

The impact of urban development patterns on travel behaviour: Lessons learned from a British metropolitan region using macro-analysis and micro-analysis in addressing the sustainability agenda

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ABSTRACT

The objective of this paper is to gain a clearer understanding of the strategic relationship between a series of studies addressing the sustainability agenda. The analysis uses qualitative and quantitative data derived from two studies: the regional (macro) integrated transport and land-use model data and the micro-analysis of ten selected neighbourhoods, both of which have taken place in the North East of England. The interview with local authorities demonstrated that, despite the sustainability agenda being high on their list, there are issues with embracing social, economic and environmental aspects in equal manner, relating to transport. The macro-analysis shows that different land-use scenarios influence only a small part of travel behaviour. The main argument was that the changes in land-uses and transport provision are relatively marginal, compared to the existing development. The micro-study, on the other hand, demonstrated that it is the attitudes of citizens, rather than the neighbourhood characteristics, which play the bigger role in influencing the patterns of car travel, thus suggesting that future policy work on attitudes may have a bigger impact in influencing travel behaviour.

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1. Introduction

Existing literature has highlighted that the relationship between transportation and land-use is complex and recursive. Researchers have investigated a wide range of factors that mediate this relationship, including density, settlement size, mix of land-use, accessibility and local street layout (Badoe & Miller, 2000; Boarnet & Crane, 2001; Cervero & Kockelman, 1997; CfT – Commission for Integrated Transport, 2009; Dieleman, Dijst, & Burghouwt, 2002; Ewing & Cervero, 2001; Ewing et al., 2010; Handy, Cao, & Mokhtarian, 2005; Kitamura, Mokhtarian, & Laidet, 1997; Naess & Jensen, 2004; Stead, 2001). Additional research is needed to understand which transportation and land-use policies can best support a move towards sustainability.

Movements such as 'New Urbanism' in the US (see for example: Duany & Plater-Zyberk, 1991) and the 'Compact City' in Europe (see for example: Jenks, Burton, & Williams, 1997) have been trying to re-assess the approach of how to build and/or re-build cities. The Dutch 'ABC transport planning principle' has also been in place since the 1990s, to reduce urban traffic growth (Verroen, de Jong, Korver, & Jansen, 1990). In the UK, however, discussion on the compact city paradigm concludes that, despite its contribution to a reduction in

pollution (through lower car use), prevention of the loss of open countryside and promotion of urban regeneration, it is not appropriate for many places (Breheny, 1996; Hall & Hass-Klau, 1988). One of the reasons for this is the spatial reality in which polycentric urban regions have become the dominant form of urbanisation in North-western Europe (Bontje, 2003). Another is that land-use patterns are the outcome of historical development patterns, which are a function of policy, economic factors, technology and culture (Giuliano & Narayan, 2003). Thus, to re-engineer an existing city is as tricky as to build a new one. More recently, the Planning White Paper 'Planning for Sustainable Future' (HM Government, 2007), which reflects the findings of recent significant reports from Eddington (2006) (transport), Barker (2006) (land-use planning) and Stern (2006) (climate change), offers guidance on the future direction of different types of sustainable development. A number of 'eco-town' projects are currently under discussion between the UK government and local authorities, regarding new development. Nevertheless, it remains unclear how this new housing would be built. Furthermore, what will the layout of towns and cities look like in a proposed low carbon future? What supporting transport and planning measures will exist to assist in meeting sustainable urban environment targets?

The aim of this paper is to analyse current evidence relating to the impact of urban form on travel behaviour, at different levels of spatial scales. The data were generated by two studies of urban form and travel behaviour in the Tyne and Wear metropolitan area and region,

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situated in the North East of England. The first study uses a regional, macro-modelling framework that represents an integrated model of land-use and transport (named 'macro-study' for ease of reference throughout this paper). The second study uses interviews with local authorities and a comprehensive household questionnaire survey from ten selected communities (named 'micro-study'). The remainder of this paper is structured as follows: [Section 2](#) is a literature review; [Section 3](#) is a description of the case study area/region; [Section 4](#) discusses data, methodology and results from the macro-analysis and [Section 5](#) discusses the micro-analysis study. The final conclusions and discussions are presented in [Section 6](#).

2. Literature review

2.1. Macro-level model study

The LUTI model (land-use/transport interaction model) originated from the work of [Lowry \(1964\)](#) and refers mainly to the activities using space where people live and work. The integrated model is built to capture the effects of the major changes, derived from transport system development of land-use, that influence the location choices of households and businesses and hence the number of trips, their destinations and modes of travel ([Wegener, 2004](#)). The scope of the data encompasses the population of a region (both as individuals and as households) and the businesses and other productive organisations (including property developers, transport infrastructure providers and transport service providers) ([Simmonds & Feldman, 2011](#)).

Since the LUTI model is designed as a forecasting tool on a regional scale, it is necessarily a simplification of the real world. The application of LUTI is worldwide and the models developed can vary from one region to another, but this is acknowledged as not fundamentally different ([Echenique, 2011](#)). [E. Miller \(2004\)](#) identified four components critical to the LUTI model: land development; location choice of households and employers; travel and trip making behaviour; and car ownership. Furthermore, it is suggested that the drivers for modelling urban systems are: demographic change; regional economic evolution (employment type, size and distribution); government policies (zoning and road user charging); and all modes of the transportation system ([E. Miller, 2004](#)). Because of their comprehensiveness in forecasting the effects of major transport and/or land-use changes, LUTI models have been recognised, at national legislation level, as part of planning ideology. They have consequently been used to address a sustainability agenda that embraces economic, social and environmental aspects (see for example: [Curtis, 2005](#); [Echenique, 2005](#); [Locantore, Montagu, Rudy, & Sabina, 2009](#)).

2.2. Micro-level model study

In the development to gain better understanding of the relationship between land-use and transport, three types of study were identified: hypothetical, descriptive and multivariate statistical analysis ([Boarnet & Crane, 2001](#)). The LUTI model earlier described, is a clear example of hypothetical study. This approach has usually tended to focus on the overall structure of a city or metropolitan area and is not intended to explain behaviour; rather it makes assumptions regarding behaviour and then applies those to alternative situations to see what happens.

Descriptive studies provide an account of travel experiences, either individually or on average, and have the strong advantage of working from actual behaviour, so forming an extremely important part of the process of understanding what is going on. Sample British studies can be seen in [Headicar and Curtis \(1998\)](#), [Van and Senior \(2000\)](#) and [Cram \(2006\)](#). These concluded that local neighbourhood attributes, such as good public transport services, good access to local facilities and a mixture of land-use, are associated with low private car travel and thus reduced emissions.

Multivariate statistical studies examine observed, rather than hypothetical, behaviour and are therefore attempts to explain, rather than merely to describe, what is going on. This type of study can be divided into two models: an ad hoc model and a demand model. Whilst the demand model is designed to feed the LUTI model (hypothetical study), for specific components of LUTI (e.g. function of travel costs, production location, trade, transport flows etc. – see for example [Echenique, 2011](#)), ad hoc models consider many measures of urban form whilst attempting to control for differences among communities, neighbourhoods and travellers. Many ad hoc studies lead to a better understanding that travel patterns are affected by multi-dimensional characteristics, including socio-economic, built environment ([Boarnet & Sarmiento, 1998](#); [Cervero & Kockelman, 1997](#); [Dieleman et al., 2002](#); [Meurs & Haaijer, 2001](#); [Naess & Jensen, 2004](#); [Stead, 2001](#)) and travel attitude characteristics ([Cao, Mokhtarian, & Handy, 2007](#); [Handy et al., 2005](#); [Kitamura et al., 1997](#)). Whilst most of these studies use a cross sectional approach, [Handy et al. \(2005\)](#) advocated a longitudinal design to involve the effect of time order, thus capturing the 'before' and 'after' relocation of householders, in order to identify causal relationship, whilst addressing the residential self-selection issue.

