TRANSPORT AND REDUCED ENERGY CONSUMPTION: WHAT ROLE CAN URBAN PLANNING PLAY?

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Abstract

Traffic volumes and energy consumption from the transport sector continue to rise, yet the potential role of urban planning in contributing to reduced transport energy consumption continues to be largely underplayed. The growth of suburban areas tends to increase traffic volumes by dispersing activities and hence facilitates private car travel. Public transport orientated development as an evolving practice tends to be focused very much on urban areas.

This paper draws on research in suburban Surrey to suggest that urban planning can be applied more fully, at the strategic and local levels, to reduce energy consumption in car use. The future locations of housing growth are critical to our future travel behaviour – the lessons from Surrey can be applied to a certain extent to the Growth Areas and Housing Pathfinder Areas and elsewhere – however it is only through a careful integration of transport and urban planning that the potential for reduced travel can be realised. Regression analysis shows that urban form variables contribute up to 10% of the variation in transport energy contribution.

The conclusion reached is that integration requires action across a wide range of fields and from a wide range of actors. New households, for example, should be located in a coordinated manner in relation to the density of development, settlement size, distance from urban centres and transport networks, jobs and housing balance, local streetscape layout, public transport accessibility and green belt designation. Ad-hoc "pepperpotting" of new housing development no longer remains an option.

"Smart growth" strategies can reduce transport energy consumption, with greater transport sustainability being achieved through clearer direction on the location and form of major new development.

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1. INTRODUCTION

Transport and energy consumption, and the potential contribution of urban planning in reducing energy consumption, is a topic that is becoming increasingly important as efforts to attain sustainable lifestyles and sustainable travel behaviour are being sought, yet prove intractably difficult to achieve.

The role of urban structure, at the strategic and local scales, would appear, intuitively, to be critically important in facilitating travel. Urban structure provides the framework for the location of housing, employment and other developments, such as health, education and leisure facilities. Urban structure thus provides the physical rationale for travel alongside socio-economic and cultural factors. We might expect different urban forms (say low density sprawl and high density, public transport orientated development) to be clearly associated with different travel behaviours on the ground.

The difficulty in much of the previous empirical research in this area, however, is that it remains inconclusive. Some authors contend that certain land use variables, for example density, are strongly associated with energy consumption in travel (e.g. Newman and Kenworthy, 1989 and 1999). Some are more cautious and suggest that land use factors are, at most, only a small part of the picture, and that other factors, such as income, are more important in influencing the variation in travel (e.g. Gordon et al, 1997). Others add a further dimension in contending that the suburbanisation of the labour force has actually led to reduced trip lengths, with both residences and jobs being located in the suburbs (Gordon and Richardson, 1989). Finally there are issues raised around the acceptability of various policy stances, particularly the public acceptability of compaction (Breheny, 1992); it is argued here that suburbanisation has been stimulated by lifestyle choice and that attempts towards urban compaction are futile.

The complexity inherent in the rationale for travel appears to make analysis of urban form and travel problematic. There is certainly little consensus within the body of research as to the relationships between

land use and travel, and less still as to how (or indeed whether) land use can (or should) be structured to reduce travel.

Although this debate has been running for 25 years, it seems very timely, indeed critical, that we revisit the issues and provide some new evidence. There are a number of reasons for this: the growing imperative of global warming and the apparent need to conserve finite energy resources, the interest in moving towards sustainability in transport and urban (and suburban) living, an increased emphasis on quality in urban design, rising house prices in most parts of the UK (partly as a result of restricted housing supply), future plans for much increased housing supply, and an associated ambitious development agenda in the UK and elsewhere. This area of research hence becomes particularly topical and important.

In terms of potential future development levels in the UK, Gordon Brown recently (11 July 2007[1]) announced increased housing targets of 240,000 per annum, to be delivered through a new body in Communities England. This represents 3 million new houses by 2020. This follows a steady increase in the forecast numbers, from the Barker Review (HM Treasury, 2004) and the previous high aspirations for development in the Growth Areas and Housing Market Renewal Pathfinder Areas (The Sustainable Communities Plan, ODPM, 2003). The added impetus is thus with us already in developmental terms. In terms of strategic policy direction, the Stern Review (HM Treasury and Cabinet Office, 2006) reinforces the imperative to act against climate change, with a strong argument for an immediate response. Work specific to the transport sector adds little on this particular topic; Eddington (HM Treasury and Cabinet Office, 2006), for example, being far too narrow in remit, concentrating solely on transport and productivity issues. The current Planning White Paper (DCLG, 2007) is also critical here, aiming to speed up the planning process through new requirements for consultation and faster land release and the use of outline planning permissions which should lead to less land banking.

The argument hence seems to be emerging that the global warming, energy consumption and development agendas, when considered together, mean that we require a very different approach to the integration of urban and transport planning. Urban planning as a discipline needs to contribute more to sustainability in transport. The transport planning profession needs to think more widely in terms of the "toolkit" available for achieving sustainability in transport. This includes the pivotal role of urban structure. The first step here is to reassess the potential contribution of urban planning in reducing energy consumption in transport.

This paper revisits the urban planning and travel behaviour field by:

[1] Gordon Brown announcing the new legislative agenda for 2007/08 (Hansard, 11 July 2007).

- Deconstructing the previous literature;

- Assessing the relationships between a wide range of urban structure variables and travel behaviour (as represented by the commute to work);

- Considering the relative contributions of urban structure and socio-economic variables to changes in travel behaviour;

- Synthesising the lessons to be drawn for policy and practice.

2. DECONSTRUCTING THE PREVIOUS LITERATURE

The key debates within the literature in this field evolve around whether and to what extent travel behaviour is associated with land use and socio-economic variables. Table 1 reviews the literature, first by examining the existing, at times contradictory, knowledge and then by highlighting a number of the "under researched" areas. Research findings from the literature are organised by topic and author.

Table 1: The Knowledge Review - Land Use and Transport Interactions

Existing Knowledge	
Resident Population Density and Travel	**Comment**
▪ Increasing densities reduces energy consumption by transport (Newman and Kenworthy, 1989). ▪ There is no clear relationship between the proportion of car trips and population density in the USA (Gordon et al, 1989). ▪ Having more people close to their jobs will reduce vehicle miles travelled, freeway traffic and tailpipe emissions (Cervero, 1996). ▪ Compact cities may not necessarily be the answer to reducing energy consumption, due to effects of congestion, also decentralisation may reduce trip length (Breheny, 1995 and Gordon & Richardson, 1996). ▪ 'Decentralised concentration' is the most efficient urban form in reducing car travel (Jenks et al, 1996). ▪ Density is the most important physical variable in determining transport energy consumption (Banister et al, 1997). ▪ Higher densities may provide a necessary, but not sufficient condition for less travel (Owens, 1998). ▪ As people move from big dense cities to small less dense towns they travel more by car, but the distances may be shorter (Hall, in Banister, 1998).	Newman and Kenworthy defined the field here, but with important contributions from Gordon and Richardson, Cervero, Breheny, Banister and others. Dispute remains as to whether increasing densities impacts on modal choice, travel distance and energy consumption. Various views as to optimum urban form for reducing car travel; ranging from compact cities to 'decentralised concentration' and even, controversially, to low density suburban sprawl.
Resident Population Size and Travel	**Comment**
▪ No correlation between urban population size and modal choice in the USA (Gordon et al, 1989). ▪ The largest settlements (>250,000 population) display	Ecotec made an important early contribution in the UK. Dispute remains as to whether

