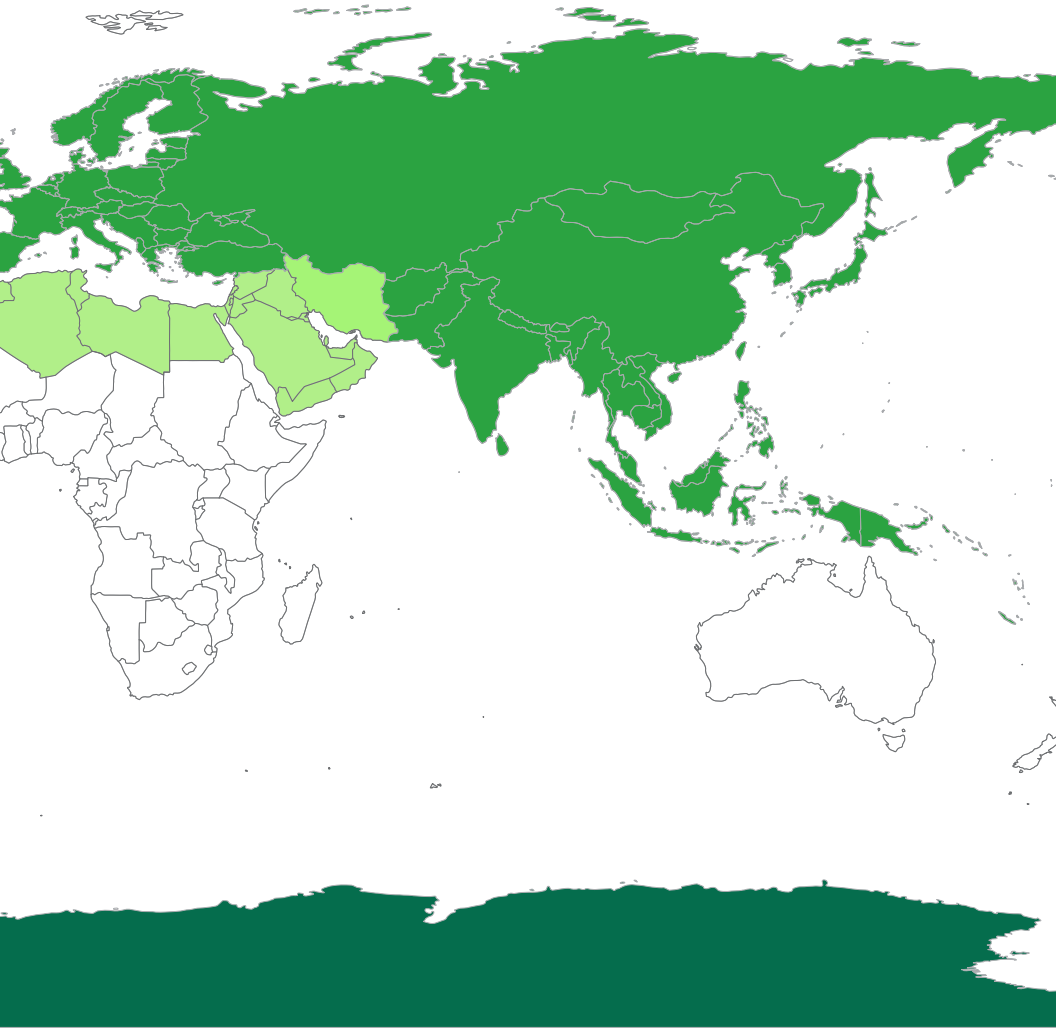
SUSTAINABLE TRANSPORTATION

AN INTERNATIONAL PERSPECTIVE



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SUSTAINABLE TRANSPORTATION
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COVER IMAGE Map courtesy of Eva Kassens; data courtesy of World Resources Institute, 2005. This map shows CO_2 emissions by transport as a percentage of emissions. The more grey the continent, the higher the CO_2 transport emissions in relation to total emission of that continent; the more greeen the continent, the lower the CO_2 transport emissions in relation to total emission of that continent.

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NEIGHBOURHOOD DESIGN IMPACT ON TRAVEL BEHAVIOR : A COMPARISON OF US AND UK EXPERIENCE

ABSTRACT

This paper presents evidence from the UK in respect of the impact of neighbourhood design on travel behaviour using a neighbourhood, micro scale, case-study approach. Whilst there is an extensive American literature on this subject, this is limited in applicability to European or British practice since the urban form variables, such as street layout and levels of car use in all areas, have a different scale.

Neighbourhood design and travel attitude characteristics were modelled using factor analysis and the causation relationship was established using reported vehicle miles driven (VMD) as the dependent variable in a subsequent regression analysis. Despite modest differences in VMD between UK and US, there are significant differences in its explanation. The most important predictors for the UK study are the socio-economic variables, followed by travel attitudes, neighbourhood characteristics preferences and land-use type in contrast to the US experience which identifies travel attitude as the biggest predictor of VMD.

Many studies in this field suffer from the criticism that respondents select their area of residence because of specific neighbourhood characteristics and this gives rise to a 'self-selection' issue. This study addresses this by the collection and analysis of quasi-longitudinal data from respondents who moved home in the previous eight years. This analysis shows that travel accessibility is sensitive to changes in walking and public transport use, suggesting that residents of British neighbourhoods are more aware of public transport than their US counterparts and more likely to use sustainable, low carbon means of travel.

