Terraced housing: is a style of medium-density housing that originated in Europe in the late 17th century, where a row of identical or mirror-image houses share side walls. Semi-detached housing: consists of pairs of houses built side by side as units sharing a party wall and usually in such a way that each house's layout is a mirror image of its twin

The survey was carried out in Spring 2007 in the form of a self-administered 8 page survey which was personally addressed using names and addresses from the electoral register and delivered to households in each of the 10 neighbourhoods identified in the previous section. A sample of approximately 220 households in each neighbourhood was selected to meet the number of the neighbourhood catchment represented by the Lower Super Output Area (LSOA) unit identified by National Statistics.

The survey was administered using a delivered-out, mail-back approach. Surveys were delivered and a pre-paid self-addressed envelope was enclosed inside each questionnaire delivered. One week later, a reminder postcard with individual names stated on the postcard was delivered to the respondents. In total 2157 questionnaire were delivered. The number of returned questionnaires totalled 716 giving a response rate of 33% of which 32% provided valid data for the analysis. In this study, 219 respondents out of a total of 716 respondents reported they had moved to their current residence within the last 8 years. Changes in the neighbourhood design were measured by taking the difference between perceived characteristics of the current and previous neighbourhoods. Table 2 presents sample characteristics of these movers.

The questionnaire was designed to capture changes in travel behaviour that result from different neighbourhood characteristics. This was planned by asking respondents who had moved to their current address to indicate how they drive now as compared to before they moved from 'a lot less', 'a little less', 'about the same', 'a little more', or 'a lot more'. This was combined with asking these same respondents to rate the neighbourhood characteristics of their previous neighbourhood in similar way to the neighbourhood in which they now reside.

Table 2 Sample characteristics (source: this study)

Housing types	Terraced to semi			Semi to detached			Detached			
	South Shields	Low Fell	Fulwell	Lemington	Tynemouth	Cleadon Park	Chapel Park	Preston Grange	Pelaw-Wardley	Washington
Number	27	30	14	20	19	18	23	28	23	17
Percent Female	58	57	58	37	35	39	59	58	52	56
Average car ownership	0.93	1.21	1.00	1.20	1.28	1.56	1.48	1.57	1.39	1.47
Average age	40.0	40.3	49.3	39.5	48.9	47.1	43.6	49.3	36.5	48.8
Average Household size	1.52	1.97	2.36	2.45	2.42	2.78	2.87	2.71	3.00	2.82
Percent Household with children	15	27	36	35	37	28	43	36	65	53
Percent home owners	74	87	86	100	74	89	87	96	100	100
Mean Household income (£k)	21.7	28.1	29.0	29.7	29.7	32.1	31.4	31.9	34.0	45.8
Median Household income (£k)	30	30	30	40	40	40	40	40	40	40

Urban structure characteristics and attitudinal attributes

Neighbourhood characteristics and neighbourhood preferences were measured using 27 statements which were divided into 6 aspects of neighbourhood design. The questionnaire design was loosely based on Handy et al. (2005) and there were a number of differences introduced. In this study the preference statements were grouped under different sub-headings of neighbourhood design aspects rather than simply listing all the statements with the sub-headings being derived from the Handy et al. work (2005) and the initial factor analysis of this study in its pilot phase. The motivation for this was to make it easier for the respondents to become familiar with the questions asked and their context. In addition, all questions were translated from American experience to the British experience so that, for example, sidewalk was replaced with pavement; big street trees with tree lined street; transit with public transport use, etc.

These statements were measured using a 4 point scale from 'not at all true' until 'entirely true' to obtain a series of answers for opinions of the respondents on the perceived built environment characteristics. In identifying the residents' opinion of the preference of the same neighbourhood characteristics in selecting residence a 4 point scale from 'not at all important' until 'extremely important' was used for measuring. Travel attitude/preference were measured using a series of 28 statements on a 5-point scale from 1 'strongly disagree' to 5 'strongly agree' against the respondents. Factor analysis was then used to extract these 28 statements, for similar reasons to those for neighbourhood characteristics.

Common Factor Analysis (CFA) was used to extract 27 statements on neighbourhood design characteristics and 28 statements of travel attitudes/preferences. Through this analysis, perceived and preferred neighbourhood characteristics were extracted into seven factors which have been identified as factors relating to safety, travel accessibility, residential spaciousness, social factors, shopping/facilities accessibility, outdoor space accessibility and neighbourhood attractiveness. The travel attitudes were reduced to eight factors including pro-public transport use, travel minimising awareness, pro-cycling, travel time sensitivity, safety of car, pro-walking, pro-travel and car dependent. The complete table of factor loadings can be seen in Table 3.