lower travel distances and less by car (Ecotec, 1993). ▪ The most energy efficient settlement in terms of transport is one with a resident population size of 25-100k or 250k plus (Williams, 1998). ▪ The search for the ultimate sustainable urban form perhaps now needs to be reorientated to the search for a number of sustainable urban forms which respond to a variety of existing settlement patterns and contexts (Jenks et al, 1996)	population size impacts on modal choice, travel distance and energy consumption. There appears to be much variation by context.
Provision and Mix of Land Uses and Travel	**Comment**
▪ Mixing of uses is not as important as density in influencing travel demand (Owens, 1986). ▪ Communities with approximate jobs-housing balance see a majority of residents working in their home community (Cervero, 1989). ▪ Diversity of services and facilities in close proximity reduces distance travelled, alters modal split and people are prepared to travel further for higher order services and facilities (Banister, 1996). ▪ Much research advocates 'contained', compact, urban layouts with a mix of uses in close proximity, i.e. a move away from functional land use zoning (Williams, 2005)	Cervero led the field here; with little comparable analysis in the UK or elsewhere. Dispute remains as to whether jobs and housing balance impacts on modal choice, travel distance and energy consumption. Theoretical jobs-housing balance may be outweighed by wider factors behind travel in certain contexts.
Location and Travel	**Comment**
▪ Location of new housing development outside existing urban areas, or close to strategic transport network, or as free-standing development increases travel and influences mode split (Headicar and Curtis, 1994 & 1998). ▪ Location is an important determinant of energy consumption and car dependency (Banister, 1997). ▪ Development close to existing urban areas reduces self-containment and access to non-car owners (Headicar, 1997). ▪ Deconcentration of urban land use to suburban locations and new towns almost certainly promotes the use of the private car for all purposes and leads to less use of public transport as well as cycling and walking. Distance to work however does not necessarily increase (Schwanen et al, 2001)	Headicar and Curtis (1994) highlight the importance of location. Banister and, later, Schwanen make further contributions. Dispute remains as to importance of context/impact of location – in terms of distance from urban centre and strategic transport network - on modal choice, travel distance and energy consumption. There is an important point in here – PPG13 (DETR, 2001), encourages development in urban areas, but doesn't differentiate between urban areas. All are treated as one.
Socio-Economic Characteristics and Travel	**Comment**
▪ Trip frequency increases with household size, income and car ownership (Hanson, 1982) ▪ Travel distance, proportion of car journeys and transport energy consumption increases with car ownership (Naess, 1996). ▪ Attitude to travel is more strongly associated with travel behaviour than land use characteristics (Kitamura et al, 1997). ▪ Socio-economic determinants of travel behaviour change are more important than land use factors, accounting for some 21%-58% of the variation in distance travelled at the individual and ward level. Land use factors are still important, accounting for up to 27% at the survey area level (Stead, 2001).	Dispute remains as to the range of impact of personal and household characteristics on modal choice, travel distance and energy consumption (this is very likely to vary by context). But emerging consensus that personal/household characteristics are more important determinants of travel than land use characteristics. Stead makes an important quantification, and the critical point that land use characteristics become more important at an area level (rather than individual).

	Very interesting work from Kitamura et al on attitudinal influences on travel; little comparative work in the UK or elsewhere.
Travel Definitions	**Comment**
▪ Trip frequencies appear to be primarily a function of socio-economic characteristics of travellers and secondarily a function of the built environment; trip lengths are primarily a function of the built environment and secondarily socio-economic characteristics; and mode choice depends on both (Ewing and Cervero, unpublished working paper).	Little work considers the issue of different definitional assumptions, and makes general conclusions from an understanding of this. Studies that concentrate on trip length are most positive in terms of correlations with urban structure.

Source: Based on Banister and Hickman (2006)

As we can see, there are many contradictions in the research results, and little actual consensus. The reasons for this include:

- Definition of problem: different measures of variables are used in studies, the classic example being definitions of density. Resident population and resident employment density and workplace population and workplace employment density are all used in the various studies.

- Definition of the "outcome variable": travel is measured in terms of journey to work (most commonly) or of all trips; and mode choice (most commonly), trip frequency (increasingly), trip length (rarely), and composite measures (rarely) such as vehicle miles travelled and energy consumption.

- Data sources: national, regional, city-wide and/or local area datasets are all variously used.

- Analysis: different research techniques are also employed, ranging from simple cross-tabulations, descriptive case study and bi-variate analysis, to more complex multi-variate analysis and simulation studies.

- Location: different geographical areas of research also give varying results. It is not surprising that research from California, US gives different results to that from Oxford or Surrey, UK or Perth, Australia.

- Time: many of these effects take place over a considerable period of time, thus making if difficult to establish causality, and there is potential for "contamination" from the effects of external factors that are not controlled for in the analysis.

There are important methodological issues to be discussed here. Causation and co-linearity are not well understood in much of the analysis. In terms of causation, different land use factors are often associated with different socio-economic and attitudinal characteristics and there are likely to be many interactions. Socio-economic characteristics, for example, are very likely to affect land use characteristics (the reverse of what is usually assumed). In terms of co-linearity, a further unresolved issue is, for example, whether increased density is associated with more or less travel, or whether other factors which co-vary with density (say a central location or good public transport accessibility) are more closely linked to levels of travel.

It is within this rich body of literature, together with its uncertainties and controversies that this paper now builds.

3. THE RESEARCH FRAMEWORK

The research reported on in this paper attempts to draw on this review of the previous literature, focusing on bringing together the broad range of previous analysis and also some of the perceived research gaps. Figure 1 outlines the research framework. The research hypothesis is drawn from an understanding of the wider sustainability and urban planning field, and of unresolved issues in the sub-set literature of land use and transport interactions.

The dependent variable in the analysis is travel, as represented by energy consumption[2] (a composite of journey length, time, mode share and occupancy) in the journey to work. Commuting trips are used rather than all trip types to highlight the strong relationship between housing and employment location and how this might change over time, and also was a result of what was available data-wise from new household survey type analysis. Independent variables cover a range of urban structure and socio-economic characteristics as outlined below:

- Land use: including resident population density, resident employment density, workplace population density, workplace employment density, resident population size, workplace population size, distance from urban centres and strategic transport networks, jobs-housing balance, resident location (relative to the urban area), type of journey to work, neighbourhood streetscape layout, public transport accessibility, and resident location (relative to the green belt).

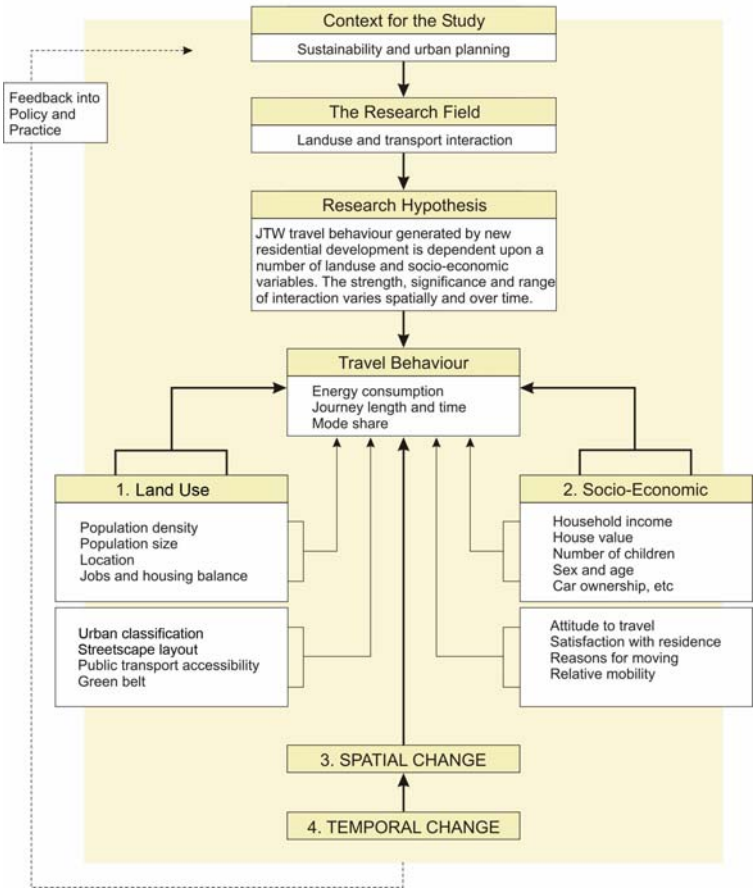
- Socio-economic: household tenure, house type, house size, number of children, car availability, company car ownership, household income, house value, respondent sex, respondent age, marital

[2] The method used for calculating energy consumption is as derived in Banister et al (1994).

status, occupation, qualification, attitude to travel, attitude to home and relative levels of mobility.

The study is heavily empirical in its approach as it tries to test the relationships between land use and socio economic variables, and their effects individually and in combination on energy use in transport.