INTRODUCTION

Whilst individuals appear increasingly wedded to their cars, there are new trends emerging from the developments of neighbourhoods arising out of the 'New Urbanism' movement in the US and 'Compact City' movement in Europe. These movements promote a state of sustainable travel identified as a low carbon based travel. Governments have been quite sensitive in their response to this idea with 'Smart Growth' in the US, the 'ABC' policy in the Netherlands and PPG13 in the UK being the confirmation of governmental support of such movements. These trends also confirm the increasing research findings that support a less car dependent environment and promote alternatives travel through land-use planning. Although it has long been thought that urban form, land-use and design can influence travel demand (Cervero & Kockelman, 1997), recent research findings have revealed that land-use characteristics impacts on travel behaviour through quite complex relationships (Boarnet & Crane, 2001). Socio-economic variables, attitudes and preferences towards travel and neighbourhood characteristics, and residential self-selection, are some of the contributing characteristics which also bring about change in travel behaviour (Handy et al, 2005).

Most studies looking at the impact of the built environment on travel behaviour identify that the provision of higher density, mixed land-use, public transport service accessibility and pedestrian friendly built environment can contribute to a less car dependent environment. At the macro scale (i.e. density and mixture of land-use) there is considerable evidence identifying advantages and improving understanding towards sustainable travel development (see for example: Newman & Kenworthy, 1989; Badoe & Miller, 2000; Ewing & Cervero, 2001) although the implementation of this in the planning policy at all levels (despite Governmental support) has never been a straightforward issue (Curtis, 2007). At the micro scale (i.e. neighbourhood design characteristics and personal travel behaviour) more recent studies are emerging showing that neighbourhood characteristics can influence people's travel pattern towards sustainable travel (see for example: Handy et al., 2005, Bhat & Guo, 2007). The planning practice to implement development to promote sustainable travel pattern at this micro level has (again) not been easy (CABE, 2004), particularly as it is against a growth in car ownership and increases in car travel. However, the trend of looking at the micro scale of land-use and travel behaviour relationships identifies a need to understand design at a human scale. The message is quite clear that urban form should be built for the human not car if sustainable travel is to be achieved.

There is a considerable American literature on land-use and travel behaviour and in the UK, the most extensive work has been undertaken by Stead (2001) who concluded that socio-economic factors explained more than 50% of the variation in the amount of travel by census wards (which are slightly larger than the US census track). Recently there have been two publicly funded projects to address this issue. 'City Form', started in 2001, has been looking at the macro scale

to answer the extent the ways urban form contributes to sustainability. Its main finding is that density is the largest explanatory variable of sustainability. The second, 'SOLUTIONS', started in 2004, is also working at the macro scale to identify how far, and by what means, towns and cities can be planned so they are socially inclusive, economically efficient and environmentally sustainable. The study reported in this paper is conceived at the micro scale of neighbourhoods with the objective of understanding the links between neighbourhood design characteristics and travel behaviour that contribute towards sustainable travel patterns.

Although there have been many studies, these have concentrated on looking at the association between neighbourhood design characteristics and travel behaviour. In the US, an important step forward has been the investigation of causal relationships between neighbourhood design characteristics and travel behaviour (Handy et al., 2005). Perhaps even more importantly, work in this area has shown that changes in neighbourhood design lead to changes in travel behaviour (Cao et al., 2007). This paper will report British evidence of the impact of neighbourhood design characteristics on travel behaviour. The study approach uses a case study and a quasi-longitudinal questionnaire methodology to investigate the relationships between travel behaviour and neighbourhood design characteristics as well as to capture changes in travel behaviour before and after people relocate.

In the cross-sectional analysis, the study found that there is a similarity between the US and the UK evidence where the built environment characteristics impacts on travel behaviour although in UK the impact is relatively bigger. In contrast, whilst the US evidence found that travel attitude explained the vehicle miles driven (VMD) better than the socio-economic variables, the reverse is true in the UK with socio-economic variables being more influential in the explanation of VMD suggesting that travel behaviour in the UK and US are different.

In the quasi-longitudinal analysis, undertaken to look at the issue of residential self-selection, the study found that travel accessibility perception in the UK is sensitive to changes in walking and public transport use. This suggests that residents of British neighbourhoods are more aware of public transport than their US counterparts and more likely to use sustainable, low carbon means of travel. However, this is influenced by the transport and land-use patterns and in the UK these are different from the US. Many of the suburban residential neighbourhoods of the UK are not as isolated as the suburban neighbourhoods of the US. In the US evidence, residents who live in the suburban neighbourhoods and who claim to prefer not to use private car have no alternative. In contrast UK residents who live in suburban neighbourhoods still have access to public transport service and local facilities, especially when living in a metropolitan conurbation area such as Tyne and Wear which has an extensive public transport system. This means that residential self-selection may not be as big an issue in the UK, as compared to the US, because alternatives are more available for those who have preferences – both pro-public transport and pro-car.

LITERATURE REVIEW

The literature reported here is looking at the trend of analysis over time in the search for evidence of land-use planning contributing to sustainable travel. In the US the idea that land-use and design polices could be used to influence travel behaviour started in the late 1970s whereas in the UK this was not happening until the late 1980s when the issue began to attract research interest (Headicar, 2003). The work of Newman and Kenworthy (1989) looked at a sample of international cities and established that density could have a strong relationship with travel behaviour. Their campaign to overcome car dependence in favour of more environmentally sustainable travel patterns has led to many subsequent questions as to the cause and effect between urban form and travel behaviour. Since the early 1990s there have been many studies (especially in the US) which have put effort into testing the hypothesis that polices that shape the built environment can be used to reduce car travel where the built environment is defined as consisting of three components: land-use patterns, transportation system and design (Handy, 2005).

In broad terms, research on the influence of built environment on travel behaviour can be classified into three different approaches: hypothetical studies, descriptive studies and multivariate statistical studies (Boarnet and Crane, 2001). In hypothetical studies, the general idea is to construct situations, in a strategically and controlled environment, where different land-use patterns and other urban features can be linked to travel. Traditional transportation models are used to predict differences in total travel between typical suburban neighbourhoods and hypothetical neo-traditional neighbourhoods (Handy, 1996). These studies are not intended to explain behaviour; rather they make certain assumptions regarding behaviour and then apply those to alternative situations to see what happens. This approach has usually tended to focus on the overall structure of a city or metropolitan area, in terms of the distribution of employment and residential activities and/or the structure of the transportation network (Handy, 1996). Figure 1 describes the illustration of the differences of street pattern that may lead to differences of travel pattern with the 'preferred' layout being associated with more sustainable travel.