3. Study area

The case study area of Tyne and Wear is interesting because this metropolitan district is typical of a medium sized polycentric British city. The transport and urban system profile of Tyne and Wear includes light rail, high quality public buses, conventional public buses, taxis, DRT (Demand Responsive Transport), a number of bus and bicycle priority lanes, pedestrianised historic town centres and many retail parks. The area is well served by highways and both the A1 and A19 trunk roads run north–south through the area where, at most times of day, the road network is relatively uncongested (there is relatively little traffic congestion compared to cities in, for example, the south of England). Since the 1960s, the metropolitan area, led by the city of Newcastle, has embraced 'green belt' planning policy to control urban sprawl and the areas covered have been extended since the 1980s ([J. Miller, 2004](#)). However, this fact leads to the limitation of urban densification and more attention is being paid to the possibility of development within green belts ([Barker, 2006](#)).

The Tyne and Wear area itself covers about 212 sq. miles and is surrounded by parts of Northumberland and Durham to give an overall study area of 918 sq. miles. This area, known as the Tyne and Wear City Region (TWCR), can be seen in [Fig. 1](#). The 19th century industrial revolution brought prosperity to the city and region, centred upon shipbuilding and heavy engineering industries. Since the second half of the 20th century, these industries have been in decline and this has impacted heavily on travel patterns ([Gillespie, 1998](#)). The new sources of employment are centred on the service and financial sectors, as well as on advanced manufacturing. This has resulted in employment activity becoming relatively peripheral and dispersed ([Gillespie, 1998](#)). [Pemberton \(2000\)](#) observed that Tyne and Wear exhibits a low level of car ownership and high (although falling) levels of public transport patronage, related to the light rail constructed in the 1970s and the centralisation of economic, retail and leisure activity (in contrast to other urban areas). The formation of Tyne and Wear Local Transport Plan (comprising 5 districts: Newcastle-upon-Tyne (pop: 260,000); Sunderland (281,000); Gateshead (191,000); North Tyneside (192,000); and South Tyneside (153,000)) acknowledged that the relaxation of land-use policies in the 1980s has resulted in a dispersal of development from Newcastle (as the sub-regional hub of TWCR), adding to the growth in car usage and problems of accessibility for non-car owners ([Hull, 2005](#)). Furthermore, the region has been acknowledged as a poor performer on most of the national economic indicators ([Hull, 2005](#)).

The regional spatial strategy of the North East – via the central government appointment of the North East Assembly in 2000 –

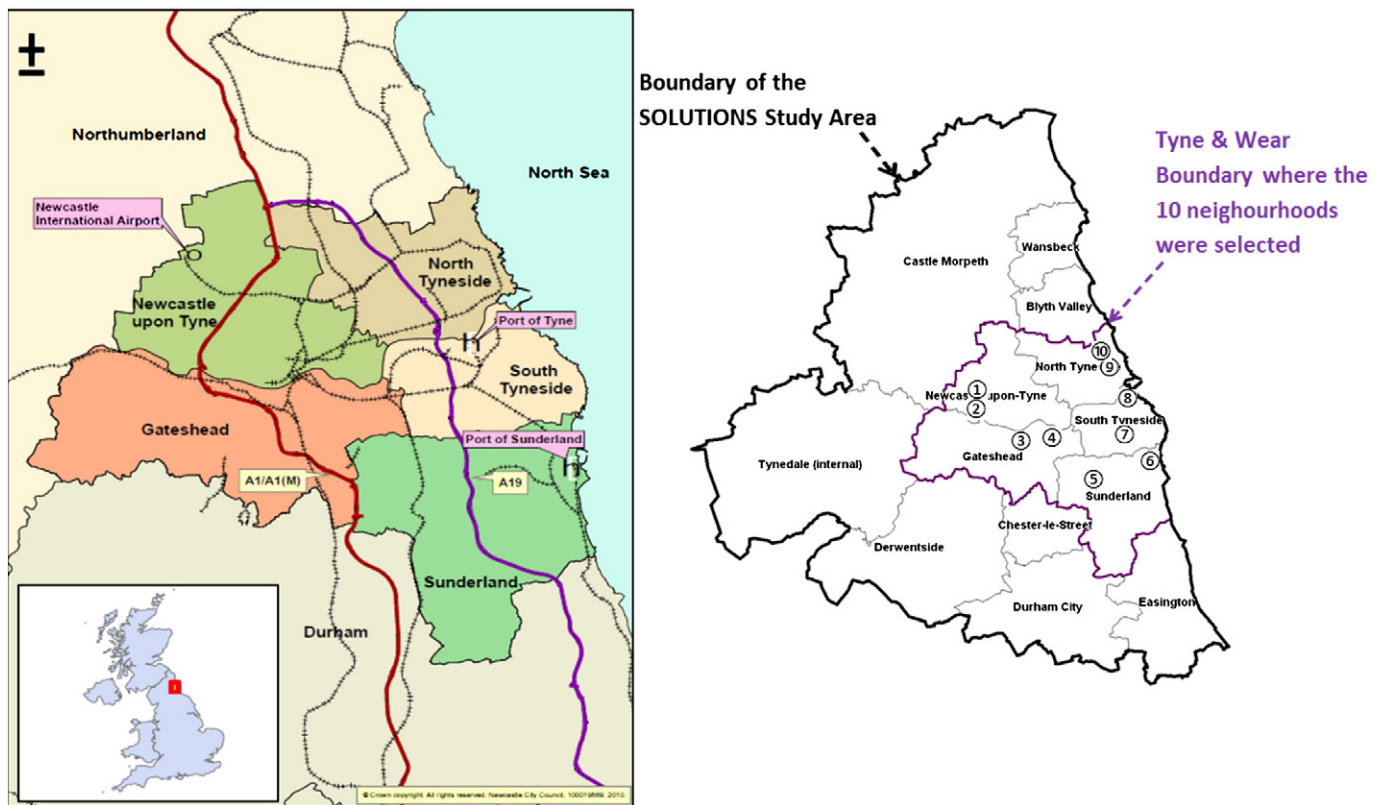


Fig. 1. Major transport system of Tyne & Wear City and Region (source: LTP, 2011) and study area.

directed investment and regeneration to the conurbations of Tyne and Wear and Teeside (Hull, 2005). The regional transport strategy aimed to upgrade the strategic road capacity and to improve public transport provision to make the recently developed employment and commercial centres readily accessible by car (Hull, 2005). Although, at the time, the proportion of journeys made by public transport was one of the highest in the country, bottlenecks on the A1 and A19 motorways, as the access points to Tyne and Wear, were obvious and it was therefore the commissioning of the Tyne and Wear Multi-modal Study (TAMMS) was no surprise.

4. Macro-level analysis – SOLUTIONS Tyne and Wear case study – data, methodology and results

4.1. Data

The Sustainability Of Land Use and Transport In Outer Neighbourhoods (SOLUTIONS) project was part of the Sustainable Urban Environments (SUE) project, funded by the UK research council EPSRC (Engineering Physical Sciences Research Council). The overarching objective was to identify how far, and by what means, towns and cities can be planned so that they are socially inclusive, economically efficient and environmentally sustainable. The study, which ended in June 2009, had taken 2 British metropolitan areas (the Greater South East and Tyne and Wear) to demonstrate three different future land-use design scenarios:

- (1) isolated settlements – a new, relatively self-contained development disjointed from existing urban areas or greenfield/brownfield land;
- (2) urban periphery – a development contiguous with existing urban area, previously non-urbanised;
- (3) infill – development which utilises unused space between existing built-up areas.