Table 3 Factor loadings from CFA on neighbourhood characteristics (left) and travel attitude characteristics (right) (Source: Aditjandra, 2009)

Factors (a)	Statements – variables	Loadings(b)
Safety	Safe neighbourhood for walking	.829
	Low crime rate	.777
	Safe neighbourhood for children outdoor	.686
	Low level of car traffic	.673
	Quiet Neighbourhood	.603
	Good street lighting	.364
	High level of neighbourhood's upkeep	.240
	Easy access to highway network	-.233
Travel accessibility	Easy access to a good P.T. service	.877
	Good P.T. service	.804
	Easy access to highway network	.417
	Pavements - easy walking routes	-.394
	Local shops within walking distance	.353
	Good street lighting	.226
Residential spaciousness	Adequate space of garden at the front	.919
	Adequate space of garden at the back	.857
	Adequate parking space	.560
Social factors	Lots of people out and about	.787
	Lots of interaction among neighbours	.665
	Diverse neighbours	.465
	Economic situation of neighbours similar	.386
Shopping/ facilities accessibility	Easy access to a district shopping centre	.913
	Easy access to town centre	.713
	Other amenities/facilities nearby	.468
	Local shops within walking distance	.316
	Easy access to highway network	.217
Outdoor spaciousness accessibility	Parks and open spaces nearby	.586
	Extension of cycle routes	.576
	Other amenities/facilities nearby	.309
	Pavements - easy walking routes	.270
	Tree lined street	.240
Neighbourhood attractiveness	Attractive appearance of neighbourhood	-.771
	High level of neighbourhood's upkeep	-.723
	Variety in housing style	-.440
	Tree lined street	-.261

Factors (a)	Statements – variables	Loadings (b)
Pro-public transport use	Like travel by public transport	.876
	Prefer travel by public transport than drive	.870
	Travel by public transport easier than drive	.743
	Car safer than public transport travel	-.215
Travel minimizing awareness	Prefer to organise errands for fewer trips	.634
	Fuel efficiency factor in choosing a car	.617
	Limit driving for improved air quality	.598
	Fuel price effects choice of daily travel	.570
	Often use phone/internet to avoid travel	.399
	Buying something from closet store possible	.393
	Vehicle taxed for pollution they produce	.368
Pro-cycling	Prefer cycle rather than drive	-.930
	Like cycling	-.782
	Cycle easier than drive	-.751
Travel time sensitivity	Travel time is wasted time	-.643
	Destination oriented	-.618
Safety of car	Car safer than public transport travel	.801
	Car safer than walk	.775
	Car safer than cycling	.488
	Build more roads to reduce traffic congestion	.295
Pro-walking	Like walking	.730
	Prefer walk than drive	.728
	Walk easier than drive	.582
Pro-travel	Importance of journey	-.720
	Use time productively	-.618
	Manage well with fewer car	-.210
Car dependent	Need a car to do many things	.632
	Work without car is a hassle	.551
	Like driving	.293

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
(a) Rotation converged in 8 iterations.
(b) Degree of association between the factors and the statements

Socio-demographic variables measured include gender, age, economic status, educational background, household income, household size and number of children. Changes in household income, household size and number of children before and after relocation were also captured in this survey.

MODEL RESULTS

Modelling approach

The work of Cao et al. (2007) is used as the approach to SEM model specification in this study. Changes in travel behaviour, changes in built environment and changes in car ownership were initially selected as endogenous variables. The direction of the presumed causal effects is as follows: changes in the built environment affect both changes in car ownership and changes in travel behaviour. The relationship between changes in car ownership and changes in travel behaviour are also tested. The exogenous variables are changes in socio-demographic variables and current attitudinal factors.

Conceptual Model and Model Estimation

The original conceptual model consists of three sets of endogenous variables: changes in the built environment, changes in car ownership, and changes in driving behaviour (Figure 2). In a longitudinal analysis, the directionalities of the hypothesized effects are important due to the temporal sequences of events and previous research has well documented that residential choice is a long-term choice, car ownership is a medium term decision, and travel behaviour is conditional on both residential choice and car ownership choice (Ben-Akiva and Atherton, 1977). Therefore, similar to Cao et al. (2007), it is assumed that changes in the built environment affect both changes in car ownership and driving behaviour, and changes in car ownership in turn impact changes in driving behaviour. It is hypothesized that endogenous variables are also affected by a few groups of exogenous variables: demographic attributes and their changes, current neighbourhood attribute, and current attitudinal factors.