Descriptive studies provide an account of travel experiences, individually or on average. These studies provide a picture of observed behaviour and may contain important data and revealing insights regarding travel patterns in different settings. However, these studies can not explain travel behaviour and only report what is observed. Multivariate statistical studies examine observed rather than hypothetical behaviour. These studies attempt to explain rather than merely describe what is going on. The studies in this category vary from descriptive studies in several significant ways. First, they ask different questions of their data. Second, their data captures different features of the built environment and of travellers and at different levels of detail. Third, they investigate their data by (usually) statistical means (Boarnet & Crane, 2001). For example,

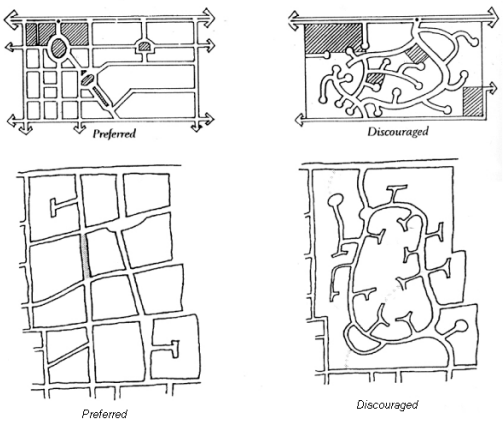

FIGURE 1. Examples of 'Preferred' + 'Discouraged' neighborhood street layouts. *Source*: Marshall, 2005.

Ewing and Cervero (2001) in their meta analysis of built environment impact on travel behaviour came to the conclusion that the built environment has a greater impact on trip length than trip frequencies and that mode choice depends on socio-economic as much as the built environment characteristics. Cervero and Kockelman (1997) in their study of mode choice impact on built environment concluded that compact, mixed land-use and pedestrian friendly urban development can significantly reduce car travel.

A questionnaire that simply asks for information on the current residential neighbourhood is open to the criticism of ignoring the issue of residential self-selection. For this reason, recent studies have involved a longitudinal design to capture the effect of time order. Thus, the issue of causality of the neighbourhood design impact on travel behaviour is the main focus in recent US studies (e.g. Handy et al., 2005 and Krizek, 2003). The studies involving time order factors have revealed causal relationships between neighbourhood design and travel behaviour (Meurs & Haaijer, 2001, Krizek, 2003, Handy et al., 2005). An extensive residential self-selection study by Schwanen and Mokhtarian (2005) found that neighbourhood type does impact on travel behaviour.

Table 1 brings together the results from some influential studies in urban form and travel behaviour relationships. This extensive American literature gives mixed results. There appears always to be a positive result (in terms of built environment can impact on travel behaviour to reduce car travel) when a hypothetical or descriptive approach is taken but this same effect is not shown in multivariate analysis which has given rise to both negative and positive results. Thus it is clear that the explanation as to why people have certain travel patterns depends on many factors. More evidence is needed to strengthen the understanding of various land-use impacts on travel. Where land-use characteristics are used to measure car use (e.g. Vehicle Miles Driven as known VMD), density, mixed land-use, pedestrian pavements and public transport provision play a role

in reducing car travel (Cervero & Kockelman, 1997, Meurs & Haaijer, 2001, and Krizek, 2003) but this is not always clear cut as there are some studies confirming negative results of land-use characteristics in explaining VMD (Boarnet & Crane, 2001, Handy et al., 2005).

When socio-economic and travel attitudes are accounted for, the results suggest land-use characteristics play less of a role in explaining car travel (Kitamura et al., 1997, Stead, 2001, Dieleman et al., 2002, Boarnet & Crane, 2001, Naess and Jensen, 2004 and Handy et al., 2005), although a recent study by Bhat and Guo (2007) without travel attitude consideration, confirms that built environment characteristics affect residential choice decisions as well as car ownership decisions. However, the studies that have looked at longitudinal data to capture what happens when people move residence and the way their travel changes according to the available built environment characteristics has revealed causal relationships in terms of land-use transport issues (Meurs & Haaijer, 2001, Krizek, 2003, Handy et al., 2005). Furthermore, European studies such as Naess and Jensen (2004) and Meurs and Haaijer (2001) show that neighbourhood design characteristics clearly influences travel behaviour.

More recent US studies are now focussing on residential self-selection. The argument is that if people choose to live in a neighbourhood which favours their preferences, then it is their preferences what make them travel the way they do, not the neighbourhood design characteristics (Handy et al., 2005). (Cao et al., 2009 - forthcoming) undertakes a thorough review of methods used to investigate the residential self-selection issue and concludes that the methodology employed by Handy et al. approach is the most powerful. For this reason, this study has developed the approach of Handy et al. (2005) to include travel attitude characteristics and to look at the impact of residential self-selection.

In the UK, the issue of how neighbourhood design impacts on travel behaviour together with the issue of residential self-selection has been less well researched. As land-use patterns in the UK are different from the US, this paper addresses whether the impact of neighbourhood design and residential self-selection might also be different. Many of the suburban residential neighbourhoods of the UK are not as isolated as the suburban residential neighbourhoods of the US (Schwanen and Mokhtarian, 2005). In the US evidence, residents who live in the suburban neighbourhoods and who claim to prefer not to use private car have no alternative. In contrast UK residents who live in suburban neighbourhoods still have access to public transport service and local facilities. This means that residential self-selection may not be as big an issue in the UK, as compared to the US. For this reason, looking at the neighbourhood design impact on travel behaviour in the UK will give insight to the extent to which neighbourhood characteristics or residential self-selection play a role in explaining travel behaviour.
The UK based study by Stead (2001) looked at the three dimensional relationships of land-use,

travel patterns and socio-economic variables but did not consider travel attitudes and preferences. The evidence presented in this paper provides evidence for this gap using disaggregated data to focus on the British evidence on the impact of neighbourhood design and residential self-selection on travel behaviour.