The case study sites were tested against three strategic options: market forces, planned urban expansion and the compact city. These scenarios were then compared to the trend scenario as the reference case, which reflected current existing Regional Spatial Strategies and Local Transport Plans. The full study is available from the SOLUTIONS website (<http://www.suburbansolutions.ac.uk>), but this paper looks only at the results from Tyne and Wear. This macro scale project uses adjustment of housing density, employment, dwelling distribution and (public) transport infrastructure investments, in order to examine different land-use scenarios. Whilst the overall objectives were to measure various sustainability indicators, such as economic, resources, environment and social aspects, this paper focuses on the transport and land-use aspects, as part of the work carried out by the author during research preceding.

SOLUTIONS uses a LUTI model based on an existing model originally developed for the Tyneside Area Multi-Modal Study (TAMMS) by ARUP (2002). The original data used by the TAMMS model formed the year 2000 base case for the SOLUTIONS project. This data contained transport inputs (such as the public transport services and highways network) and land-use inputs from the 1991 census, using a ward level zoning system. This base year was then updated to better represent the then current situation, creating a year 2006 reference case model by including the major transport schemes implemented in the intervening years and by updating the land-use inputs using 2001 census data. From the 2006 reference case year onwards, land-use strategies and transport schemes being considered (whether planned, to form a trend scenario, or aspirational) have yet to be implemented so, theoretically, there was still flexibility in how the land-use development might evolve and how the available transport funding could be spent. This provided the opportunity to design and test a number of different scenarios, to investigate future impacts up to the year 2031. Before undertaking the scenario testing, a number of validation checks were made on the model's performance, in order to assess its appropriateness.

For transport, the sensitivity of the model in reacting to changes in cost is crucial. Based on the Department for Transport (DfT) research (Goodwin, Dargay, & Hanly, 2004), car drivers' price elasticity should be at least -0.3 , meaning that a 10% increase in cost results in a 3% reduction in demand. To test the sensitivity of the model in responding to changes in highway costs a road user charge (RUC) was introduced, and overall the charge resulted in a change in disutility of car trips of 31%. The effect of this on the length of vehicle travel was to reduce total vehicle-km by 16%. This represents a price elasticity of -0.53 (a 10% increase in cost results in a 5.3% reduction in demand). The price elasticity was actually found to be variable, depending on the purpose of the trip. For example, home-based work (HBW) or commuter trips have a price elasticity of -0.29 which is in line with the DfT research (Goodwin et al., 2004), whilst home-based employers business (HBEB) trips have a much lower elasticity of -0.05 , reflecting the fact that, when the employer is paying, the driver is less sensitive to changes in cost.

4.2. Methodology

In the SOLUTIONS LUTI model, the total amount of new business floorspace and residential dwellings was the same for each land-use option tested. This was based on figures from Regional Spatial Strategies for dwellings and future year projections for employment. The land-use option to be tested determines the location for additional supply of floorspace for business and the number and type (or density) of dwellings. The allocation of supply affects rental prices, which impacts on demand from firms and households to locate in an area. The relative location of firms and households then generates demand for travel (e.g. between home and work). The land-use model produced sets of origin and destination (OD) demand, between zones, by trip purpose and car ownership, which were inputs to the transport model. The OD demands were assigned to the transport networks by the transport model. Different future transport networks have been designed for the different land-use options. The transport model determines the mode split and levels of congestion on the highway network. Finally, the transport model produces cost and disutility of travel between zones. This affects the attractiveness of locations and results in small adjustments to the distribution of the supply of floorspace for business and dwellings. This process was repeated a number of times until equilibrium was reached. Crucially, the cost and disutility parameters that drive the modelled change in travel behaviour take no account of non-cost or time-based attitudes and preference characteristics. The time frame used in the study was a 30-year horizon from the base year 2000 up to the year 2031. Four policy scenarios were evaluated: trend; compaction; market-led dispersal; and planned expansion.

The trend scenario, as a reference case, was the simulation of base case that included investment in major transport schemes, derived from TAMMS documentation, the Tyne and Wear Local Transport Plan and Tyne and Wear Transport Innovation Fund proposals (basically the transport infrastructure development plan for the region). It assumed continuation of current land-use planning policy and transport investment in major schemes, split evenly between highways and public transport (based on the transport investment plans between 2000 and 2011 of the Tyne and Wear local authorities).

The compaction scenario concentrated projected new dwellings and employment floorspace in central areas, in a controlled fashion, and assumed that all projected major scheme transport funding was spent on the public transport infrastructure. This scenario followed the ideas of many urban designers exemplified by 'new urbanism', 'compact cities' and 'transit oriented development', with the aim of locating people in high-density developments close to where they work and live (see for example: Boarnet & Crane, 2001; Jenks et al., 1997).

The market-led dispersal scenario assumed a relaxation in planning legislation to allow new dwellings and employment floorspace to be located where the market demands and also that all projected major scheme transport funding was spent on highway improvements to accommodate the more dispersed travel demands that would result. This scenario reflected the idea of post WWII American planners (see for example: Gordon & Richardson, 1997). The main objective was to allow the market to operate freely, following user preferences for houses with large gardens and private cars, and consequently to use more greenfield sites for urban development.

The planned urban expansion option focused the majority of new developments in a small number of zones on the edge of the existing urban area, where there was economic growth and where transport investment was split between highways and public transport, but focussed along the corridors linking the edge expansion zones with the city centre. This scenario followed the idea of the Town and Country Planning Association that promotes the creation of 'ecotown' settlements (see for example: Booth, 2008, for reference). The four land-use design options are summarised in Table 1.

4.3. Results



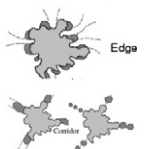
For each of the land-use option tests, three rounds of experimental model runs were carried out to fine-tune the inputs and to obtain the convergent outputs. The first run of a given policy option was based on the initial option design for distribution of dwellings and employment floorspace to the identified urban and suburban zones. Based on the results of the first run, the inputs of dwelling and floorspace were fine-tuned by making sure that the amount and distribution of households and employment were reasonable, keeping the study's area-wide totals unchanged for a particular forecast year. This process was repeated at the third run, for convergence of the outputs. Fig. 2 shows the output of the trend option and demonstrates the percentage increase in rents to be much greater in the outer areas than in Tyne and Wear. Housing costs increase, largely due to higher demand for more housing space resulting from the shift towards 'white collar' households, as the economy continues to transform from its industrial past to more office and retail based employment. White collar households, on average, demand larger houses, and generally prefer to live in the more suburban and rural parts of the region, rather than the former industrial areas. This tended to result in a mismatch between supply and demand for housing, with demand being higher in outer, more rural areas, but the majority of supply being in urban areas (Echenique, Barton, Hargreaves, & Mitchell, 2010).

The overall forecast daily travel demand, based on the number of person trips, was forecast to increase by 6.1% over the period year 2000 to 2031. However, the number of car trips was forecast to increase by over 20%, resulting in an increase in the modal share of car trips from 50% to 58%. Car ownership was expected to increase substantially from 57% to 73% of households by 2031. The proportion of households in the study area without a car fell from 43% in 2000 to 27% by 2031; this fact corresponds well with the reduction in the proportion of trips by public transport and slow modes, shown in Fig. 3.

The percentage change in the cost of living and wages in the three other land-use alternative options, against the trend in the year 2031, can be seen in Figs. 4 and 5. It can be observed that the compaction option reduces the cost of living and wage cost in Newcastle and Gateshead because of the increased supply of dwellings and employment floorspace within the urban centres of these districts, but that living costs increase in other areas, resulting in an overall increase of costs. By contrast, the dispersed option reduces costs overall and in particular in the areas outside the conurbations, where the absolute cost of property and labour is higher.