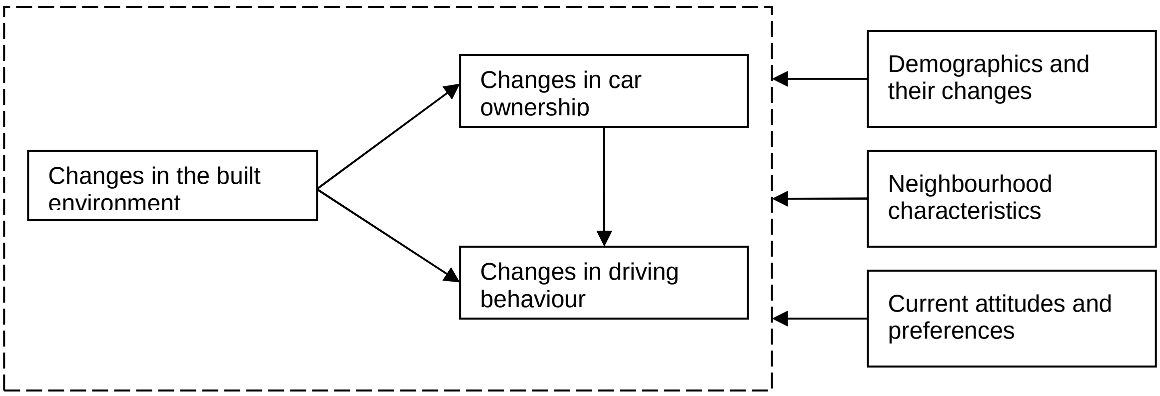

Figure 2 Conceptual model

The maximum likelihood estimation (MLE) approach, commonly used in practice, is used to develop the SEM. Because the data contain missing values, the option of "estimate means and intercepts" is chosen with 0.1 (10%) as the critical significance level. Initial investigation found that amongst the various dimensions of changes in the built environment, only two were significant: changes in safety in the built environment was positively associated with changes in car ownership and changes in travel access had a negative association with changes in driving. In terms of neighbourhood attributes both social factor and shopping accessibility were significantly associated with changes in car ownership and driving. In the equations for changes in the built environment, no exogenous variables were found to significantly affect changes in safety built environment and only one variable, the pro-walking attitude, was significant associated with changes in travel access. Due to these observations, a more parsimonious model structure was designed by treating changes in the built environment as exogenous variables (Figure 3).

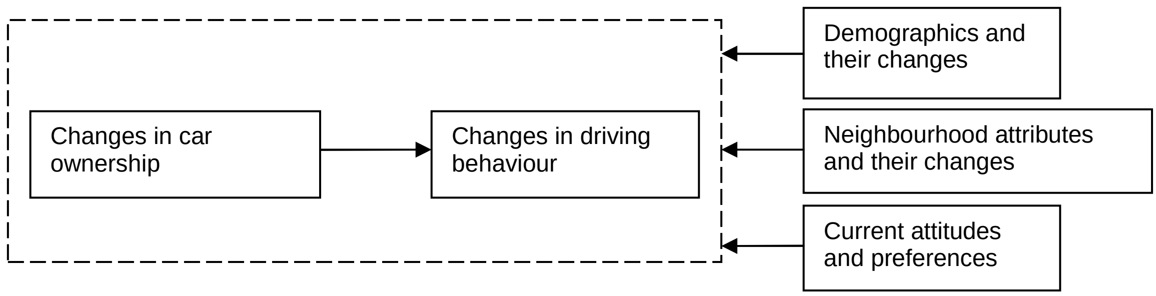

Figure 3 Parsimonious conceptual model

This model differs from the earlier one mainly by the way in which *changes* in measures were used instead of *levels* or current measures: this applied to the social factor and to shopping accessibility. The rationale for this was that changes in variables offer more insight than the level measures given the longitudinal nature of the analysis. This new parsimonious model performed better by reference to a number of goodness of fit statistics shown in Table 4 which shows the model has an acceptable fit. Attempt is made to evaluate the multivariate normality assumption of the data. However, AMOS does not produce statistics regarding normality assumption when the option of “estimating means and concepts” is selected. If cases with missing values are removed, the effective sample size will be reduced by about 25% (from 219 to 169). Given relative small sample size, retaining as many observations as possible would be more valuable.