METHODOLOGY

The objectives of the study presented here are to explore the relationship between neighbourhood design and travel behaviour with a deliberate focus on a British case study at the micro level. As such it provides evidence to assess whether the US literature in this field has a direct applicability to British cities where the urban form variables, such as street layout and levels of car use in all areas, have a different scale. In addition to scale differences, of the association and causation between different neighbourhood design characteristics and travel behaviour, the travel attitudes and preferences in the UK could differ from the US experience because of underlying cultural differences. Thus the underlying hypothesis to this study is

> *"Neighbourhood design characteristics and travel behaviour association in the UK may be different to those exposed for the US in the existing American literature because of differences in the nature of urban form and underlying differences in travel attitudes and preferences"*

A questionnaire methodology was used to capture four aspects of neighbourhood design characteristics (through respondents' perception and preferences and also for their previous residence if they had moved in the past 8 years): travel attitudes, socio-economic variables and travel patterns (including information on Vehicle Miles Driven known as VMD). These are important for this study as the intention is to model the impact of the built environment characteristics and travel attitudes, in addition to the normal travel demand characteristics, on travel behaviour.

Selection of case study neighbourhoods

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 Marshall (2005) (See Figure 2). However this typology does not easily create comparison with the existing American literature, and for the purpose of this paper, traditional and suburban neighbourhood comparison is used to make a descriptive comparison. Traditional neighbourhoods were built mostly before World War II and suburban neighbourhoods were built

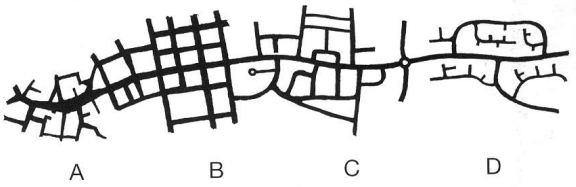

FIGURE 2. ABCD typology as transect. *Source*: Marshall, 2005.

TABLE 2. Case-Study areas classified by ABCD typology, Census 2001 percentage of sustainable travel to work and neighbourhood types

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

(T) = traditional neighbourhood
(S) = suburban neighbourhood

post-1960s. Thus to compare the results of this study with the American based literature, the suburban typology has been classified as D type neighbourhoods and the traditional neighbourhood as C type or B type although the scale of street design in the UK is lower than in the US.

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[1] 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.

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 traditional and suburban layout were selected as the areas for the case-study approach.

Table 2 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. Aerial views of Tyne and Wear with the geographical position of these 10 selected neighbourhoods is shown in Figure 3.

Survey and sampling

The survey was undertaken in late spring 2007 in the form of a self-administered 8 page questionnaire booklet. The survey was delivered to personally addressed households in each of the ten neighbourhoods identified in the previous section. A sample of approximately 220 households in each neighbourhood was selected in proportion to the total size of the LSOA. Names and addresses were obtained from the electoral register of voters. A prepaid self-addressed envelope was enclosed inside each questionnaire which was hand delivered. One week later, a reminder postcard with individually addressed was delivered.

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. A comparison of sample characteristics (based on British Census 2001) shows that overall the socio-economic variables of the sample characteristics are quite similar to the population characteristics with the exception of age and the number of households with dependent children. The number of people aged above 45 is higher than displayed in the Census and the number of household with dependent children is less than recorded in the Census. However, the average number of years lived at the current address is extremely high for respondents (over 20 years in the traditional neighbourhood and over 15 years in the suburban neighbourhood) and thus a proportion of households which would have dependent children in 2001 would have not had dependent children at the time of this survey, six years later. Given the growth in car ownership nationally it is also not surprising that the respondents from the survey showed more cars per household than at the time of the Census. Despite these differences of the sample against the Census, the focus of this study is on explaining the relationships of other variables to travel behaviour rather than on describing travel behaviour on its own and these differences are not expected to affect the results (Babbie, 2004).

7. Cleadon Park, South Tyneside

1. Chapel Park, Newcastle

4. Pelaw-Wardley, Gateshead

8. South Shields, South Tyneside

2. Lemington, Newcastle

5. Washington, Sunderland

9. Tynemouth, North Tyneside

3. Low Fell, Gateshead

6. Fulwell, Sunderland

10. Preston Grange, N. Tyneside

FIGURE 3. Google Earth aerial view captured for ten selected neighbourhoods in the Tyne and Wear metropolitan district. *Source*: Aditjandra, 2008.

EMPIRICAL RESULTS

This section considers the results of this survey. In the first, neighbourhood design characteristics and travel attitude characteristics are analysed. The characteristics were measured through statements used in the questionnaire which derived from Handy et al. (2005) work. Initially this replication of work will allow result of neighbourhood characteristics and travel attitude to be compared between the US and the UK. Factor analysis has been used to disentangle the many statements used in the questionnaire into fewer factors that construct the neighbourhood and travel attitude characteristics. The travel pattern variable is described in the second section and this is followed in the third section by a descriptive analysis of differences between the urban forms identified in this study using ANOVA. The fourth section shows the results of modelling the relationship between the factors obtained in the earlier sections, socio-economic variables and travel patterns using ordinary least square regression. The final section considers the results of quasi longitudinal analysis of travel behaviour.

