

Is the Urbanisation of Young Adults Reducing their Driving?

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Abstract

In recent decades, in many developed countries, licence-holding, car ownership and driving, amongst young adults have declined. One of the explanations advanced for these declines is the urbanisation of young adults, their growing concentration in the denser areas of larger cities. This study analyses the changing spatial patterns and travel behaviour of young adults over time using a complete national dataset for England between 2001 and 2011. It uses a fractional response model to analyse the changing relationship between the proportion of young adults driving to work, and using public transport to get to work, and population density and settlement size. It finds that urbanisation contributed to less driving and more public transport use amongst young adults aged 16 to 34. These changes followed a change in national planning policy which encouraged higher density development in urban areas. These policies caused a re-urbanisation of the population as a whole, with the strongest trends amongst young adults. The re-urbanisation of the population was accompanied by a widening of the differentials in travel behaviour between those in the densest areas and the largest settlements (who drove less) and the rest. These findings cast new light on the controversy over 'residential self-selection'. They suggest that a change in planning policy probably caused a modest national fall in driving. Residential self-selection, which is often considered a barrier to such policies, facilitated those outcomes.

Keywords: urbanisation; young adults; urban intensification; density; car use; residential self-selection

1. Introduction

In recent decades, in many developed countries, licence-holding, car ownership and driving, amongst young adults have declined. A growing body of literature has sought to explain these trends, with respect to a range of economic, social and other causal factors (Delbosc and Currie, 2013, Aretun and Nordbakke, 2014, IFMO, 2013). A recent study commissioned by the UK Department of Transport conducted a comprehensive review of the international literature and analysed several UK datasets in order to explain the changing travel behaviour of young adults since the 1990s (Chatterjee *et al.* 2018). One element of that study analysed evidence on the changing spatial patterns of young adults, particularly their 're-urbanisation' (a shift towards the denser areas of larger cities and towns) in recent years. This article draws on that research.

Studies of re-urbanisation have generally found that much of the population growth in larger settlements has come from young adults (Rérat, 2016, 2016, Moos, 2014). A few studies have suggested that their growing concentration in larger settlements, particularly their inner districts, has contributed to their fall in licence-holding (Delbosc and Currie, 2013), car ownership and driving (Oakil *et al.*, Chen *et al.*, 2014). This study uses census data covering the population of England to compare where young adults lived in 2001 and 2011 and their use of the car for travel to work, relating those changes to settlement size and residential density. It is the first study to date that has analysed those relationships using national datasets.

The relationship between re-urbanisation and travel behaviour is controversial. Advocates of 'smart growth' (e.g. Litman, 2016) cite reductions in traffic and increases in active travel as two of several reasons for spatial planning policies that increase the density of development in urban areas. Others have argued that such policies force

reluctant people (particularly young adults) to move towards inner urban areas because of a lack of new housing elsewhere (Bolick, 2000, Evans and Unsworth, 2012).

The effectiveness of such planning policies in achieving their transport objectives depends partly upon the potentially confounding force of 'residential self-selection'. The fact that people in denser urban areas drive less and use other modes more than people in less dense suburban or rural areas is uncontested. To what extent those neighbourhood differences *cause* changes in travel behaviour, and to what extent they simply attract people with different travel preferences has been the subject of many studies. A consensus appears to suggest that a causal relationship does exist, notwithstanding the self-selection issue, although uncertainties around methodologies and data limitations remain (Cao *et al.*, 2009). This study will provide some further evidence for that debate based on analysis of national data for England.

The next section reviews the international literature and the policy context in England where significant changes in planning policy were made in 2000 (England is the largest of the UK nations with 84% of its population; planning is a devolved power in the other nations of the UK, where policies differed). Section 3 explains how the 2001 and 2011 Census data for England was analysed. Section 4 shows the changes in the spatial distribution of young adults (aged 16 to 34) and the population as a whole, and their respective changes in commuting behaviour. It presents the results of regression modelling, examining the extent to which changes in the spatial distribution of young adults explain the changes in commuting behaviour. As the only travel questions in the Census ask about commuting, Section 4 also draws on the UK National Travel Survey to provide some broader context to the analysis. Section 5 discusses the implications of the findings for the population as a whole and for young adults and draws conclusions on the broader impacts of planning policy on travel behaviour.