Figure 1: The Research Framework



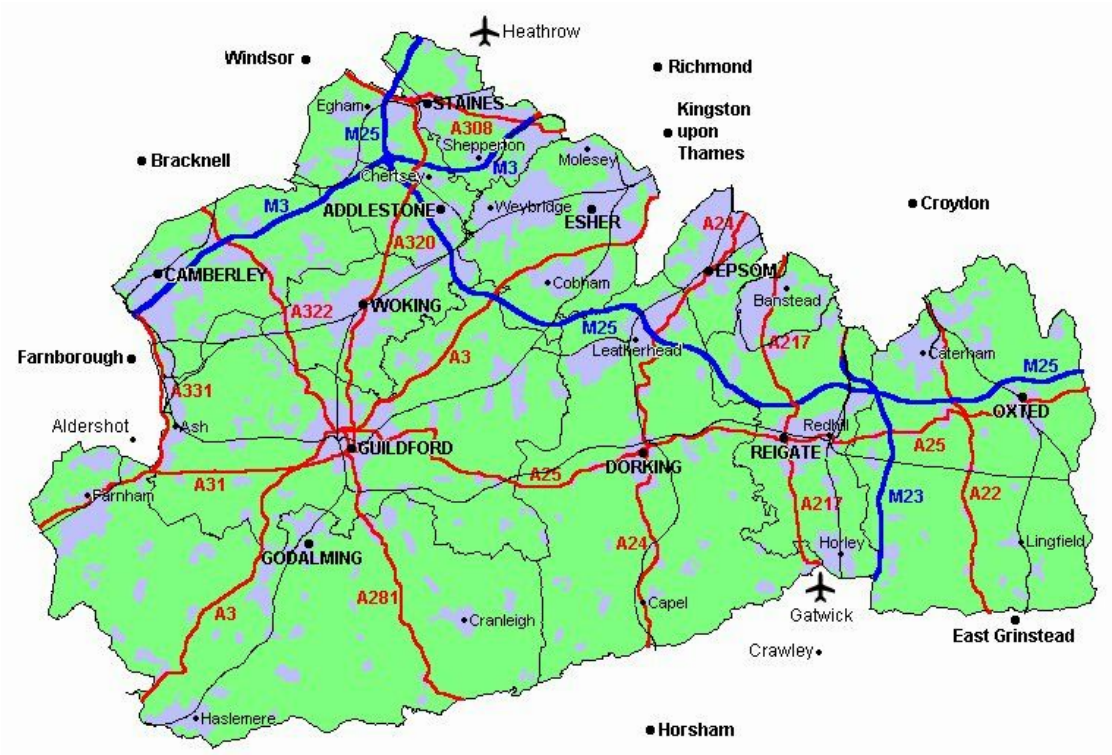
4. SURREY AS A CASE STUDY

The case study used is Surrey, a county located immediately to the south-west of London in the UK (see Figure 2). The major towns in Surrey are Guildford (with a population of over 65,000) and Woking (56,000), and Epsom, Camberley, Ewell, Farnham and Redhill (all over 30,000). The main transport links are the M25, M3, M23 and A3, and a series of (mainly radial) rail lines directed north-east towards London.

The county represents classic London fringe/suburbia in Epsom, Esher and Staines, with other self-standing settlements in more rural settings such as Guildford and Woking. The county is generally very affluent

(although isolated parts have relatively high multiple deprivation ratings, e.g. parts of Woking or Guildford).

Figure 2: The Case Study of Surrey



A survey of new household occupiers in 1998 is used as the basis for the analysis, together with additional, complementary data taken from local authority datasets. Descriptive data from the survey is as described in Table 2.

Table 2: Survey Descriptive Data

Key Data	1998
Number of surveys	2,920
Response rate	54%
Total households returned	1,568
Total adult respondents	2,865
Total working respondents	1,916

Category	1998	
	Frequency	Percent
Sex		
Female	1,470	51%
Male	1,369	48%

Not stated	26	1%
Total	2,865	100%
Age		
0-16	893	24%
17-24	237	6%
25-44	1,531	41%
45-retirement	678	18%
Over retirement	402	11%
Not stated	17	0%
Total (discounting under 16s)	2,865	76%
Total	3,758	100%
Occupation		
Employed: full time	1,499	52%
Retired	443	15%
Looking after home or family	307	11%
Self employed	222	8%
Employed: part time	195	7%
Student	105	4%
Unemployed	43	2%
Other	51	2%
Not stated	0	0%
Total	2,865	100%

5. ASSESSING THE RELATIONSHIPS: EVIDENCE FROM SURREY

The research analysis is summarised in a series of key findings. This aims to further our understanding of the complexity of travel behaviour and the subtlety of the relationships with urban structure.

5.1 Land Use Characteristics

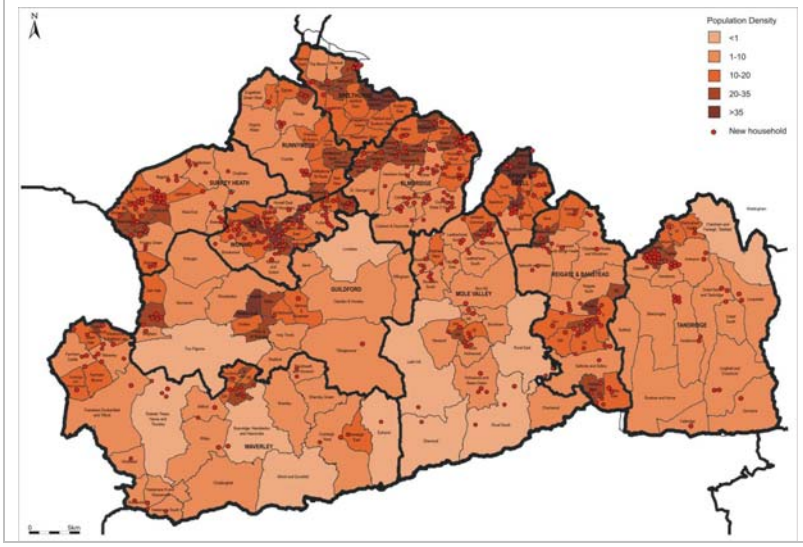
Generally the findings from the Surrey dataset are positive in tone: urban structure appears to influence travel behaviour in the journey to work (JTW). It seems that the role of urban planning has been underplayed in reducing journey to work energy consumption. Yet, within this, there are a large number of nuances to the findings. Rather than a small number of relationships at work (such as density and travel), there are a wide range of relationships involved. Each variable, by itself, offers a relatively weak relationship with travel, but when considered with others becomes important. The lesson perhaps is that we should widen our aspect somewhat in looking at the land use and travel debate.

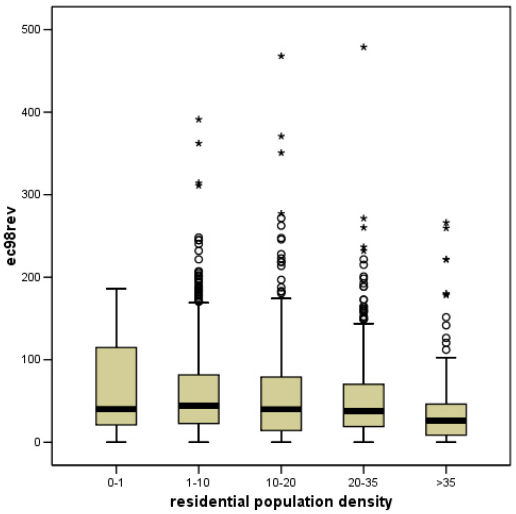
Population density: an inverse relationship is found between residential population density and energy consumption: lower residential population densities are associated with higher energy consumption patterns, and higher densities with lower energy consumption patterns, in the commute

to work. Housing located in wards with the highest densities (over 35 persons/ha) is associated with 29% less energy consuming commutes than the sample average. Hence the Surrey data supports the original Newman and Kenworthy thesis, but with certain caveats. A detailed analysis is provided within the analysis of travel behaviour, considering journey length, time, mode share and energy consumption - and from this we can see that much of the difference in energy consumption is due to journey distance. Importantly, the land use and energy consumption relationship varies greatly if different definitions of density are used: workplace population and employment densities show no similar relationships with travel behaviour (Figure 3).