Neighbourhood design characteristics and travel attitudes

Respondents were given 27 statements about neighbourhood characteristics and asked to rate how true these were for where they lived on a four-point scale from 'not at all true' until 'entirely true'. If respondents had moved to their current address within the last 8 years, they were asked to do the same for their previous address. These neighbourhood characteristics, as perceived by survey respondents, reflect the fundamental differences in neighbourhood design. The importance of these characteristics to respondents when they were looking for their 'ideal' place to live was also measured with a four-point scale from 'not at all important' to 'extremely important'. Handy et al. (2005) has highlighted that the comparison of individuals' perceived neighbourhood characteristics for their current residence and their preferences for neighbourhood characteristics indicates how well their current neighbourhoods meet their preferences. Since many of these characteristics measure similar dimensions, factor analysis is used to reduce the data so as to identify the main factors of perceived and preferred neighbourhood characteristics respectively.

Factor analysis was conducted to identify the underlying constructs of perceived and preferences for neighbourhood characteristics since many statements of neighbourhood design characteristics used in the questionnaire measure similar dimensions. Through this analysis perceived and preferred neighbourhood design characteristics were extracted into 7 factors which include safety, travel accessibility, residential spaciousness, social factors, shopping/ facilities accessibility, outdoor space accessibility and neighbourhood attractiveness as shown in Table 3.

Travel attitudes were measured by asking the respondents of their level of agreement on a series

of 28 statements on a five-point scale from 'strongly disagree' to 'strongly agree'. For the same reason as the above neighbourhood characteristics perceptions and preferences, factor analysis was carried out again to reduce the many statements into fewer factors and these are shown on the right side of Table 3. The 28 statements were reduced to 8 factors including pro-public transport use, travel minimising awareness, pro-cycling, travel time sensitivity, safety of car, pro-walking, pro-travel and car dependent.

There are a number of differences between these British results and the US results reported by Handy et al. (2005). First, the analysis has identified more factors for perceptions and preferences of neighbourhood characteristics and travel attitudes. In particular, this study has found three factors of accessibility of neighbourhood: travel accessibility (which has a high association with public transport service), shopping/facilities accessibility (which has a high association with access to a shopping centre) and outdoor space accessibility (which has a high association with parks and open space). Whilst 'outdoor space accessibility' is a similar factor to the 'physical activity options' factor found in the US study, the US 'accessibility' is only correspond to the 'shopping/facilities accessibility' in this study. The separation of 'travel accessibility' and 'shopping/facilities accessibility' in this study suggest that for British neighbourhoods, public transport service use is recognised as a useable option which in turn suggests that public transport can be made to be a reasonable alternative to a car.

In travel attitudes, the respondents in this study differentiate between travel attitude factors for walking and cycling. This finding contrasts with the result from the US study which found that walking and cycling were identified as a single factor, suggesting that US respondents perceive walking and cycling as similar. It is also suggests that cycling and walking are thought of as different in British neighbourhoods: this could be because cycling is often thought of as a recreational activity whereas walking within the neighbourhood can be part of a daily commuting or shopping pattern as well as a recreational activity.

Travel pattern

Travel patterns of the respondents were measured in the questionnaire by asking respondents to report the vehicle miles driven (VMD), chosen as the dependent variable because of its importance in the planning process. The questionnaire asked for information on the commute trip separately from other travel. In capturing VMD, the respondents were asked to give this information day by day for the previous week's travel by car and to identify if this reported mileage was typical. If the mileage was not typical, respondents were asked to identify their typical VMD and to report this separately. Respondents were also asked to give information of their household VMD by leaving space for other member of the household to report their VMD. The total reported typical VMD per week is used as the dependent variable in cross-sectional model.

Weekly VMD per household by the suburban neighbourhood group is 54% higher than the traditional neighbourhood group (Table 4). This pattern contrasts with the US evidence that shows that their traditional neighbourhoods had higher VMD but that their suburban neighbourhood had lower average VMD than this study. This finding suggests that British neighbourhoods show a

TABLE 4. Vehicle miles driven (VMD) and explanatory variables by neighbourhood type

	Average for traditional	Average for suburban	p-value[b] traditional only	p-value[b] suburban only	p-value[b] traditional/ suburban pooled
Weekly VMD by household	123	190	0.00	0.00	0.00
Perceived neighbourhood characteristics[a]					
Safety	-0.08	0.07	.00	.45	.00
Travel accessibility	0.14	-0.12	.00	00	.00
Residential spaciousness	-0.38	0.21	.00	.00	.00
Social factors	0.20	-0.15	.01	.01	.00
Shopping/facilities accessibility	0.23	-0.20	.00	.00	.00
Outdoor space accessibility	-0.16	0.25	.00	.00	.00
Neighbourhood attractiveness	0.14	-0.12	.00	.05	.00
Preferred neighbourhood characteristics[a]					
Safety	0.05	-0.03	.42	.59	.38
Travel accessibility	0.08	-0.07	.30	.00	.01
Residential spaciousness	-0.17	0.11	.00	.40	.00
Social factors	0.10	-0.10	.06	.14	.04
Shopping/facilities accessibility	0.03	-0.01	.13	.28	.95
Outdoor space accessibility	-0.03	0.06	.43	.46	.19
Neighbourhood attractiveness	0.12	-0.08	.25	.32	.01
Travel attitudes[a]					
Pro-public transport use	0.09	-0.07	.34	.00	.01
Travel minimising awareness	0.01	-0.05	.19	.48	.35
Pro-cycling	0.04	-0.09	.09	.19	.06
Travel time sensitivity	-0.02	0.00	.37	.46	.81
Safety of car	0.00	0.02	.04	.37	.45
Pro-walking	0.13	-0.09	.00	.12	.02
Pro travel	-0.09	0.10	.75	.36	.03
Car dependent	-0.12	0.07	.12	.01	.02

SOURCE This study

[a] Scores normalised to a mean value of 0 and variance of 1

[b] p-value for F-statistics from analysis of variance (ANOVA)

Significant at 5% level

bigger variation between different neighbourhoods. The high VMD average in British suburban neighbourhoods suggests that this type of residential development is much different compare to the American suburbs but that the British suburb exhibits even higher levels of car travel.