The market-led approach assumed that a greater proportion of dwellings and employment would disperse to these more prosperous areas, to reduce the disparity between supply and demand, meaning

Table 1
SOLUTIONS four land-use design options.

	Trend (reference case)	Compaction	Market-led dispersal	Planned expansion
Land-use policy	Based on current existing Regional Spatial Strategies and Transport Plans	All new floorspace and dwellings focused close to city centre or near main public transport nodes on edge of city	Greater proportion of new developments to zones outside city	New development focused on the edge of the urban area or on transport corridors in and out of main urban area
Transport Investments	Evenly mixed between highways and public transport	Focused entirely on public transport schemes	Focused entirely on highway schemes	Mixed but focused on selected corridors
Strategic design illustrations	City Region (consist of Tyne & Wear and outer areas) forecast 15% increase in the number of dwellings and 12% increase in the number of employees by 2031			

that overall price rises in the City Region were lower than the trend. The expansion option also tended to reduce costs in these outer areas, but to a lesser extent than the dispersed option, due to less of a match between supply and demand.

Table 2 shows the impact of different land-use options on the number of trips against the trend. It can be observed that the change in car travel behaviour is marginal to all of the land-use options tested. However, the biggest change can be achieved through the big investment in public transport infrastructure, such as Metro Complimentary Route (MCR) and Bus Rapid Transit (BRT).

Fig. 6 shows the percentage change in passenger-km on each mode, for all land-use options. It can be seen that Compact City has the biggest impact on low carbon based mobility patterns, but this figure was argued to be unrepresentative of the full sustainability picture since, even with the most favourable assumptions for the location of employment, there was only a small reduction in vehicle-km travelled. The increase in densities reduces the land development in the region, but at a cost of reduction in space standards that might not be acceptable to the public at large, which slightly increases the economic cost of the region. The study concluded that the alternative design options could make only a small contribution to the overall sustainability of the region, because the changes in land-use, or in transport provision, were relatively marginal compared to the existing development and the spatial strategies played only a small part in determining people behaviour. Furthermore, the low growth forecast of 0.5% per annum in employment and households was blamed for the marginal impact of the land-use policy option on travel mode choice (Echenique et al., 2010).

5. Micro-level analysis – interview with local authorities and ad hoc multivariate statistical modelling – data, methodology and results

In parallel with the launch of SOLUTIONS, a micro-level study was undertaken at the School of Civil Engineering and Geosciences at Newcastle University, with the idea of gaining insight into options to make other forms of travel more attractive through understanding the relationships between built environment and travel behaviour. The research question was to examine whether urban form can contribute to changes in travel behaviour. During the study, it was acknowledged that the SOLUTIONS project had looked at the higher level of urban form such as city, town or district zones (macro-scale), therefore this study focussed on the lower (micro) level of urban form: neighbourhood design characteristics. The neighbourhood design relates to land-use at the lowest scale, starting from dwellings/buildings and their direct vicinity. The full study is documented in Aditjandra (2008) and deeper analysis can be seen elsewhere (see for example: Aditjandra, Mulley, & Nelson, in press; Aditjandra, Cao, & Mulley, 2012). This paper adds to the analysis of previous publications, by bringing new insights into the differences underlying the micro- and macro-studies, supported by qualitative study.

The study hypothesises the interaction between land-use, travel patterns, socio-demographic and travel attitude characteristics. Unlike the macro-study, that uses macro-regional framework and land-use scenarios as the power to address the sustainable agenda of the region, the micro-study started with questioning how Tyne and Wear authorities in fact address their sustainability agenda. The

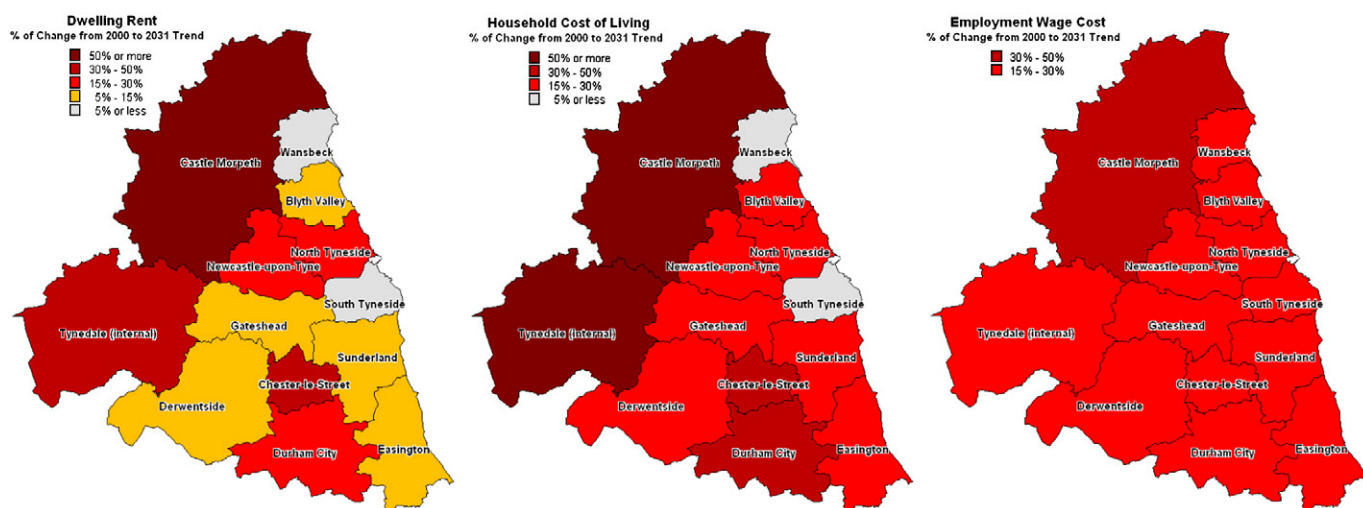


Fig. 2. Distribution of changes in rent, living costs and wage costs in trend from 2000 to 2031.
Source: Echenique et al., 2010.

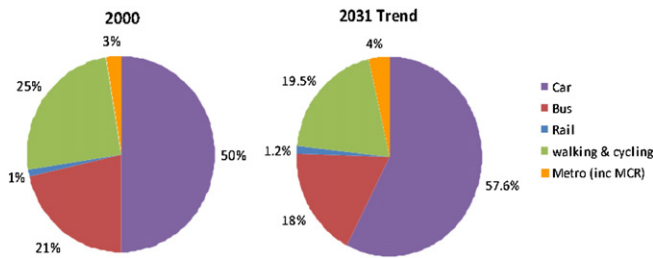


Fig. 3. Trend in mode split by number of trips.
Source: Echenique et al., 2010.

interview with officers of the local authorities of Tyne and Wear were undertaken prior to the household survey, in order to gain a better knowledge of local districts and neighbourhoods within the Tyne and Wear metropolitan area and to lead the choice of specific locations/neighbourhoods/communities for the survey. In addition to the focus of identifying neighbourhood hotspots for the household survey, the interview was also intended to gain better understanding of how authorities perceive sustainable mobility practice within Tyne and Wear districts, where sustainable mobility is defined as travel using less carbon-based fuel (Banister, 2008).