Figure 3: Residential Population Density and JTW Energy Consumption

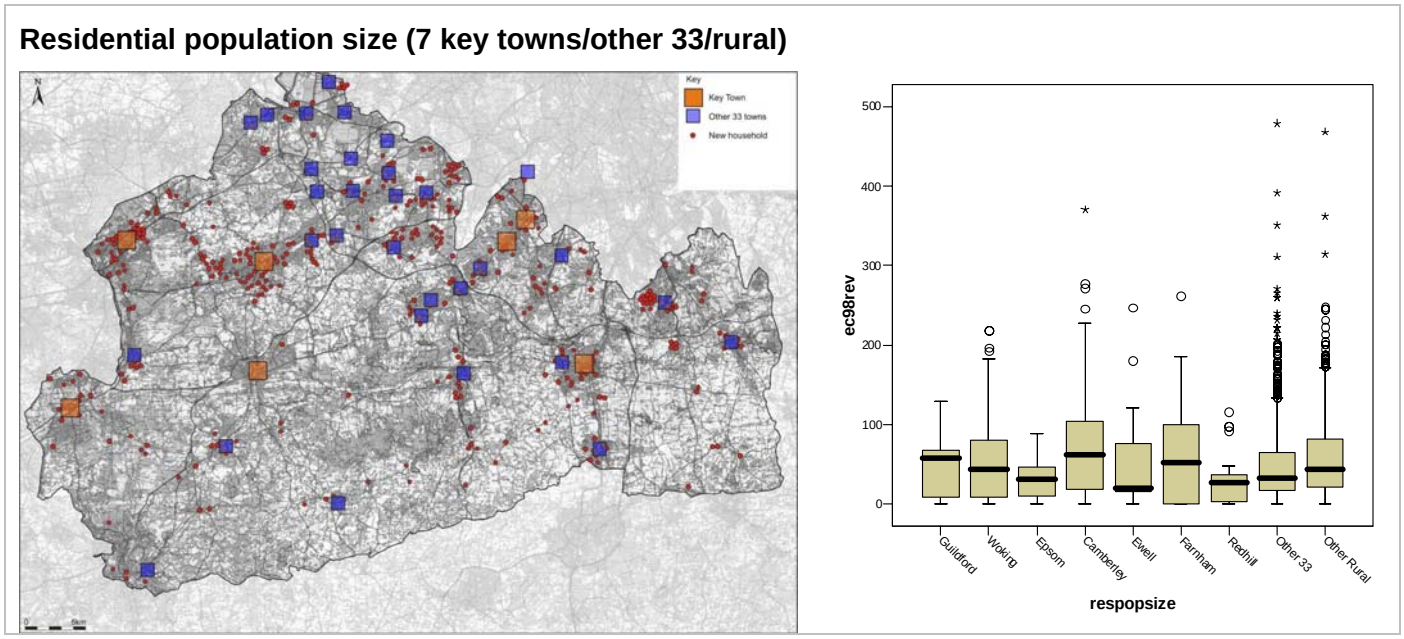
Residential population density (resident population/ha)





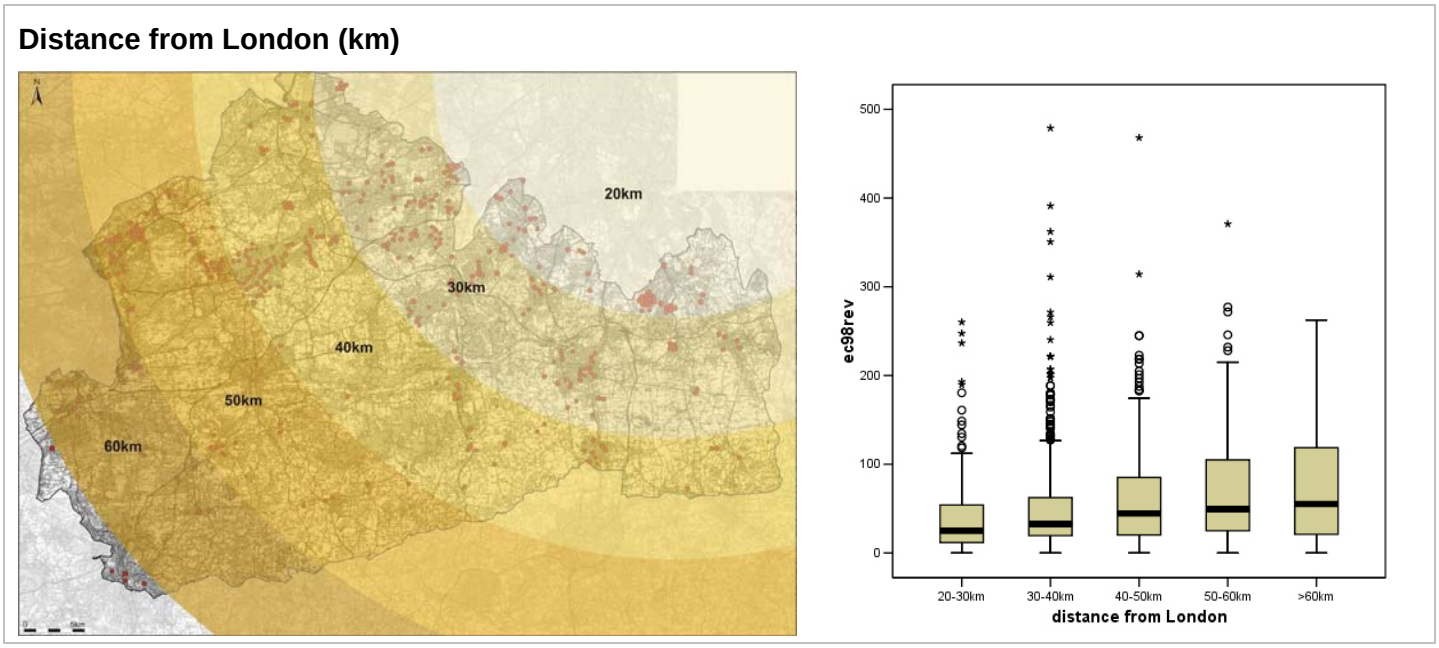
Population size: reflecting the Banister (1997) threshold debate, households located in towns (and rural areas) in Surrey, below a threshold of 25,000 residential population size, are associated with high energy consumption patterns. There is however more subtlety within the evidence: there is much variation within the towns above the 25,000 threshold, reflecting the complexity of commuting possibilities in Surrey. Journeys to workplaces in London are a very distinctive cohort: relatively lengthy and typically by rail. Journeys to Outer London and other adjacent counties are high energy consumers. Journeys to the 7 key towns in Surrey (including Guildford and Woking) are the lowest energy consumers. Wider factors, such as household income, have an important impact on the expected land use/transport relationship. As they increase in importance (i.e. larger incomes and greater car availability) then the expected effects of location are 'crowded out' and become less important (Figure 4).

Figure 4: Residential Population Size and JTW Energy Consumption



Distance from London: increased residential distance from London is associated with higher energy consumption, reflecting the general findings of, for example, Spence and Frost (1995), Banister (1992) and Naess and Sandberg (1996) for varying central urban areas. Within Surrey, residents living over 60km from London consume on average 91% more energy in their journey to work trips than residents living 20-30km from London (1998 data). There is no plateau in energy consumption as distance from London increases (Figure 5).