2. Context

Section 2.1 will begin with a brief overview of the wider literature on the relationships between spatial factors and travel behaviour, focussing on two of the principal measures of urban form: density and settlement size, followed by the contested issue of causality. Section 2.2 will then examine the more specific evidence on the changing spatial patterns and travel behaviour of young adults. Section 2.3 will briefly review the changes in planning policy that contributed to the re-urbanisation of England's population.

2.1. Density, Settlement Size and Travel Behaviour

The relationships between spatial factors and travel behaviour have generated a vast literature, which it would not be possible to fully review here; Litman and Steele (2018) and Ewing and Cervero (2010) provide two useful summaries. Much of that literature has focussed on the relationships between population densities and travel behaviour; higher densities are generally associated with reduced travel distances, less driving and more travel by other modes. Litman and Steele state that on its own the travel impacts of population density are "modest"; it is associated with a range of other factors that exert a more direct effect on people's travel behaviour such as: regional accessibility, land-use mix, parking management and transport system diversity. Gorham (2002) characterised many studies in this area as sharing "a restless drive to displace density as the proxy for all things land-use". The enduring use of density as a proxy partly reflects data availability but is also because rising population densities entail many of those other factors. For example: it is easier to provide better public

transport in denser areas; pressure on road capacity tends to increase and the need for parking constraint becomes more pressing in such areas (Melia *et al.*, 2011).

Population density is the most common proxy for *local* spatial factors; settlement size has been commonly used as a proxy for *sub-regional* spatial factors. There is a negative association between settlement size and travel by car in the UK (Headicar, 2013) and some other European countries (Limtanakool *et al.*, 2006), although the picture is less clear in the United States (Stead and Marshall, 2001). The interactions between density, settlement size and settlement structure (e.g. centralised or decentralised, monocentric or polycentric) are complex, although Næss (2012) has observed that in general the association between population density and travel behaviour is strongest within larger settlements.

Although the aggregate relationships between these factors are clear, the direction of causality is less so. If residents of dense neighbourhoods in large cities drive less than suburbanites or small town dwellers is this difference *caused* by where they live, or do people choose to live in places that facilitate their pre-existing travel preferences ('residential self-selection')? Cao *et al.* (2009) reviewed 38 empirical studies of this issue; nearly all of them found that a statistically significant influence of spatial factors remained after controlling for residential self-selection, although self-selection also explained a significant part of the observed variations. The studies used a range of methods to model various interactions between attitudes, location and travel behaviour but none of them were able to capture all the possible influences. Residential self-selection is one possibility; so is the opposite mechanism, where moving to a different neighbourhood changes people's transport attitudes (Næss, 2014a). The causal mechanisms behind gradual change over time are difficult to identify with any confidence, particularly where changing neighbourhoods are occupied by new generations whose attitudes are still evolving.

One reason for the plethora of studies on residential self-selection relates to the controversy over planning policy mentioned in the introduction. If most people retain their existing travel preferences when they move home, then urban intensification might fail to reduce motor traffic; its main impact would be to move reluctant people, determined to continue driving, into dense urban areas. Næss (2014b) argues that the confounding role of self-selection has been exaggerated and "hijacked" by advocates of "sprawl" to argue that smart growth policies will be ineffective. Section 5 will discuss the implications of the Census analysis for this unresolved question.

2.2. The Urbanisation of Young Adults

Over recent years many studies from North America (Moos, 2014, Cortright, 2014), the UK (Thomas *et al.*, 2015a) and elsewhere in Europe (Rérat, 2016, Buzar *et al.*, 2007) have documented increasing concentrations of young adults living in larger cities, particularly their inner areas. (The definition of 'young adults' varies but generally encompasses people in their 20s and early 30s: Moos, 2015.) These population movements have contributed to an overall growth in the population and population densities of these cities.

Amongst the explanations advanced for the urbanisation of young adults in recent years, expansion of higher education leading to 'studentification' of cities with universities is one clear factor (Smith *et al.*, 2014, Haase *et al.*, 2010). International migration of young adults towards large cities in developed countries is another factor (Rienzo and Vargas-Silva, 2015). The purchasing power of young adults has been declining in many developed countries, due to falling real incomes and rising housing

costs (Taylor *et al.*, 2011, Le Vine and Jones, 2012). Moos (2015) describes how this leads young adults to seek shared accommodation in central areas of cities rather than buying houses in the suburbs but it is not clear why people with declining incomes should seek to share housing in more expensive areas (see for example the comparison between rents in Inner and Outer London on: GLA, 2016). Clearly financial pressures are not the only reason; preferences are also involved, although whether and why those preferences might have changed over time has not been established.