5.1. Interview with local authorities

Semi-structured interviews were held in late January 2006 and early February 2006, following a telephone appointment with relevant people in each of the five districts of Tyne and Wear. The interviewees were a mixture of professionals and included transport planners, town planners and district ward coordinators. The discussions were surprising, in the sense that none of the local authorities were confident that any area within their district's boundary met sustainable mobility criteria. But the interviews revealed that town planners were generally more interested in the sustainable development programme, compared to the other professionals. In Sunderland, for example, a large scheme to adopt a neighbourhood centre accessibility catchment area was in progress, to improve pedestrian infrastructure. In contrast, transport planners appeared to be more concerned with finding solutions for transport problems occurring within the neighbourhoods per se. One of the arguments used by transport planners was that the different districts of Tyne and Wear have different transport problems and that the

transport planners were charged with solving these problems because of their importance in the regional development agenda and that this took priority over looking at sustainable travel within individual neighbourhoods. For example, in Newcastle a transport problem occurred in one traditional neighbourhood, which could otherwise have been classified as a good case for a sustainable neighbourhood: this area was experiencing heavy car traffic because a school and a newly built business district were located within its boundary. This attracted car traffic from outside the area and affected local residents. As a result, complaints arose from the local community that later became the agenda for the local council to find a transport solution which may not be in line with sustainability issues. In South Tyneside, the transport problem, as reported from the interview, was to accommodate a heavy traffic flow going outside the district because of low job opportunities within the district, giving rise to more inter-regional car travel. In Gateshead, the authorities reported that 4 Home Zone schemes were implemented, re-designing local neighbourhood streets to be less car-oriented (via traffic calming, shared space design for all modes, etc.). One of the schemes is a retrofit, involving community stakeholders.

In summary, the interviews with local authorities give a general picture of the Tyne and Wear metropolitan area and touch on many issues relating to transport and land-use. The local authorities, in addressing the transport issues, do have a good idea of what sustainable mobility practice is, but are constrained by their need to deliver a higher priority agenda within their district – for example, the need to provide mobility access to go outside the district area. Each district has a different approach to this, which is why this study encapsulates district criteria in choosing neighbourhood 'hotspots', as discussed in the next section. The emergence of Home Zones, as part of the new planning approach, demonstrated that sustainable mobility issues have been echoed within the current planning practice. However, very little was known of its effectiveness to date, especially in regard to the addressing of the sustainability goals. This led to the further (micro)-study being undertaken.

5.2. Household survey data

It was realised from the outset that looking at the micro-scale urban form would need to identify various types of urban form measures to capture the effect of built environment upon travel behaviour. Built environment was defined as consisting of three general components: land-use patterns that refer to the spatial distribution

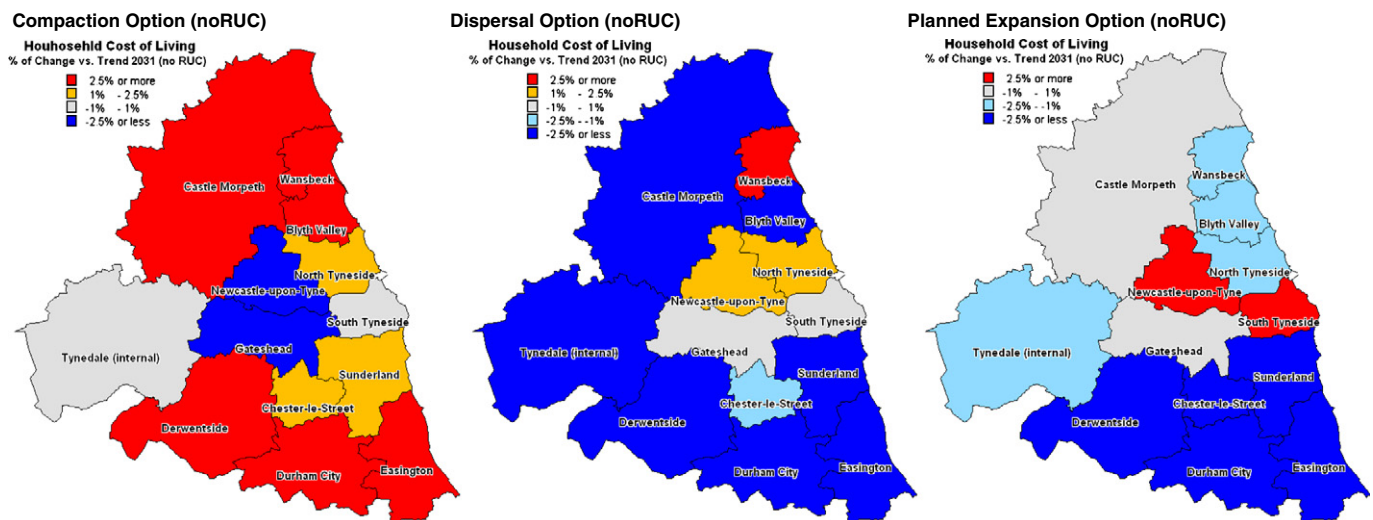


Fig. 4. Percentage difference in cost of living as compared to trend.
Source: Echenique et al., 2010.

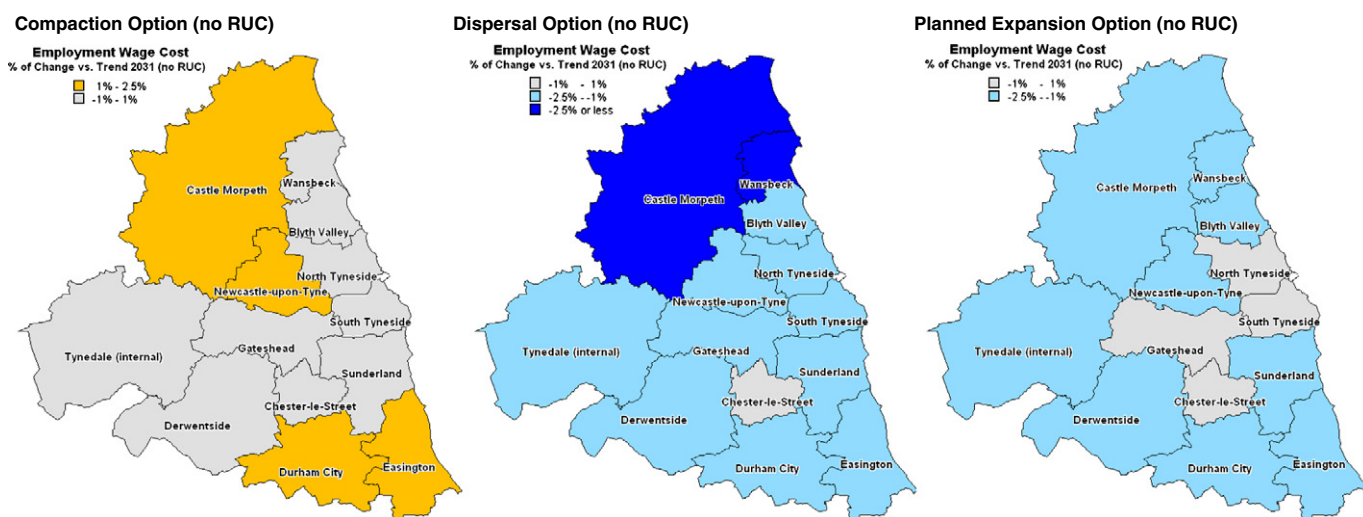


Fig. 5. Percentage difference in wage costs as compared to trend.
Source: Echenique et al., 2010.

of human activities; a transportation system that refers to the physical infrastructure and the services that make up the transportation system and provide the spatial links (connectivity) between activities; and design that refers to the aesthetic qualities of the built environment and overlays both land-use patterns and the transportation system, particularly the design of buildings and the design of street-scapes (Handy, 2005). Earlier studies at the micro land-use transport interaction analysis use a classification of 'traditional' and 'suburban' neighbourhood layouts to contrast the difference of travel behaviour (Boarnet & Crane, 2001; Ewing & Cervero, 2001). The traditional neighbourhoods were built mostly before World War II and the newer, suburban neighbourhoods post-1960s. However, to involve the European tradition of typo-morphology and to enrich the variants of neighbourhoods, the ABCD typology advocated by Marshall (2005) was also considered, to select the potential neighbourhoods. To further complicate the variance of neighbourhood 'hotspots', British Census data on journey to work was also used, to contrast the neighbourhood with more walking, cycling and public transport use as opposed to contrasting the neighbourhood with more driving.