Table 4 Model Goodness-of-Fit (GOF)

Degrees of freedom	65
χ^2: measures discrepancy between the sample and model-implied covariance matrices; the smaller the better*.	103.8
χ^2/d.f.: a “relative chi-square value” corrected for degrees of freedom; values of 3 or less indicate a good fit and values as high as 5 represent an adequate fit.	1.60
Hoelter Critical N: A parameter to judge if sample size is adequate. A critical N of 200 or better indicates a satisfactory fit and a value under 75 is unacceptable.	196
Root Mean Square Error of Approximation (RMSEA): measures the estimated discrepancy between the model-implied and true population covariance matrix, corrected for degrees of freedom; values less than 0.05 indicate a good fit, and values as high as 0.08 represent a reasonable fit.	0.053

* The chi-squared statistic increases with the sample size and so it is not a good measure of goodness-of-fit (GOF). However as the basis for other GOF measures, it is always reported anyway (Byrne, 2001)

Model Discussion

Table 5 presents the matrix of standardised direct effects and total effects of the parsimonious model. In terms of endogenous variables, changes in car ownership were found to have a positive relationship with changes in driving behaviour. Regarding socio-demographic attributes, an increase in household income and/or an increase in household size tended to result in an increase in car ownership. However, there were no significant influences of the two variables on changes in driving behaviour. The variables of current measures of travel attitudes and residential preferences influence changes in car ownership and driving behaviour, particularly the latter. Individuals who favoured alternative modes of transportation (public transport, cycling, and walking) were more likely to reduce their driving. People who devalued their travel time while driving (the travel time sensitivity score) were likely to have a lower car ownership and drive less. Those who preferred to have a high access to shopping facilities tended to increase their driving.

Table 5 Standardized direct and total effects (N=219)

Variables	Changes in car ownership	Changes in driving behaviour
Endogenous variables		
Changes in car ownership		.173 (.173)
Changes in driving behaviour		-
Exogenous variables		
Socio-demographics		
Changes in income	.262 (.262)	0 (.045)
Changes in household size	.406 (.406)	0 (.070)
Travel attitudes		
Pro-public transport		-.173 (-.173)
Pro-cycling		-.116 (-.116)
Travel time sensitivity	-.144 (-.144)	-.124 (-.149)
Pro-walking		-.117 (-.117)
Residential preferences		
Shopping accessibility		.124 (.124)
Neighbourhood characteristics		
Changes in safety built environment	.119 (119)	0 (.021)
Changes in shopping accessibility	-.123 (-.123)	0 (-.021)
Changes in travel accessibility		-.157 (-.157)
Change in social factor		-.145 (-.145)
Squared multiple correlations	*.248*	*.169*

Notes: The numbers in brackets are total effects. A blank cell indicates that this variable was found to be insignificant at the 0.1 level in the model therefore estimated as a zero coefficient.

After controlling for demographic and attitudinal factors, four built environment variables were found to be associated with changes in car ownership and driving behaviour. In particular, an increase in safety aspect of the residential environment tends to lead to an increase in car ownership. The safety variable may act as a proxy for suburban neighbourhood because safety tends to be positively associated with suburban neighbourhoods and suburbanites tend to have a high level of car ownership. Therefore, a substantial increase in neighbourhood safety (such as a move from town centre to suburban communities) may require people to acquire an additional vehicle. An individual who moved to an area with easy access to a shopping centre and town centre (high shopping accessibility) was more likely to shed a private car. People who experienced an increase in access to the transportation system (especially public transport) tended to reduce their driving. Changes in the social environment were negatively associated with changes in driving behaviour. The more people exposed to socially conducive neighbourhood, the less they drove their car. As modelling change variables in the longitudinal analysis addresses the time precedence of an association and the SEM controls the confounding factors and interactions among variables, the significant relationships found in this study provide a robust inference for the causal influences of the built environment on driving behaviour (Singleton and Straits, 2005).

Furthermore, a comparison of standardized total effects shows that the sizes of built environment variables' influence on driving behaviour are equivalent to those of other variables. Similar to Cao et al. (2007), if the three built environment variables having negative coefficients are increased by one standard deviation and the built environment variable having positive sign is decreased by one standard deviation simultaneously (as might be the case with a move from a suburban to an urban neighbourhood, since the former three variables and the latter variable might tend to vary together but in opposite ways), then this model suggests that on average, the indicator of driving behavior will be reduced by 0.344 standard deviations (=-0.021-0.021-0.157-0.145). In other words, roughly speaking, the overall marginal effects of built environment variables on driving behavior are 0.344. This magnitude is similar to the finding in Cao et al. (2007).