Comparison between traditional and suburban neighbourhoods

The results of an ANOVA are shown in Table 4 where p-values indicate significant at 5% level are shaded. This table shows that for the perceived neighbourhood characteristics have many significant intra-group differences for the traditional and for the suburban neighbourhoods. In addition, whilst there are some intra-group variation in the preferred neighbourhood characteristics, this is less than for the perceived characteristics. Despite these intra-group differences, the ANOVA shows that there are significant differences between traditional and suburban in all of the perceived neighbourhood factors. The traditional neighbourhood group score significantly higher than suburban neighbourhood group on factors for 'travel accessibility', 'social factors' and 'shopping/facilities accessibility' but lower on 'safety', 'residential spaciousness', 'outdoor space accessibility' and 'neighbourhood attractiveness'. Comparing travel attitudes, the traditional

TABLE 5. Ordinary Least Square Regression: model result for ln(VMD+1)

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.
	B	Beta		
(Constant)	.370		2.140	.033
Female	-.263	-.066	-2.789	.005
Employed	.599	.146	5.464	.000
Driving license to H/H	.953	.403	14.337	.000
Cars per adult	1.421	.289	10.753	.000
Pro-walking	-.078	-.039	-1.663	.097
Pro-public transport	-.280	-.141	-5.494	.000
Safety of car	.132	.066	2.827	.005
Car dependent	.266	.135	5.444	.000
Shopping / facilities accessibility preference	-.128	-.064	-2.708	.007
Suburban (dummy, suburban=1, traditional=0)	.217	.054	2.283	.023

SOURCE This study

N = 659, R-square = 0.651, Adjusted R-square = 0.645 (significant with p-value of 0.000)
Dependent Variable: LnVMDplus1
Predictors: (Constant), Suburban, Shopping accessibility preference, Safety of car, Female, Pro-walking, Pro-public transport use, Cars per adult, Car dependent, Employed, Driving license to H/H.

neighbourhood group score significantly higher on the factors of 'pro-public transport use', 'pro-walking' and 'pro-travel' but lower on 'car dependent' attitude. However, these results are only descriptive and to examine the relative importance of these characteristics in explaining the amount of private car use, a multivariate modelling exercise was undertaken which is reported in the next section.

An interesting finding which also shows a significant difference between the UK and the US is that the traditional neighbourhoods in the UK case study were reported as less attractive by its residents as compared to the suburban neighbourhoods. This contrasts with the US evidence where the traditional neighbourhoods were reported to be more attractive than the suburban neighbourhoods. For planning authorities this is an important finding. As this case study is in Tyne and Wear, the planning authorities may wish to support an improvement to make traditional neighbourhoods more attractive to live in whilst maintaining the operation of frequent public transport service and promoting a walking lifestyle so as to meet better sustainable travel mobility practice.

Cross-sectional analysis of VMD

An Ordinary Least Square model was constructed using log weekly VMD household (ln VMD) as the dependent variable. In anticipating respondents who were reporting zero VMD, a value of one was added to all the zero reported VMD so the true dependent variable is ln (VMT + 1). The model regression initially included variables identified as important in US work before testing a wider variety of variables. The results are presented in Table 5. The single equation approach was adopted from Handy et al. (2005)

In the US analysis, 'age' was included in the model but in the British data this was found to be highly correlated with 'employment status' and it was felt that this predictor should therefore be excluded. In the US, the 'car dependent' attitude was the strongest predictor but in British case, the presence of a driving license is the strongest predictor of VMD (shown by the highest standardised coefficient). Being employed (and in general being older, given the high correlation between employment status and age) and having a car dependent attitude also serve the increase VMD whereas, with similar magnitude but opposite in direction, having a pro-public transport attitude will reduce the number of VMD. This finding suggests that in British neighbourhoods, travel by car or public transport can be considered as substitute modes in contrast to American neighbourhoods where there are less alternatives to driving.

A dummy variable was included to see if there were differences between the responses from the respondents living in traditional or suburban neighbourhoods. This is significant at the 5% level suggesting that land-use type also a good predictor in the model. Furthermore the magnitude

TABLE 1. Summary of literature review of urban form and travel behaviour relationships

Author	Place of study	Year	Type of analysis	Urban form considered
Newman and Kenworthy	Global worldwide	1999	D	Cities
Headicar and Curtis	Oxford, UK	1998	D	Suburban vs Town
Naess and Jensen	Frederikshavn, Denmark	2004	D, M	Urban and Peripheral settlements
Dunphy and Fisher	National Transportation Survey, USA	1996	D	Cities
Van and Senior	Cardiff, Wales, UK	2000	D	High mix, low mix, and no mix
Meurs and Haaijer	The Netherlands	2001	D, H, M, L	Rural vs village vs suburban vs urban
Simmonds and Coombe	Bristol, UK	2000	H	Trend vs Compact City vs Alternative scenario
1000 friends of Oregon	Oregon, Portland, USA	1996	H	No build vs Highways vs LUTRAQ
Cervero and Kockelman	San Francisco Bay, California USA	1997	M	Neighbourhoods chosen according census tract
Kitamura et al.	San Francisco Bay, California USA	1997	M	5 neighbourhoods
Dieleman et al.	Dutch National Travel Survey	2002	M	Cities, Regions
Stead	UK	2001	M	8400 wards in England
Boarnet and Crane	San Diego, California, USA	2001	M	Traditional vs Suburban
Handy et al.	California, USA	2005	M, L	Traditional vs Suburban
Krizek	Central Puget Sound, Seattle, USA	2003	M, L	Neighbourhood accessibility high vs low
Bhat and Guo	San Francisco Bay, California, USA	2007	M	Transport analysis zones