The first stage of screening used the Lower Layer Super Output Area (LSOA), the lowest level of administration area, to ensure that income and other characteristics were above average for the area, and were compared using the Index of Multiple Deprivation, 2004 (ODPM, 2004). The Index of Multiple Deprivation (IMD) is a UK measure of deprivation of an area where, the lower the number, the higher the level of deprivation. In England 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. The purpose of the screening in the choice of 'hotspots' was to find neighbourhoods where people would choose to live, rather than areas where housing might be allocated on the basis of need, so that the sample included respondents

who had choice, ensuring that preferences in the choice in the built environment could be measured. Ten neighbourhoods were selected, representative of the typical housing neighbourhood profile of Tyne and Wear metropolitan area. The justification of the selected neighbourhoods is described thoroughly in Aditjandra et al. (in press). The final choices of neighbourhood hotspots can be seen in Fig. 7.

5.3. Methodology

About 220 questionnaires were distributed in each of the selected neighbourhood hotspots, resulting in a response rate of 32% (about 700). The questionnaire was divided into five sections, which gave data at either individual or household level on: travel patterns; built environment characteristics; attitudes and preferences to travel; change in travel patterns and residential move issues and socio-economic characteristics. The built environment and attitude and preference statements were developed from an adaptation of the work of Handy et al. (2005). The survey was undertaken in late spring 2007, in the form of a self-administered 8-page questionnaire booklet. Names and addresses were taken from the latest electoral register. A pre-paid self-addressed envelope was enclosed inside each questionnaire delivered. One week later a reminder postcard, again individually addressed, was delivered to the respondents.

Travel patterns – in particular car travel behaviour – were measured, using weekly reported vehicle miles driven (VMD). Neighbourhood characteristics were measured using 27 statements

Table 2
Number of trips in average AM peak hour: Comparison of land-use options.

Mode	Trend (in thousands)	Land-use options (percentage change)		
		Compaction	Dispersal	Expansion
Car	154.30	−2.6%	0.9%	−0.7%
Bus	57.50	6.4%	5.6%	−5.4%
Metro	9.50	−0.4%	−3.6%	10.3%
MCR & BRT	2.40	114%	−95%	70%
Rail	3.77	6.0%	−30.6%	3.8%
Walking & cycling	58.00	1.5%	−1.05%	−0.7%

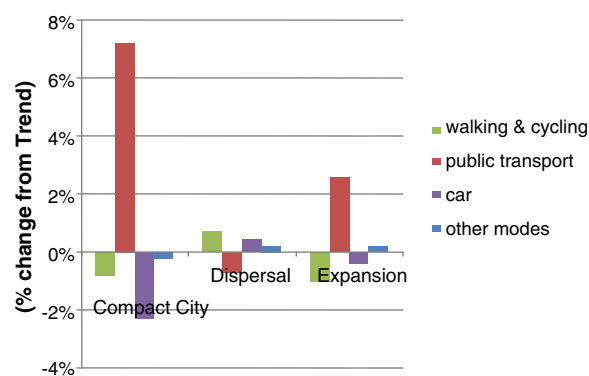


Fig. 6. Change in pass-km on each mode for all land-use options against the trend in 2031.



	North Tyneside	Newcastle	Gateshead	South Tyneside	Sunderland
Traditional (IMD)	 ⑨ (23,446)	 ② (21,291)	 ③ (20,140)	 ⑧ (11,147)	 ⑥ (20,072)
Suburban (IMD)	 ⑩ (25,297)	 ① (23,705)	 ④ (15,726)	 ⑦ (11,774)	 ⑤ (22,050)

Fig. 7. Google Earth aerial view captured on 10 selected neighbourhoods in Tyne and Wear metropolitan districts; ⑩ corresponds to the location in Fig. 1.
Source: Google Earth.

of perceived/preferred neighbourhood design characteristics. The term “neighbourhood”, as introduced to the respondents, was determined as the area within approximately 5–10 minute walk of the respondent's dwelling. Attitudes and preferences were measured using 28 statements of travel behaviour related issues. Socio-economic variables included gender, age, economic status, etc.

The neighbourhood characteristic statements were measured using a 4 point scale from ‘not at all true’ to ‘entirely true’, in order to obtain a series of opinions about the perceived neighbourhood characteristics. In identifying the residents' opinion (preference) of the same neighbourhood characteristics in selecting an alternative residence, a 4 point scale from ‘not at all important’ to ‘extremely important’ was used. For travel attitude characteristics, a 5 point scale from ‘strongly disagree’ to ‘strongly agree’ was used to measure the attitudes of respondents. Since many variables used in the questionnaire measure similar dimensions of neighbourhood design and attitude/preferences, it was unsurprising that many were highly correlated. Factor analysis was conducted to identify underlying constructs of perceived and preferred neighbourhood characteristics and attitude/preference characteristics. The criterion ‘eigenvalue > 1’ was used to determine the number of factors. The results of the factor analysis can be seen in Table 3. Comparison between perceived, preferred, and travel attitude characteristics towards different group setting (i.e. traditional vs suburban; commuting by car vs commuting by other modes; ABCD street layout typology) demonstrated significant differences between (neighbourhood) groups which were beyond just travel accessibility issues (see: Aditjandra, Mulley, & Nelson, 2007; Aditjandra, Mulley, & Nelson, 2009a; Aditjandra, Mulley, & Nelson, 2009b; Aditjandra et al., in press).

5.4. Results

The relationship between neighbourhood characteristics and travel behaviour was constructed using a regression model with reported household vehicle miles driven (VMD) used as the dependent variable. As some respondents reported zero VMD, a value of one was added to all the zero reported VMD so the true dependent variable in this model was $\ln(\text{VMD} + 1)$. The log-transformed distance was used because of the skewed distribution of VMD. This y variable was regressed against socio-economic characteristics, perception and preferences of neighbourhood characteristics and travel attitudes. The model regression initially included variables identified as important in Handy et al. (2005), before testing a wider variety of variables. This process was undertaken sequentially by first entering the set of preferred neighbourhood characteristics into the existing model, removing insignificant variables (at 10%) and then re-estimating the model before entering the

set of perceived neighbourhood characteristics. The cross-sectional analysis identifies socio-economic characteristics (driving licence, car ownership and employment status) significant at 5%, and explains the major part of the variance in VMD. Attitudinal aspects were also significant, with attitudes towards either public transport or car dependence contributing to a relatively large variation, but in the opposite direction to causation.