CONCLUSIONS

This study applies SEM in a British quasi-longitudinal data to understand the relationships between neighbourhood design and travel behaviour. The literature suggests the superiority of SEM over linear regression in uncovering relationships among travel behaviour, urban form and travel attitudes characteristics. The study shows that in terms of standardized coefficients, changes in socio-economic characteristics are the main contributor to the changes in car ownership and changes in urban structure characteristics, such as a safety factor and shopping accessibility, have important influences. These variables also affect changes in driving behaviour indirectly through their influences on changes in auto ownership. Furthermore, changes in the built environment characteristics, such as travel accessibility and social factor, tend to bring about changes in driving behaviour. The sizes of the effects are comparable to those of the effects of attitudes and changes in auto ownership. This finding is consistent with Cao et al. (2007), thus confirming that urban structure impact on travel behaviour has similar effect across different geographical boundaries.

These findings are interesting in the British land-use policy context. The safety factor has a strong contribution to car ownership as does the shopping accessibility factor although the two coefficients have opposite signs. For land-use policy this can be interpreted that an environment less conducive to driving should have a good shopping accessibility. This finding provides evidence for the recommendations of the Barker review (2006): it is important to develop accessible supermarket to meet local residential market. This would encourage supermarket chains to expand their business rather than concentrate on fewer large stores. However it should be noted that accessibility in this context refers to all modes rather than just car, because we also found that those who preferred to have a high access to shopping facilities tended to increase their driving (This is consistent with Handy et al., 2005 and Aditjandra et al., 2007). How British policies guide commercial development, for example, building a new supermarket such as Tesco (the biggest supermarket chain in Britain which usually located out of town with big car parking area) or requiring smaller Tesco Metro (local supermarket size), will significantly influence car ownership of its residential population. It should also be noted that safety is important according to this analysis and the evidence suggests that this is associated with suburban neighbourhoods. Resources to make traditional neighbourhood as safe as suburban ones would also be an effective policy.

Changes in travel accessibility (which has high associations with public transport access) and changes in social factors (which has high associations with interaction among neighbours) significantly reduce driving. Therefore, when developing a new town or a new neighbourhood, (public transport) accessibility and the lay out of housing to accommodate social interactions would contribute to the reduction in driving level.

In addition, this study also confirms the role of residential self-selection in changing travel behaviour. Individuals who favoured alternative modes of transportation (public transport, cycling, and walking) were more likely to reduce their driving. This evidence can be used to make the case for developing more compact city type of neighbourhoods which are self supporting in terms of facilities, and thus, meeting the housing market that fits residents with less car dependent orientation. This is consistent with the recommendations of other studies: shaping more balanced, smarter infrastructure growth, mixed-use patterns in urban development towards meeting the low carbon future (Falk, 2009, Scheiner, 2010 - forthcoming).

Revisiting the debate of the development of Eco-Town in Britain towards meeting future sustainable travel, this study shows that built environment characteristics can play an important role to meet these goals.

REFERENCES

Aditjandra, P.T. (2008) The relationship between urban form and travel behaviour: a micro-analysis in Tyne and Wear. PhD Thesis. November 2008. School of Civil Engineering and Geosciences, Newcastle University.

Aditjandra, P.T., C.A. Mulley and J.D. Nelson (2009) Neighbourhood design impact on travel behaviour: a comparison of US and UK experience. Projections, MIT Journal of Planning Vol. 9: Planning for Sustainable Transportation: an International Perspective, pp. 28-56.

Aditjandra, P.T., C.A. Mulley and J.D. Nelson (2007) Neighbourhood design perception and travel behaviour in Tyne and Wear, North East England, United Kingdom. Paper presented at the 10th European Urban Research Association (EURA) 'Vital City'

Conference 12-14 September 2007, Glasgow, UK. Available online at: http://www.gla.ac.uk/media/media_47889_en.pdf

Axhausen, K. and Gärling, T. (1992) Activity-based approaches to travel analysis: conceptual frameworks, models, and research problems. Transport Reviews, Vol.12, No.4, pp.323-341.

Bagley, M.N. and P. Mokhtarian (2002) The impact of residential neighbourhood type on travel behaviour: a structural equation modelling approach. Annals of Regional Science, 36, 279-297.