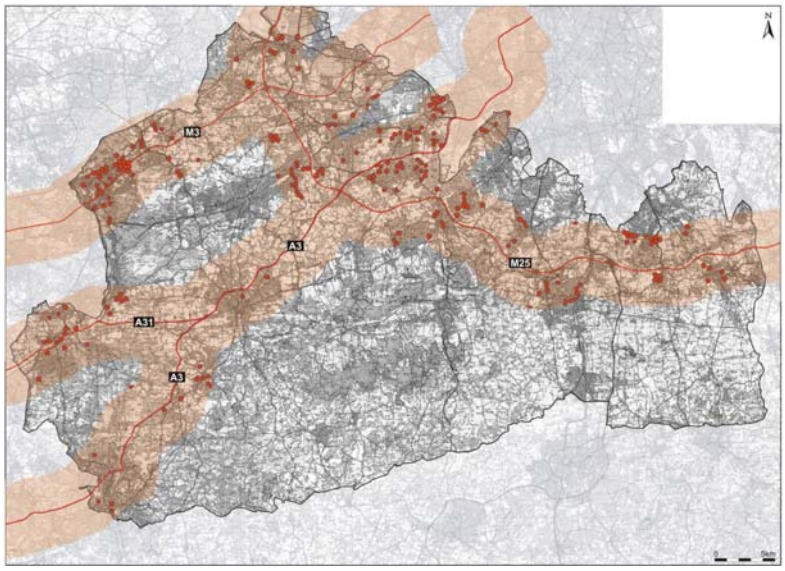
Figure 5: Distance from London and JTW Energy Consumption

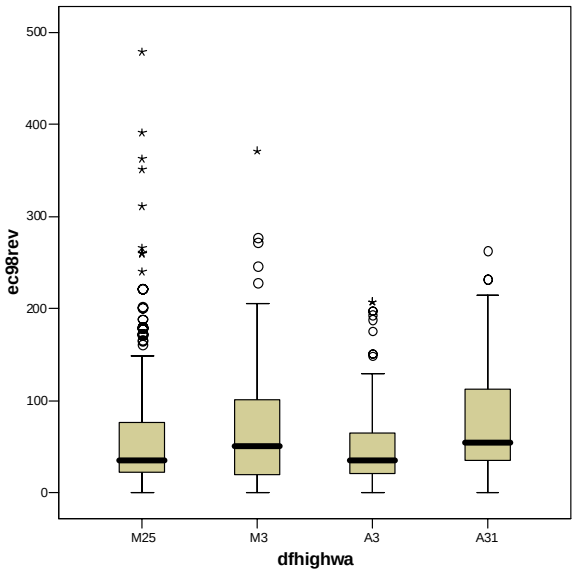


Distance from strategic road network: households located close to the strategic highway network are associated with high energy consumption patterns: the A31 (in particular), A3, M25 and M3 all contribute to lengthy commutes by car. This reflects the initial findings of Headicar (1997) in Oxfordshire, but uses a different scale of analysis. Better access to the strategic road network in Surrey extends the distance that can be travelled in a fixed time of around 45 minutes. The analysis in Surrey shows that resident locations within 3km of the uncongested M3 and A31 are associated with commutes consuming 44% more energy than resident locations >3km from the strategic road network. Journey to work distance and mode shares contribute to these trends (Figure 6).

Figure 6: Distance from the Strategic Highway and JTW Energy Consumption

Distance from the strategic highway network (3km buffer – M25/M3A3/A31)





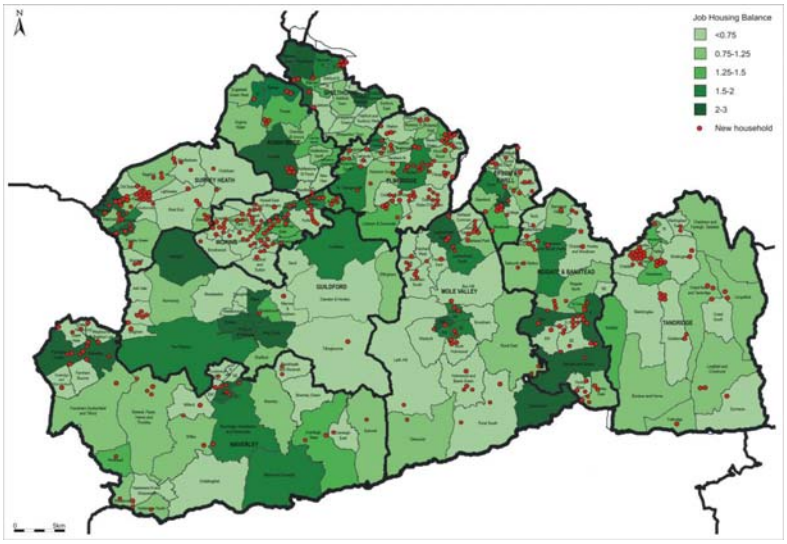
Jobs-housing balance: the conventional viewpoint in the literature is that the mix and balance of land uses affects the separation of activities and, in part, determines travel behaviour. Much of the available research is from the US (Cervero, in particular 1989 and 1996). Little evidence is available covering the UK experience, with the exception of some analysis concerning the New Town experiences. Within Surrey, households located within areas with jobs-housing balance are associated with low energy consumption in the journey to work: for example, households located in the 1.25-1.5 jobs-housing cohort are 25% less energy consuming than the sample average (Figure 7).

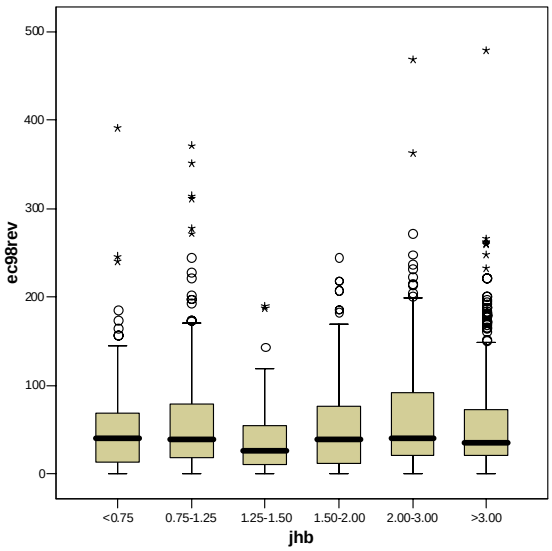
This finding appears to be very important. Perhaps we need a revised emphasis on job-housing balance in the UK, at varying spatial scales. Although theoretical balance does not guarantee people live and work locally, it does, at the aggregate scale, enable shorter average commutes and a higher public transport mode share (if jobs-housing

balance is associated with a good public transport offer). Hence the policy presumption should be to create an effective balance of jobs-housing at various scales – at the regional and sub-regional level, for journey to work catchment areas and, more locally, at centres of new high density development around public transport nodes.

Figure 7: Jobs-Housing Balance and JTW Energy Consumption

Jobs-housing balance (jobs/households)

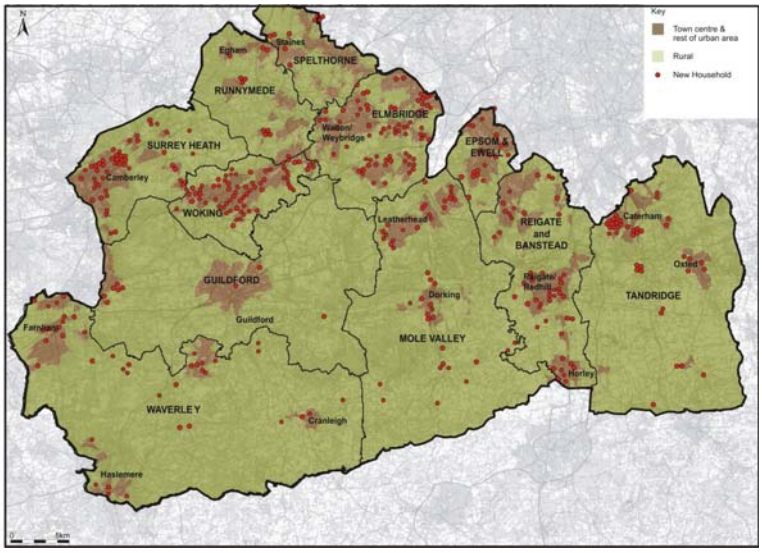


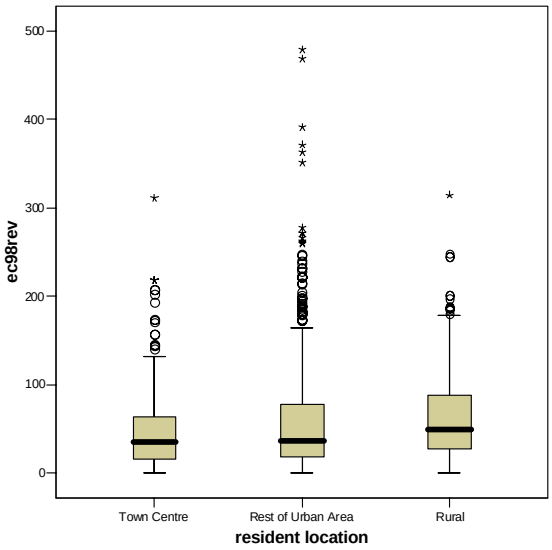


Location relative to urban area: the premise in much of the national policy guidance (for example PPG13, DETR, 2001) is that new housing is better located in urban areas for travel generation reasons. The Surrey data gives evidence to this: average energy consumption for households located in rural areas is 24% higher than in town centres, or 13% higher than in the rest of the urban area. However we should note the earlier settlement size conclusions – there is much variation in travel between different urban areas (Figure 8).