D = Descriptive; H = Hypothetical; M = Multivariate analysis; L = Longitudinal

Travel measurement	Empirical Result (+ is positive result of land use-contributing to sustainable travel and – is the opposite conclusion)	
Density, Energy, Journey to work distance, Mode	+ +	Density and mixed land-use contribute to sustainable travel patterns
Modes share, travel distances, public transport service	+	Public transport provision associated with lower mode share per car and lower distance travel by car
Total travel distance and mode choice	+ +	Urban structural characteristics influences travel activity even after accounting socio-economic and attitudinal characteristics
Public transport use, density	+	Public transport use high and lower car travel in higher density communities
Travel mode, frequency, distance, trip purpose,	+/-	Residents with some local shops may make just as many, or even more, car journeys than residents of neighbourhoods with no shops, although such car journeys are likely to be shorter
Total journey, home, street, n'hood characters.	+ +	Home, street and neighbourhood characteristics have a clear impact on mobility
Travel mode, Time, and frequency	+/-	Slight reduction in total travel but no answer to number of trips, travel mode and other decision
Trip mode, VMD	+	LUTRAQ doubles the mode share for community trips by public transport use trips and VMD by car drop accordingly
Travel diaries, VMD, mode choice, density	+/-	Land-use variables had significant effect but elasticities implied by regression coefficients were small compared to socio-economic variables
Travel diaries, VMD, land-use and travel attitudes	-	High density related to proportion of non car trips. Residential attitude explains the travel pattern better than land-use characteristics
Trip purpose, Mode travel, and distance	-	Regression models revealed that personal attributes and circumstances have impact on modal choice and distance travelled
Distance, mixed use, density	-	Socio-economic factors explain more than 50% of variation in travel patterns. Land-use explains less than a third of variation.
Time, Density, Socio-economic variables	-	Complex conclusion; street patterns and commercial concentrations are associated with fewer non-work car trips
VMD, Built environment, socio economic, attitudes	-/+	Cross-sectional analysis shows attitude and socio-economic variables are predictors of VMD but longitudinal analysis shows land-use variables effect VMD
VMD, Persons miles travelled, no. trips, no. tours	+	Increase in neighbourhood accessibility results in reduced VMD and person miles travel (regardless of modes) and reduced no. of trips but increased no. of tours.
Car ownership, residential location, socio-economic variables	+	Built environment does effect residential choice decisions as well as car ownership decisions; density is proxy variable to street block density and public transport accessibility

SOURCE This study

TABLE 3. Factor loadings from CFA on perceived and preferred neighbourhood characteristics (left) and travel attitude characteristics (right) (Source: this study)

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
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	.685
	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 tranport 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

TABLE 6. Percent respondents by change in driving or walking or public transport use vs. change in neighbourhood characteristics*

(a) Change in driving vs change in neighbourhood characteristics

Change in driving	Decrease characteristics			Increase characteristics			Chi –square **
	More driving	No change	Less driving	More driving	No change	Less driving	
Safety	21.4	55.1	15.3	22.6	53.0	19.1	.703
Travel accessibility	27.4	53.4	15.1	19.3	54.3	18.6	.227
Residential spaciousness	15.8	61.1	15.8	27.1	48.3	18.6	.413
Social factors	25.5	56.6	12.3	18.9	51.9	22.6	.042
Shopping/facilities accessibility	24.6	54.4	16.7	19.2	53.5	18.2	.451
Outdoor space accessibility	27.7	48.2	17.0	15.8	60.4	17.8	.176
Neighbourhood attractiveness	17.1	58.6	20.0	24.5	51.7	16.1	.226

(b) Change in walking vs change in neighbourhood characteristics

Change in walking	Decrease characteristics			Increase characteristics			Chi –square **
	More walking	No change	Less walking	More walking	No change	Less walking	
Safety	29.6	52.0	16.3	42.2	44.0	12.9	.167
Travel accessibility	30.1	45.2	23.3	39.7	48.9	9.9	.009
Residential spaciousness	35.4	52.1	10.4	37.3	44.1	17.8	.277
Social factors	33.6	47.7	16.8	38.7	48.1	12.3	.288
Shopping/facilities accessibility	34.2	53.5	12.3	39.0	41.0	17.0	.648
Outdoor space accessibility	33.9	45.5	19.6	39.2	50.0	8.8	.035
Neighbourhood attractiveness	31.4	54.3	14.3	38.9	44.4	14.6	.675

(c) Change in public transport use vs change in neighbourhood characteristics

Change in driving	Decrease characteristics			Increase characteristics			Chi –square **
	More p.t. use	No change	Less p.t. use	More p.t. use	No change	Less p.t. use	
Safety	20.6	53.6	16.5	27.6	49.1	18.1	.651
Travel accessibility	15.1	45.2	30.1	29.3	54.3	10.7	.000

Residential spaciousness	26.3	57.9	9.5	22.9	45.8	23.7	.023
Social factors	18.9	53.8	17.0	29.2	49.1	17.9	.378
Shopping/facilities accessibility	18.4	62.3	17.5	31.3	38.4	17.2	.202
Outdoor space accessibility	25.0	45.5	21.4	23.8	57.4	12.9	.299
Neighbourhood attractiveness	27.1	52.9	15.7	23.1	50.3	18.2	.503

SOURCE This study

* Residents who moved residence within the last 8 years only; n = 214

** Respondents reported no change in travel pattern are not included n = 109

Significant at 5% level

of standardised coefficient shows that land-use type as well as neighbourhood characteristic's preference predictors come after socio-economic and travel attitude variables. This result contrasts with the US evidence where a similar analysis did not report any significant land-use variables. This evidence thus supports the hypothesis that British neighbourhoods are different to the US neighbourhoods.

Quasi-longitudinal analysis of travel behaviour

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 within the last eight years 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.