Table 4 shows that additional preferred and perceived neighbourhood characteristics can be good predictors of VMD. It is important to note that, although built environment characteristics and travel attitudes were constructed in the model, these were constructed via opinions and are very likely to be linked to an individual's behaviour and physical characteristics. Thus, the model is simply capturing how people actually travel according to their limited built environment circumstances (e.g. people who walk more are, not surprisingly, travelling shorter distance). Since the selection of neighbourhood hotspots has taken account of the deprivation level, we may assume income and other variables are controlled for. From Table 4, travel attitudes and neighbourhood design preferences clearly play a role in explaining differences in VMD. The shopping/facilities accessibility variable (at 5% significance level) and the residential spaciousness variable (at 10%) can be seen, demonstrating that the urban form variables impact on VMD variance (driving behaviour). shopping/facilities accessibility preference (standardised coefficient, beta: $-.066$) has a negative relationship with VMD, which means that better access to shopping/facilities would have significantly reduced VMD. Residential spaciousness has a positive (.044) relationship with VMD, meaning that the bigger the house, the more likely the residents are to increase VMD. However, the magnitude of impact (standardised coefficient) of these two variables is relatively small compared to the other variables (i.e. socio-economic and attitudes). To illustrate the scale of changes in travel behaviour that these results represent, let us consider the example of the predictor ‘residential spaciousness’, which has B value (unstandardised coefficient) of .088. It can be interpreted that, if everything else is held constant, a one-unit increase in this variable associates to an increase in $\ln(\text{VMD} + 1)$ of .088 units. Thus, if the household reported a weekly average VMD of 100, an additional space in the garden and or parking (the main elements representing ‘residential spaciousness’ factor) would generate only an extra .55 VMD – a total of 100.55 VMD. This suggests a marginal effect on VMD by neighbourhood characteristics. But, taking another example: the B value of pro-public transport attitude ($-.289$): if everything else is constant, a one-unit increase in this attitude by neighbourhood residents correlates to a decrease of $\ln(\text{VMD} + 1)$ of .289 units. Thus, if the household reported a weekly average VMD of 100, an additional resident with this attitude would

Table 3
Factors of neighbourhood characteristics and travel attitude.

Neighbourhood characteristics factors	Statements	Loadings
Safety	Safe neighbourhood for walking	.829
	Low crime rate within neighbourhood	.777
	Safe neighbourhood for children to play outdoor	.686
	Low level of car traffic on neighbourhood streets	.673
	Quiet neighbourhood	.603
	Good street lighting	.364
Travel accessibility	Easy access to a good public transport service (bus/metro/rail)	.877
	Good public transport service (bus/metro/rail)	.804
	Easy access to highway network (main road)	.417
	Pavements – easy walking routes throughout the neighbourhood	.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 off-street parking (garages or driveways)	.560
Social factors	Lots of people out and about within the neighbourhood	.787
	Lots of interaction among neighbours	.665
	Diverse neighbours in terms of ethnicity, race and age	.465
Shopping/facilities accessibility	Economic situation of neighbours similar to my level	.386
	Easy access to a district shopping centre (Tesco, ASDA, etc.)	.913
	Easy access to town centre	.713
	Other amenities/facilities such as a community/leisure centre or facilities for children available nearby	.468
	Local shops within walking distance	.316
Outdoor space ^a accessibility	Parks and open spaces nearby	.586
	Extension of cycle routes beyond the neighbourhood	.576
	Other amenities/facilities such as a community/leisure centre or facilities for children available nearby	.309
Neighbourhood ^a unattractiveness	Attractive appearance of neighbourhood	–.771
	High level of neighbourhood's upkeep (well maintained) within the neighbourhood	–.723
	Variety in housing style	–.440
Travel attitude factors		
Pro-public transport use	I like travelling by public transport	.876
	I prefer to take public transport than drive whenever possible	.870
	Public transport can sometime be easier for me than driving	.743
Travel minimising awareness	I prefer to organise errands so that I make as few trips as possible	.634
	Fuel efficiency is an important factor for me in choosing a vehicle	.617
	I try to limit my driving to help improve air quality	.598
	The price of fuel effects the choices I make about my daily travel	.570
	I often use the telephone/internet to avoid having to travel somewhere	.399
	When I need to buy something, I usually prefer to get it at the closet store possible	.393
	Vehicle should be taxed on the basis of the amount of pollution they produce	.368
Dislike-cycling	I prefer to cycle rather than drive whenever possible	–.930
	I like riding a bicycle	–.782
	Cycling can sometimes be easier for me than driving	–.751
Positive utility of travel	Travel time is generally wasted time	–.643
	The only good thing about travelling is arriving at your destination	–.618
Safety of car	Travelling by car is safer overall than taking public transport	.801
	Travelling by car is safer overall than walking	.775
	Travelling by car is safer overall than riding a bicycle	.488
Pro-walking ^a	I like walking	.730
	I prefer to walk rather than drive whenever possible	.728
Dislike-travel ^a	Walking can sometimes be easier than driving	.582
	The trip to/from work is useful break between home and work (the importance of your journey to work)	–.720
	I use my time to/from work productively	–.618
Car dependent ^a	I need a car to do many things I like to do	.632
	Getting to work without car is a hassle	.551

Extraction method: Principal axis factoring. Rotation method: Oblimin with Kaiser normalisation.

^a Factors with eigenvalue < 1 by parallel analysis but eigenvalue > 95 percentile of random data.

generate 1.4 less VMD – a total of 98.6. However, the attitudinal variables of this model, being categorical, are more difficult to interpret meaningfully in this way and looking at standardised coefficients (beta) for the predictors is more useful.

The micro-analysis tested different land-use variables and travel attitudes with control of socio-economic variables towards travel behaviour, in particular driving behaviour. It should be noted that the macro-analysis treated travel alternatives as bundles of attribute levels, thus the total utility of an alternative was determined by the utility an individual derived from its attribute levels. The assumption was that individuals always prefer the alternative that delivers the highest

utility or satisfaction, derived from the attributes of an alternative that were not measured directly but deduced from actual behaviour (revealed preferences), the characteristics of the alternatives (speed, cost, mode choice comfort), personal socio-economic characteristics, and the decision context, which can include land-use characteristics (Ben Akiva & Lerman, 1985).

Affective 'attitudes' evaluations (either cognitive evaluation or perceptions) were not directly included in the model but placed within the error term and were thus part of the unexplained variance (Ben Akiva & Lerman, 1985; Bohte, Maat, & van Wee, 2009); others described this as an optimising 'black box' of the conventional utility

Table 4
Model after sequential urban form variables input.

Model (predictors)	Unstandardised coefficients (B)	Standardised coefficients (beta)	t-Statistics	Sig. (p)
(Constant)	1.396		10.801	.000
Female	-.260	-.065	-2.760	.006
Employed	.638	.155	5.692	.000
Driving licence to H/H	.955	.404	14.282	.000
Cars per adult	1.433	.292	10.812	.000
Pro-walking	-.078	-.039	-1.677	.094
Pro-public transport	-.289	-.145	-5.657	.000
Safety of car	.144	.072	3.082	.002
Car dependent	.276	.140	5.650	.000
Shopping/facilities accessibility preference	-.133	-.066	-2.806	.005
Social factors preference	.087	.043	1.747	.081
Social factors perception	-.104	-.052	-2.096	.036
Residential spaciousness perception	.088	.044	1.835	.067

N = 659, R-square = 0.653, adjusted R-square = 0.647 (significant with *p*-value of 0.000); dependent variable: $\ln(\text{VMD} + 1)$.

theory (Morikawa & Sasaki, 1998). A number of attempts were made to address the issue but the most recent and influential was by Ben Akiva et al. (1999) who proposed a framework of three psychological factors, namely: perceptions, attitudes and preferences. The perceptions were defined as the individual's beliefs or estimation of the attributes of the alternatives (safety, convenience, reliability and environmental friendliness); the attitudes reflect the needs, values, tastes and capabilities of individuals (the 'importance of reliability' and 'preferences for a specific mode'); and together attitudes and perceptions determine an individual's preference for an alternative of the utility she/he derives from an alternative (Ben Akiva et al., 1999). These concepts were used in the micro-level study to model the perceived and preferred built environment characteristics and travel attitudes.

6. Conclusions and discussions

Since the early analysis by Newman and Kenworthy (1989) that established density as the main theme of the transport and land-use relationship, there are at least 10 more urban form characteristics that have been identified over time, including settlement size; strategic development location; strategic transport network; job-housing balance; accessibility of key facilities; development site location; mix of land-uses; neighbourhood design and street layout; traffic demand management; and parking (CfIT – Commission for Integrated Transport, 2009). The macro-model approach can represent most of these variables to some extent and pointed to the role that spatial strategy plays in influencing travel behaviour. The micro-study, on the other hand, has also exhibited a better understanding of the topic. That said, apart from the socio-demographic and urban form characteristics, travel attitude and preference also play a role in influencing travel behaviour.