Figure 8: Household Location Relative to Urban Area and JTW Energy Consumption

Household location (town centre/rest of urban area/rural)



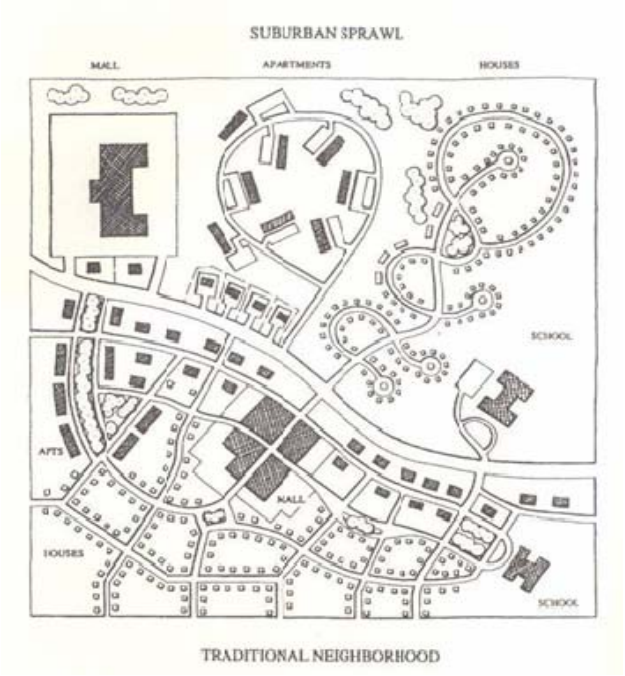


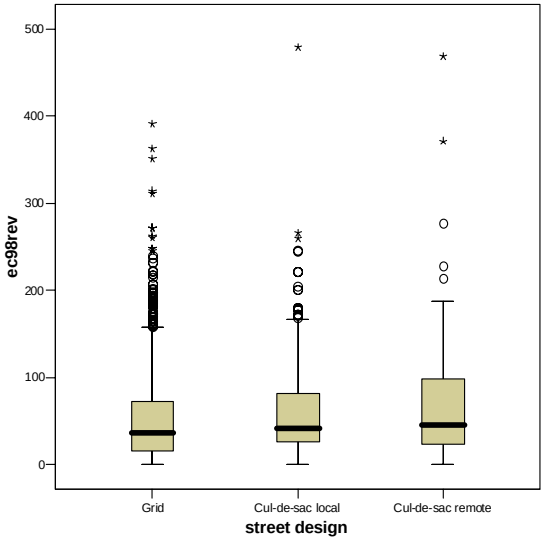
Local neighbourhood streetscape layout: the land use/transport relationship manifests itself at different scales. At the local level, a number of studies, mainly in the US, have looked at the impact of local neighbourhood layout on travel behaviour. Boarnet and Crane (1999) give a good overview of the literature, the general thesis being that traditional grid-style development patterns are associated with greater use of walking, cycling and public transport (they offer direct routes, legibility, etc.), and less use of the private car, than suburban sprawl and cul-de-sac type developments (which favour the car for quickest journey times).

A number of the studies in the US have grown out of the New Urbanism movement. Kulash et al (1990) suggest that 'traditional' circulation patterns reduce vehicular motorised traffic by 57% compared to more conventional networks. In the UK “grid style” street networks are often expounded as the most attractive urban streetscape design layout, yet there is little evidence to suggest that this may be associated with reduced energy consumption in travel behaviour. The Surrey analysis provides a first understanding of these issues in the UK. Within Surrey, energy consumption in the journey to work is lower in neighbourhood locations with neo-traditional grid street patterns (5% lower than the sample average in 1998); and higher in locations with cul-de-sac style street patterns. This is especially so when the cul-de-sac streets are remote from the village/town centre; energy consumption figures here are 13% higher than the sample average in 1998 (Figure 9).

Figure 9: Streetscape Layout and JTW Energy Consumption

Streetscape layout (grid/cul-de-sac local/cul-de-sac remote)





(Duany and Plater-Zyberk, 1992)

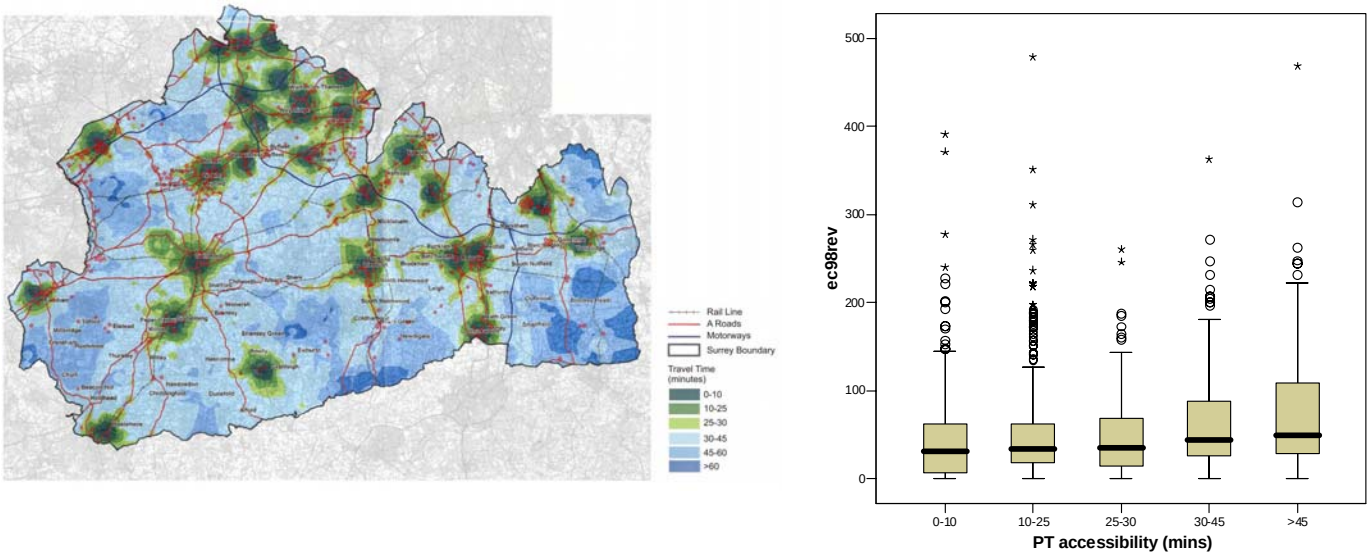
Public transport accessibility: this is now a central theme in transport planning in the UK (the DfT have sponsored the use of Accession as a modelling tool to be used throughout the UK), and public transport accessibility is strongly related to the discussion on density, settlement size and urban areas and access to the strategic highway network. Public transport accessibility is intuitively viewed as an important influence on travel behaviour. Amundsen (1995) and Pharoah (1992) discuss the ABC location policy in the Netherlands and the much-admired, but flawed, attempt to match accessibility and mobility profiles. Similar work, in terms of using accessibility profiling, has been carried out in the UK in Hammersmith and Fulham, Surrey and elsewhere.

Few attempts have however been made to test the effectiveness of such policies in terms of travel behaviour. Kitamura et al (1997) find that distance in the US from home to bus stop affects modal share. Within Surrey, the data reveals that energy consumption in the commute to work reduces with improved public transport accessibility. Energy consumption is lower for households located close to the town centre, and higher for those located further away (Figure 10). But again there are caveats to this, as the 25-30 minute isochrone is associated with the least energy consuming patterns (13% less than the sample average in 1998). Perhaps, counter intuitively, households located closer to the urban area are associated with long journey lengths, due to the tendency to commute longer distances by rail. But, as expected, by far the highest

energy consumers are households over 45 minutes from the urban areas (consuming 23% more than the sample average in 1998).