Several studies have suggested potential societal benefits of urban densification. Ewing *et al.* (2016) found greater upward mobility in more compact metropolitan areas in the USA; Sarkar *et al.* (2017) found lower levels of obesity in denser areas of the UK, after controlling for socio-economic variables. However, the policy implication of such studies, that denser development should be supported by planning policies, has proved controversial. Evans and Unsworth (2012) argued that planning policies in England were constraining reluctant young adults to move into flats in city centres. They found that young adults living in Leeds city centre regarded their stay as temporary and intended to move outwards in the future; Howley (2009) found similar intentions in Dublin. Thomas *et al.* (2015b) found that young adults in British provincial cities have stronger preferences for inner urban living than other age groups (NAR, 2017 found similar age-related differences in the USA), so notwithstanding their longer-term intentions it seems that young adults are choosing to live in such areas. Amongst the reasons for those choices, Tallon and Bromley (2004) found mainly practical explanations, such as proximity to work or facilities; Thomas *et al.* (2015b) also found proximity to work as the most important factor for the 25 to 34 age group, who also valued proximity to restaurants, leisure and cultural facilities more highly than other age groups.

2.3. The Changing Travel Behaviour of Young Adults

A large number of studies has been undertaken in the last few years seeking to explain observed declines in driving licence holding, car ownership and car use (for example: Kuhnimhof *et al.*, 2012, Delbosc and Currie, 2014; McDonald, 2015; Brown *et al.*, 2016; Klein and Smart, 2017). From a review of these studies (Chatterjee *et al.*, 2018) it has been concluded that changes in socio-economic situation (employment, income) are the most important contributors to these trends and that changes in living situations (living arrangements, residential location), demographic situations (delayed partnering and child rearing), value orientations (car as status symbol) and costs of owning and using a car have also played a role. The contribution of other factors, such as the spread of mobile technology, is less clear.

Some of these studies have commented specifically on the possible contribution of urbanisation to declines in driving or licence-holding amongst young adults (Delbosc and Currie, 2013, Davis *et al.*, 2012). A few have included spatial factors in a quantitative analysis, although the measures are usually simple, such as an urban/rural dummy (Thakuriah *et al.*, 2010). Le Vine and Jones (2012) estimated that the increase in the proportion of UK men in their 20s living in London accounted for 7% of the fall in average mileage driven by that age group between 1995/7 and 2005/7. Oakil *et al.* (2016) analysed the interactions of spatial factors with other characteristics of young adults in the Netherlands on their travel behaviour. They found that neighbourhood density has the strongest effect on car ownership among young couples, for whom the likelihood to own a car increases most strongly with decreasing densities. That study used cross-sectional data so was not able to draw direct conclusions about change over time. We were unable to find any specific studies of the relationship between the

changing spatial distribution of young adults and their changing travel behaviour over time.

2.4. Planning Policy and the Re-urbanisation of England

Changes in planning policy in the late 1990s and early 2000s contributed to the re-urbanisation of England's population following many years of counter-urbanisation (Headicar, 2013). The most significant change occurred in 2000, when national planning guidance introduced a minimum density guideline for new housing, a target of 60% of new housing to be built on previously-developed land and a maximum parking standard of 1.5 spaces per new dwelling (DETR, 2000). These principles applied with minor modifications until they were abolished in 2012 (CLG, 2012). More recent announcements have presaged a return to planning policies encouraging higher densities (CLG, 2018). The two main intentions of DETR (2000) were to conserve undeveloped land, reflecting public opposition to greenfield building, and to support national transport objectives encouraging modal shift from driving to other modes (DETR, 1998).

Demographic trends towards smaller households and other changes, such as the expansion of higher education, were increasing demand for urban housing but the timing of the changes in the density and location of new development, shown in Figure 1 leaves little doubt that the policy change was a major contributor to the re-urbanisation that occurred after 2000 (a point reinforced by Evans and Unsworth, 2012, who compare England with Scotland, where different policies were pursued). Figure 1 reflects both encouragement of urban development and also restraint of lower density greenfield development, which might have facilitated counter-urbanisation.