Barker, K. (2006) Barker Review of Land Use Planning Final Report – Recommendations. HMSO, Norwich. TSO. Available online at: http://www.hm-treasury.gov.uk/media/3/A/barker_finalreport051206.pdf

Ben-Akiva, M. and Atherton, T. J. (1977). Methodology for short-range travel demand predictions: Analysis of carpooling incentives. Journal of Transport Economics and Policy, 11, 224-261.

Bibby, P. (2009) Land use change in Britain. Land Use Policy 26S: S2–S13.

Bohte, W., K. Maat and B. van Wee (2009) Measuring Attitudes in Research on Residential Self-Selection and Travel Behaviour: A Review of Theories and Empirical Research. Transport Reviews, Vol.29, No.3, pp.325-357.

Byrne, B.M. (2001) Structural Equation Modelling with AMOS: Basic concepts, Applications, and Programming. Lawrence Erlbaum Associates, Inc., Mahwah, New Jersey.

Cao, X., P.L. Mokhtarian and S.L. Handy (2009) Examining the Impacts of Residential Self-Selection on Travel Behaviour: A Focus on Empirical Findings. Transport Reviews, Vol.29, No.3, pp.359-395.

Cao, X., P.L. Mokhtarian and S.L. Handy (2007) Do Changes in Neighbourhood Characteristics Lead to Changes in Travel Behaviour? A Structural Equations Modelling Approach. Transportation, Vol.34, No.5, pp.535-556.

CfIT – Commission for Integrated Transport (2009) Land Use and Transport: Settlement Patterns and the Demand for Travel. Halcrow Group Ltd in association with P. Headicar, D. Banister and T. Pharoah. Background technical report. October 2009. Available online at: http://cfit.independent.gov.uk/pubs/2009/sustainable/technical/pdf/pst-technical.pdf

de Abreu e Silva,J., T.F. Golob and K.G. Goulias (2006) Effects of Land Use Characteristics on Residence and Employment Location and Travel Behavior of Urban Adult Workers. Transportation Research Record, 1977, 121-131.

Falk, N. (2009) Briefing: Learning from Europe. Proceedings of the Institution of Civil Engineers. Urban Design and Planning, 162, pp: 53-58.

Golob, T. (2003) Structural equation modelling for travel behaviour research. Transportation Research Part B, 37, 1-25.

Golob, T (2000) A simultaneous model of household activity participation and trip chain generation. Transportation Research Part B, 34, 355-376.

Handy, S., X. Cao and P.L. Mokhtarian (2005). Correlation or causality between the built environment and travel behaviour? Evidence from Northern California. Transportation Research Part D, 10, 427-444.

Jöreskog, K.G. (1973) A general method for estimating a linear structural equation system. In Goldberger, A.S., Duncan, O.D. (Eds.), Structural Equations Models in the Social Sciences. Academic Press, New York.

Kitamura, R., Mokhtarian, P.L. and Laidet, L. (1997) A micro-analysis of land use and travel in five neighbourhoods in the San Francisco Bay Area. Transportation, 24(2), pp. 125-158.

Maat, K. and H.J.P. Timmermans (2009) A causal model relating urban form with daily travel distance trough activity/travel decisions. Transportation Planning and Technology, Vol.32, No.2, pp.115-134.

Mokhtarian, P.L. and X. Cao (2008) Examining the Impacts of Residential Self-Selection on Travel Behaviour: A Focus on Methodologies. Transportation Research Part B, 42, 204–228.

Naess, P. (2009) Residential self-selection and appropriate control variables in land-use-travel studies. Transport Reviews, Vol.29, No.3, pp.293-324.

Scheiner, J. (2010 – forthcoming) Far, far away – trip distances and mode choice in the context of residential self-selection and the built environment in Columbus, F. (ed., 2010): Built Environment (working title). Hauppauge, NY: Nova Publishers.

Scheiner, J. (2009) Social inequalities in travel behaviour: trip distances in the context of residential self-selection and lifestyles. Journal of Transport Geography, article in Press.

Simma, A. and K.W. Axhausen (2003) Interactions between travel behaviour, accessibility and personal characteristics: the case of upper Austria. European Journal on Transport Infrastructure and Research, 3(2), 179-197.

Singleton, R. A. Jr. and Straits, B. C. (2005). Approaches to Social Research, 4th edition. New York: Oxford University Press.

van Acker, V., F. Witlox and B.v. Wee (2007) The Effects of the Land Use System on Travel Behavior: A Structural Equation Modeling Approach. Transportation Planning and Technology, Vol.30, No.4, pp.331-353.