Figure 10: Public Transport Accessibility and JTW Energy Consumption

Public transport accessibility (PT mins to major town centres)



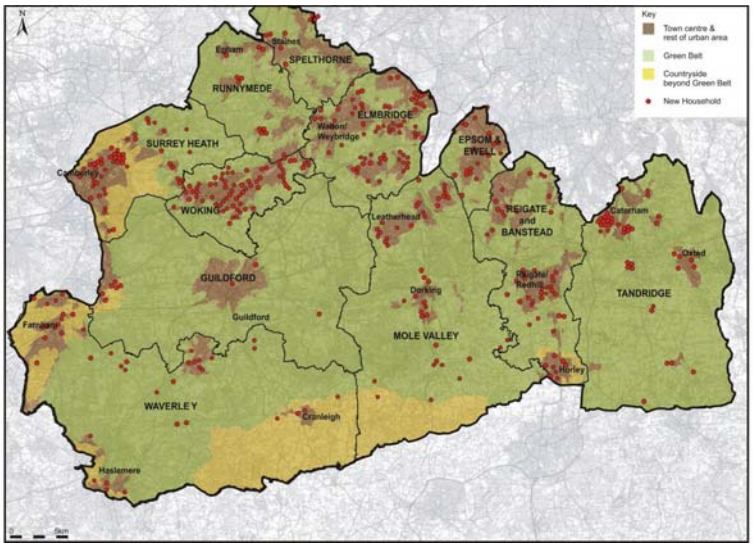
Location relative to the Green Belt: there is a separate and distinct literature field on the use and value of green belt policy in the UK. In this paper, consideration is given to the particular dimension of the impact of the green belt on travel behaviour. The main argument being that green belt provision increases journey lengths as people are 'forced' to live beyond the green belt as the urban area becomes 'filled' to capacity. Or, more likely, house prices rise within the town, forcing people to live further afield and further from workplaces. Authors such as Elson (for example 1999) and the Town and Country Planning Association have long argued that the current role of green belts should be re-examined.

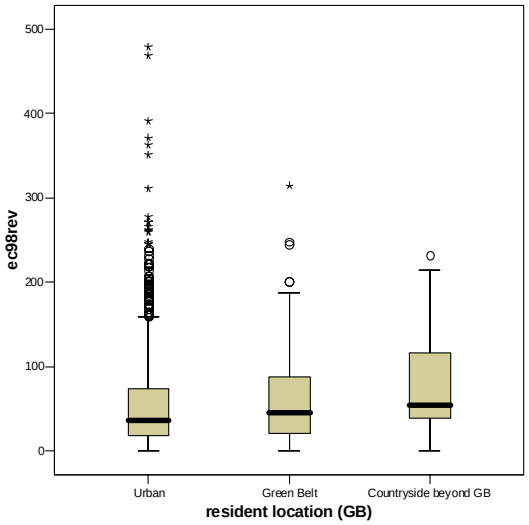
In terms of green belt impacts on travel behaviour patterns, Headicar (1997) points to evidence in Oxfordshire that - perversely - car use rates would be lower from new housing located in Oxford's green belt, than in the country towns as designated in the Oxfordshire Structure Plan. Within Surrey, green belt policy is also associated with increased energy consumption patterns (Figure 11). Energy consumption is lowest for households in the urban areas, rising markedly for those in the green belt and particularly for those in locations beyond the green belt (the latter 30% higher than urban locations in 1998). Hence, a further complication is at work, as green belts maybe beneficial for other environmental reasons, but they may also have an adverse impact on commuting patterns. Clearly a trade-off needs to be made in terms of sustainability objectives, between the environmental benefits of green

belts versus the increased emissions, energy and congestion they may bring.

Figure 11: Resident Location Relative to the Green Belt and JTW Energy Consumption

Resident location (urban/Green Belt/countryside beyond the Green Belt)





Comment: Many of these study findings appear relatively clear, especially since we are only considering bi-variate relationships in regard to a complex rationale for the commute to work. The analysis also provides consideration of a very wide range of land use variables, that all seem to contribute in part to the different patterns of energy use in transport.

Correlation analysis[3] gives an indication of the strength of the linear association between land use and socio-economic characteristics and journey to work travel behaviour. Tables 3 and 4 show correlation factors between the main land use variables and energy consumption in 1998. The most highly correlated variables are residential population density, distance from London and public transport accessibility. Hence we can see that, as well as the frequently analysed density and travel relationship, additional land use variables are also important in Surrey.

Although significant, all of the relationships are relatively weak in statistical terms. This is however to be expected, as we are considering only one of many influences on travel. Also we should note that the direction of causation is not proved by correlation. The signs within the table are as expected, with all land use variables being positively related to energy consumption with the exception of residential population

[3] Pearson's product moment correlation is used to examine interval data, Kendall's tau for ordinal variables and Chi square is used for nominal data. Significance at the 5% level is shown by * and significance at the 1% level by **. The former * means that there is a 5 in 100 (or a 1 in 20) chance of there not being a relationship between the land use variable and energy consumption; the latter ** a 1 in 100 chance of there not being a relationship.

density. Jobs-housing balance provides no significant relationship, reflecting a non-linear relationship. There is a reduction in energy consumption for households located in wards of jobs-housing balance (ratios of 1.25-1.5).

Table 3: Correlation of Land Use Variables and Energy Consumption

Land Use Variable	Correlation	EC98	JD98
Population density	Pearson Correlation	-0.132**	-0.058*
	Sig. (2-tailed)	0.000	0.019
Residential population size	Kendall's Tau	-0.024	0.001
	Sig. (2-tailed)	0.300	0.972
Distance from London	Pearson Correlation	0.179**	0.143**
	Sig. (2-tailed)	0.000	0.000
Jobs-housing balance	Pearson Correlation	0.011	0.008
	Sig. (2-tailed)	0.635	0.733
Public transport accessibility	Pearson Correlation	0.117**	0.073**
	Sig. (2-tailed)	0.000	0.003
N		1,653	1,653

EC98 (energy consumption in 1998); JD98 (journey distance 1998)

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Chi-square analysis confirms there is a relationship between distance from the highway, resident location (urban area), resident location (green belt) and neighbourhood design and energy consumption in 1998, using a significance level of 0.01. Hence we can see that a wide number of land use variables, including some that have had little consideration in the literature previously, are important in the land use/transport relationship.

Table 4: Chi-Square Tests for Land Use Variables and Energy Consumption

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Distance from Highway-EC98			
Pearson Chi-Square	91.02 [a]	15	0.000**
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 11.72.			
Resident Location (Urban Area)-EC98			
Pearson Chi-Square	13.57 [c]	4	0.009**
[c] 0 cells (0%) have expected count less than 5. The minimum expected count is 60.87.			
Resident Location (Green Belt)-EC98			
Pearson Chi-Square	12.17 [e]	4	0.016*
[e] 0 cells (0%) have expected count less than 5. The minimum expected count is 14.52.			
Streetscape Layout-EC98			

Pearson Chi-Square	29.30 [g]	10	0.001**

[g] 0 cells (0%) have expected count less than 5. The minimum expected count is 11.40.

N=1,653 in 1998

**Chi-square is significant at the 0.01 level

*Chi-square is significant at the 0.05 level

The detailed analysis of travel behaviour in Surrey, demonstrates that it is possible to understand some apparent logic behind energy consumption in the commute to work. A wide range of land use variables are significantly associated with travel behaviour. At the individual level these are traded against each other, leading to a particular travel pattern. At the aggregate level, land use and urban structure patterns are both critical structuring features behind energy consumption in the journey to work.

5.2 Socio-Economic Characteristics

Table 5 shows correlation factors between the main socio-economic variables and energy consumption in 1998. The most significant correlations in 1998 are: bedrooms, car availability, household income and respondent sex.

Table 5: Correlation of Selected Socio-Economic Variables and Energy Consumption

Socio-Economic Variable	Correlation	EC98	JD98
No. of bedrooms per household	Pearson Correlation	0.088**	0.157**
	Sig. (2-tailed)	0.000	0.000
No. of children	Pearson Correlation	-0.022	-0.012
	Sig. (2-tailed)	0.356	0.622
Car availability	Pearson Correlation	0.134*	0.095
	Sig. (2-tailed)	0.012	0.086
Household income	Pearson Correlation	0.125**	0.166**
	Sig. (2-tailed)	0.005	0.000
House value	Pearson Correlation	0.087	0.111
	Sig. (2-tailed)	0.081	0.033
Sex	Pearson Correlation	-0.068**	-0.158**
	Sig. (2-tailed)	0.004	0.000
Age	Pearson Correlation	0.004	0.007
	Sig. (2-tailed)	0.877	0.787
N		1,653	

EC98 (energy consumption in 1998); JD98 (journey distance 1998)

Chi-square analysis confirms there is a relationship between house tenure, house type, company car ownership, sex, occupation, reason for moving and surrounding mobility and energy consumption in 1998.