In this study, 216 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. A bivariate analysis of these variables for movers shows some significant associations between changes in travel behaviour and changes in neighbourhood characteristics as shown in Table 6. This shows that changes in neighbourhood characteristics have stronger association with changes in walking and public transport use as compared to changes in driving.

For changes in driving, Table 6(a) shows that only the 'social factors' characteristic (referring to the characteristics of neighbourhoods which have high association with 'lots of people out and about' and 'high interaction between neighbours' as can be seen in Table 3) is significant. This

finding suggests that if people relocate into a neighbourhood with a higher level of 'social factors' characteristics they are likely to lower their driving level as compared to before they moved. For changes in walking pattern, Table 6(b) shows that for increases in the 'travel accessibility' and the 'outdoor space accessibility' characteristics, a significantly higher share of respondents reported their walking level had increased. This suggests that if people relocated into a neighbourhood which has higher level of travel accessibility (this includes a high association with 'accessibility to public transport service' and 'good public transport service') they are more likely to walk more than before they moved. The significance of outdoor space accessibility (associated with 'parks and open space nearby a neighbourhood') suggests that this neighbourhood characteristic also attracts more walking.

For changes in public transport use as shown in Table 6(c), an increase in the 'travel accessibility' characteristic led to a significant higher share of respondents using public transport and for a decrease in this characteristic, respondents reported less use of public transport. This finding suggests that public transport friendly environment contributes to increase patronage in public transport use. Thus supporting evidence that when people were exposed to a neighbourhood conducive to a public transport friendly environment, they will likely to make use of it, no matter if the residential self-selection has taken place. For a decrease in 'residential spaciousness' characteristics, a significantly higher share of respondents reported more use of public transport. This suggests that public transport patronage is negatively correlated with residential spaciousness (this factor is highly associated with 'garden space' as can be seen in Table 3).

The US study by Handy et al. (2005) found that changes in most neighbourhood characteristics were sensitive to changes in walking but these results are not confirmative in the British experience. Many of the neighbourhood characteristics are insignificant in relation to changes in walking. However, the British case study has shown that travel accessibility is sensitive to changes in walking and public transport use, suggesting that residents of British neighbourhoods are more aware of public transport service than their US counterparts. This evidence thus supports the hypothesis (again) that British neighbourhoods are different to the US neighbourhoods and that residents of British neighbourhoods are more likely to use sustainable, low carbon means of travel (public transport and walking).

5. CONCLUSIONS

The literature review highlights the differences between the US and European experiences. A very noticeable feature which differs between the US and Europe is the way that land-use characteristics impacting on travel behaviour appear to play bigger role in Europe than in US. This is especially true in terms of urban structure variables and their associated characteristics. Whilst there have been European studies, for example Naess and Jensen (2004) and Meurs and

Haaijer (2001), these have not included the role of travel attitudes or perceptions nor at the self-selection issue. The UK studies similarly have not included the role of travel attitudes and perceptions nor have considered residential self-selection. This paper is motivated by a desire to present a convincing UK study that explored possible causal links between travel behaviour on the one hand and neighbourhood design characteristics and travel attitudes on the other. It was based on the belief that there are a number of reasons why the UK might be different, particularly from Europe. For example, the UK transport policy before the Planning White Paper in 1998 was still using a predict and provide approach, and supported significant development for car accessibility with the rationale of enhancing national economic performance, especially during the Thatcher governments (1980s to1990s). This means that UK travel behaviour may be more similar to the US pattern because of this approach with the motorised mode more important (Cram, 2006) and be more different from that in mainland Europe where multi-modal travel patterns are dominant. The fact that the UK transport land-use pattern is closer to the US than Europe and that the UK level of car dependency is high[2] suggests that US evidence may be more applicable to the UK than might previously been thought, and thus research methods from the US might be appropriately transferred.

In this study, similar questions were asked of respondents as in the US study undertaken by Handy et al. (2005) and yet the results are different suggesting that there are differences between US and UK neighbourhoods. In terms of neighbourhood characteristics, the factor of travel accessibility is present in the British case study but not in the US model and this factor has been shown to be particularly sensitive in the quasi-longitudinal analysis.

However, there are similarities between the US and British studies in the cross-sectional model predicting VMD, especially in relation to attitude characteristics being the better predictors. However, from a land-use planning point of view, the fact that preferences on shopping/facilities accessibility as well as the land-use type are shown to be strong predictors of VMD in Britain means there is a clear role for the planning and redevelopment of new neighbourhoods (See also: Aditjandra et al., 2007).

In general, Britain has a higher incidence of public transport use and this reflected in this study by higher and differentiated factors of accessibility and less strong changes in travel patterns following changes in neighbourhood characteristics. However, this study shows that British suburban neighbourhoods can be as car dependent as their American counterparts.

Concluding their study, Handy et al. (2005) suggested their results showed causality between neighbourhood design characteristics and travel behaviour and that therefore land-use policies to bring residents closer to destinations could be successful in promoting land-use change to reduce driving and thus emissions and promote more sustainable mobility practice. This study

shows that in the UK, as in the US, there is an association between changes in neighbourhood characteristics and changes in travel behaviour but this is not as strong suggesting that land use planning in the UK may have less of an impact on reducing private car travel, as compared to the US. However, the UK evidence suggests that neighbourhood design offering opportunities for sustainable mobility practice does have an impact on walking and public transport use and, for the future, this is an area where land use and transport planners can focus. When the issue of residential self-selection is added to this discussion, the experiences of the US and the UK become more different: residential self-selection is important in the US and this is reinforced by the dichotomous nature of US suburbs and US traditional areas and the extent to which they are served by alternatives to private car travel. In the UK, the influence of residential self-selection appears less important which suggests that land use planning that reinforces the use of sustainable transport modes could have a higher degree of success.

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ENDNOTES

1. 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.

2. UK is in ranked second in Europe (Commission for Integrated Transport, 2007)in the mode share of distance travelled by car.

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