The literature suggests that the uptake of the macro-model by authorities was to stimulate regional economic growth, at least in the case of Tyne and Wear City and region. The SOLUTIONS project Tyne and Wear case study tested various land-use strategies to forecast future travel patterns. The results demonstrated that, despite a huge shift in travel pattern caused by urban form strategies (i.e. compaction), there is only a small reduction in vehicle kilometres travelled and consequently, less carbon reduction (Mitchell, Hargreaves, Namdeo, & Echenique, 2011). For this reason the benefits of a compaction policy are much lower than formerly perceived, particularly due to the reduction in household living space and the lack of access to a garden, to which many householders aspire. This finding confirms Breheny's (1997) doubt of Compact City feasibility and to

Neuman's (2005) argument that said high density urban development can be achieved only at the expense of quality of life. It should be acknowledged that the term compact city refers to much more than just travel-related issues: it extends also to the consideration of the wider regional aspects, including issues surrounding the conservation of the countryside, more efficient utility and infrastructure provision and the revitalisation and regeneration of inner urban areas (Howley, Scott, & Redmond, 2009). At the later stage of the study it was concluded that the sustainability agenda cannot be met by adjusting urban form strategies, but rather that technology is perceived to offer better prospects of decarbonising urban growth (Echenique et al., 2010; Mitchell et al., 2011).

The interview analysis, prior to the micro-analysis model, demonstrated a little of the dilemmatic position of local authorities in anticipating the sustainability agenda of the region. The dependency of centralised regional spatial strategic decision had influenced the way authorities perceived sustainability, as is well acknowledged in the literature (Pemberton, 2000). But, despite the confusing message about the direction of authorities in addressing the sustainability agenda, there was evidence that local level development to support lower carbon based transport was being promoted (i.e. development of Home Zones). Naess, Strand, Naess, and Nicolaisen (2011) studied the land-use policies of two Scandinavian cities and concluded that the barriers to sustainability are lack of coordination between sectors, levels and administrative territories. This is confirmation of the output from the Tyne and Wear local authority interviews.

In the micro-analysis study, the disaggregated variables that influence driving behaviour were better described. The addition of attitudinal variables in the micro-model gave new insights into driving behaviour not explained in the macro-model. This in turn complemented a better understanding of why people drive the way they do, or why people choose public transport or walking, though the impact of built environment characteristics was also found to be marginal to the travel behaviour variance, when compared to other variables. However, given the more recent international debate on global climate change and the scenario of oil depletion, the importance of attitudinal characteristics in influencing travel behaviour has risen to prominence. More recent micro-level studies are emerging that have incorporated attitudinal variables, confirming that neighbourhood characteristics do indeed influence people's travel patterns in the use of public transport, walking and cycling (Aditjandra et al., 2012; Cao et al., 2007; Handy, Cao, & Mokhtarian, 2006). This confirms that land-use planning at local level is vital to shape travel behaviour. The importance of local neighbourhood design was also recognised in the practice of the local authorities in Tyne and Wear, who have adopted a number of approaches to address local, sustainable travel including Home Zones (LTP, 2007, 2011). Elsewhere, similar approaches were also adopted towards planning for sustainable accessibility, which focused development on places with high accessibility to all modes (Curtis, 2008; Handy, 2008). In parallel, there is also a greater emphasis on promoting active travel and other smarter choices measures (known as 'soft' transport measures). Recent research effort has demonstrated a stream towards modelling soft measures in travel demand forecasting (Schmöcker, Hatori, & Watling, 2012).

The closest link between the macro and the micro-studies is the acknowledgement of the marginal role that built environment plays in influencing travel behaviour. The results of the micro-study show that shopping/facilities accessibility preference has a negative relationship, which means that better access to shopping/facilities was significantly associated with low VMD. The macro-study results, on the other hand, show that the planned dispersal scenario option was to lead 0.7% reduction in regional car travel. Assuming that the planned dispersal was targeted at the creation of 'eco-towns' with more densely populated residential areas, a mixture of land-use (including easy access to shopping/facilities) and a built environment designed to be all modes transport friendly, the modest change in

car travel was not unreasonably justified. This macro-study however is subject to many issues that the author cannot address, since there are many modules in the LUTI model which were not rigorously assessed due to various factors including skill, cost and time. It is also important to note that the LUTI model is comprehensively developed and maintained within the private sector. Thus there was limited capability for SOLUTIONS to play with the model as if it were built as a new model from scratch.

Commenting on one of the fundamental differences between the two studies, namely the inclusion of attitudinal characteristics in the micro-analysis, it should be noted that conventional utility theory, such as that used in the macro-model, does not include attitudinal characteristics. Bohte et al. (2009) described how transport researchers have repeatedly aimed to incorporate attitudinal characteristics since the 1970s (in better understanding the relative contribution to changes in travel behaviour and not the way it can be used in the LUTI model). Although attitude is a very complex variable to be incorporated in the macro-model, it is relevant to refer to the travel choice theoretical model offered by Golob, Horowitz, and Wachs (1979) that illustrates a combination of the decision-maker's perception of the existence of constraints and his/her attitudes. The perception of the existence of constraints and attitudes is determined by the characteristics of the decision maker and characteristics of alternatives. So, attitudes and perceptions do not only influence travel choices but are also influenced by the travel choices themselves. Recent study by Abou-Zeid and Ben-Akiva (2011) has demonstrated that attitude can be incorporated in the choice of modelling framework that enhanced the behavioural realism of 'black box' models.

In the meantime, the macro-model development has been improving in helping public authorities to improve their capacity to respond to complex policy questions arising in the context of transportation, land-use and environmental planning. Despite the fact that Hatzopoulou and Miller (2009) evidenced northern American authorities as distancing themselves from the macro-modelling approach, a number of regional planning agencies in the US are using a 'post-processing' approach that adjusts mode shares by zone, based on built environment characteristics (see for example: Sadek, Wang, Su, & Tracy, 2011). The activity-based model has also gained popularity as an alternative to the traditional utility-maximisation model commonly used in LUTI models. The arguments used to support activity-based theory were that travel distance and the urban form relationship were a statistical association, as distance was not travel choice in itself, but the consequence of other decisions (Maat & Timmermans, 2009). When the activity based model is implemented at the parcel level within the land use data, the sensitivity of soft transport such as walking and cycling can be identified in the model. In short, efforts are underway to improve the macro-model approach, although challenges in research and practice are well documented (see for example: Waddell, 2011).

The use of macro-modelling approaches at the strategic national/regional level is primarily to forecast travel behaviour after changes in land-use and transport system have been introduced in the model. There are a number of inherent limitations in this approach, including the many assumptions made (car ownership model, residential/business location choice model, government policies such as road user charging, etc.) that have not necessarily been thoroughly adjusted, but the 'whole' nature of the model scale at least allows the paper to demonstrate the power of economic simulation of the region. The micro-analysis study is designed to gain better understanding of the relationship between urban form and travel behaviour at the local scale and gives more reasons behind travel behaviour variances. The limitation to the study is simply the scale of the sample (as opposed to the macro-model) which represents only a small section of the population, that is not necessarily representative of the region as a whole. Future research to expand the micro-analysis approach could benefit from investigating mode choice as a function

of travel attitudes and objective built environment form considerations. The inclusion of regional characteristics, alongside local physical characteristics and travel attitudes, could also be an interesting research area to extend the micro-study.

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