Further correlation analysis reveals significant relationships between a range of attitudinal factors and the journey to work (such as attitude to the environment, public transport, mobility, time, urban environment and traffic demand management are all significantly correlated with energy consumption in the journey to work).

5. THE RELATIVE CONTRIBUTIONS: THE INTERPLAY OF FACTORS

Durkheim's efforts to articulate the notion of society (way back in 1895) included the classic statement that: "*These types of behaviour and thinking are external to the individual*", i.e. the total of individual behaviour is more than the sum of parts. The integration of the disciplines of sociology and transport planning has made little progress over the last 100 years in the understanding of the sociology of travel. Multi-variate analysis is one statistical technique that is useful here, at least for exploring the working of factors in combination. It allows us to consider a number of independent variables together, at an aggregate spatial scale, and assess the contribution of these to change in a dependent variable.

Linear regression analysis (using "enter" regression) shows that the land use and socio-economic variables in the Surrey data, when considered together, explain 60% of the variation in energy consumption in 1998 (Table 7).

Table 7: Linear Regression (Enter) with Log Data (Land Use and Socio-Economic Variables and Energy Consumption, 1998)

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.77	0.60	0.46	0.65
Change Statistics				
R Square Change	F Change	df1	df2	Sig. F Change
0.60	4.39	22	65	0.000

Breaking down the regression analysis on the Surrey data tells us that:

- Land use variables explain a limited amount of the variation in energy consumption (9%) in 1998.

- Socio economic variables explain more of the variation in energy consumption in 1998 (28%).

- It is useful to add in attitudinal variables to the picture, by themselves they explain some of the variation in energy consumption in 1998 (3%).

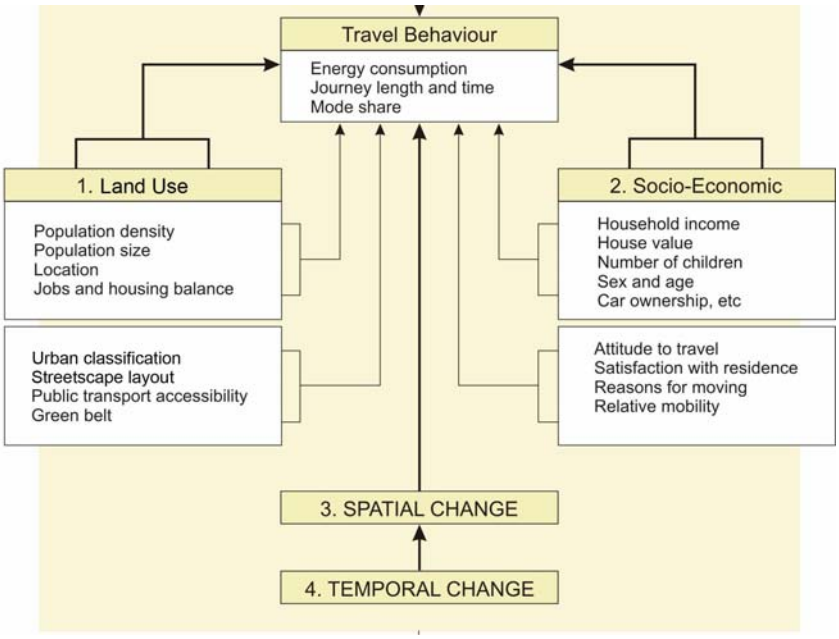
6. SYNTHESIS AND CONCLUSIONS

The importance of urban planning as a tool to help achieve sustainability in transport has historically been under estimated, possibly (1) because the disciplines of urban planning and transport planning are traditionally considered as separate issues; but also (2) because of the difficulty in providing an understanding of significant relationships between land use and travel.

The policy implications of positive findings are critical. We can move beyond the polarised debate (as represented in Table 1). Urban structure can be influenced over time and urban planning, at the strategic and local levels, becomes a very important tool in seeking to reduce energy consumption arising from travel (at least in travel associated with the journey to work). Urban structure is likely to be more significantly associated with composite travel indicators in journey to work analysis than in all trip analysis due to occupancy assumptions (commuting is associated with low private car occupancy and high public transport occupancy).

A conceptual model is now available (Figure 12) to understand the type of relationships at work. We now no longer solely think of bi-variate relationships. The density and energy consumption debate was an early (and critical) understanding of a complex field. The critique that pricing was “more important” or that attitudinal factors were not well understood were equally well founded. However it is only through multi-variate analysis that we begin to understand anything near the “full picture” of the relationships at work. But even this methodology is flawed, as a complex issue such as the rationale for travel is not well represented by statistical techniques that assess the contribution of a limited number of variables. Life is more complex.

Figure 12: A Framework for Understanding the Wide Ranging Relationships Between Land Use and Socio-Economic/Attitudinal Variables and Travel Behaviour



The previous poor understanding of the relationships between urban planning and travel has meant that the combined effects of land use and socio-economic impacts are not given sufficient weight in the search for reduced car dependence. We are beginning to understand how the disparate disciplines of urban planning and transport planning can work well together, of the benefits of integration, of likely synergies. In practice this has had large repercussions on how investment priorities - in Sustainable Community Plans, Growth Area Studies, National Transport Strategies, Regional Transport Strategies and Local Transport Plans, together with Regional Spatial Strategies, Local Development Frameworks and many local masterplans - will contribute to energy consumption targets and global sustainability aspirations.

Not surprisingly, this poor understanding of such a critical part of the urban development and travel picture means that efforts to improve the sustainability of and quality of life in our towns, cities and regions are not working to the degree we would expect. We are making major decisions on allocating new housing with little regard to future travel generation. Travel behaviour patterns have changed exponentially in recent years; yet our understanding of them, the rationale behind them, and our tools to manage travel demand have not. Current urban planning practice, particularly in suburban areas, tends to increase traffic volumes by dispersing activities and hence facilitates private car travel, and we seem to find it difficult to move away from this.

This needs to change, and this paper has attempted, through a comprehensive empirical investigation, to determine how relationships can be established between energy use in the journey to work and a comprehensive list of land use and socio-economic variables. Our conclusions would suggest that the role of urban planning in promoting sustainable transport has been historically largely underplayed. The issue discussed here is highly relevant in the context of rising house prices, future plans for increased housing supply, and the developmental agenda as presented in the Sustainable Communities Plan, the Growth Areas, Housing Market Renewal Pathfinder Areas, and in Regional Transport Strategies, Local Transport Plans and Transport Investment Funds. The urban planning "toolkit" should include consideration of at least density, settlement size, distance from urban centre and transport networks, jobs and housing balance, streetscape layout, public transport accessibility, Green Belt designation. Though not covered extensively in this paper, attitudinal factors are also important to travel behaviour and the sociological rationale for travel requires a much more thorough understanding if we are to move towards sustainability in transport planning. Urban planning, socio-economic and attitudinal characteristics between them account for up to 60% of the variation in transport energy consumption in the journey to work.

Integration requires action across a wide range of fields. New households, for example, should be located in a coordinated manner in relation to all the factors mentioned above. Perhaps a next step is to develop a composite index of urban structure that helps support sustainability in travel (based on a synthesised understanding of urban structure and travel - see Figure 13). The ad-hoc "pepperpotting" of new housing development around the edge of or in urban centres, or in rural areas, no longer remains an option. We need a strategic and coordinated approach to new housing location, together with the consideration of location of services and facilities, jobs and public transport. Through "smart growth" strategies, reduced transport energy consumption (in the journey to work at least) might be better enabled; and transport sustainability achieved in the location of major new development.

The strategic and local structure of urban structure can help us move towards reduced energy consumption in the journey to work. But it is only by understanding the complex and subtle logic behind travel that we may raise the effectiveness of our policy interventions – and actually achieve a reduction in travel by design.

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