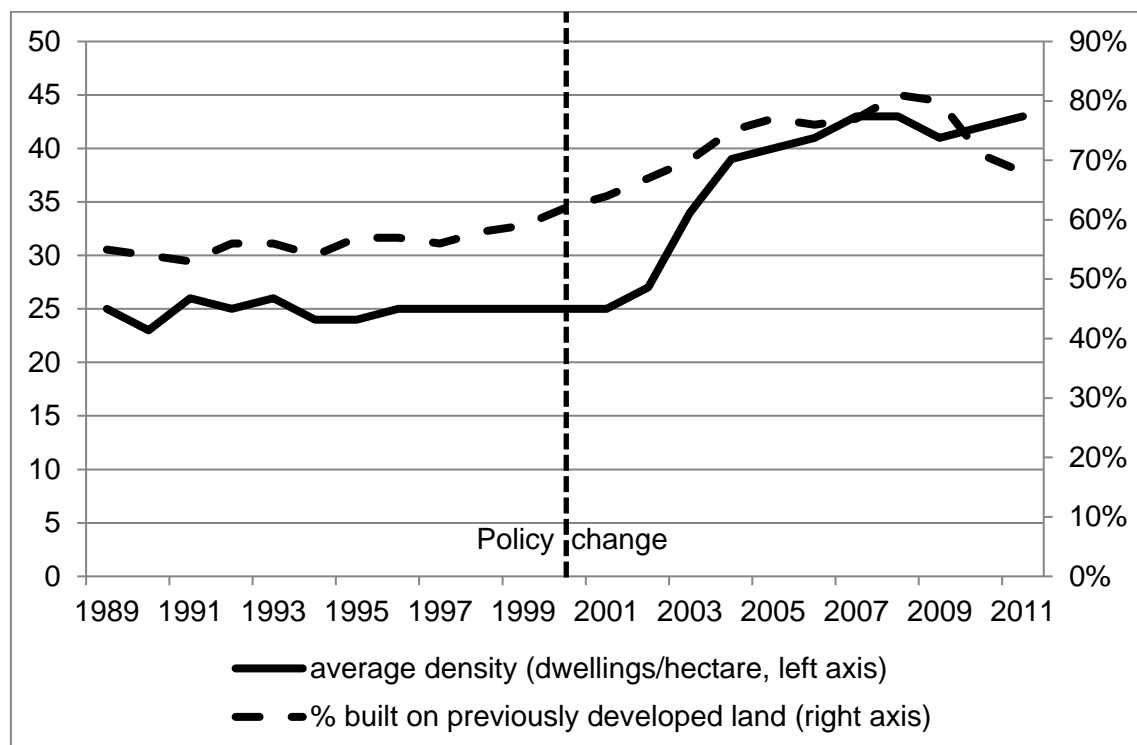


Figure 1 Average density of new housing and percentage built on previously developed land, in England 1989 – 2011 (CLG, 2016)

Melia (2016) and Headicar (2013) conclude that these policy changes made a modest contribution to reductions in commuting by car and per capita car mileage, between 2001 and 2011. Those findings were based on simple calculations using single measures of neighbourhood density and settlement types respectively. They did not explore the possible interactions between those two factors, nor did they examine those segments of the population that re-urbanised the most, as this study will do.

3. Methodology

The following analysis uses Census data for 2001 and 2011 for residents of England to analyse changes in the spatial distribution of young adults and the extent to which they drive to work. The Census was used for the analysis because it covers all geographical areas of England; it achieves a high response rate (estimated to have achieved a 94% person response rate of the population of England and Wales in 2001 and 2011); it includes questions for working people on how they usually travel to work and the location of their workplace; it also allows analysis of small geographical areas. It therefore enables precise and accurate assessments of changes over time in the spatial distribution of the English population and commuting mode shares and distances.

An alternative source of data is the National Travel Survey (NTS), which collects more detailed information about individuals and their travel. This obtains a sample of approximately 16,000 individuals each year in England based on a stratified, clustered random sample design (Lepanjuuri *et al.*, 2017). Census data was more suitable for this particular analysis for two reasons. Firstly, the smaller samples obtained each year by the NTS will mean greater uncertainty in the outcomes of interest. In 2016 there were responses from 622 individuals aged 17-20 and 1470 individuals aged 21-29 (DfT, 2017). Secondly, the NTS data available to researchers does not include specific information about the residential location of respondents. It includes the type of geographical area (London Boroughs, Metropolitan built-up areas, Other urban over 250K, etc.) but not the particular characteristics of the area where respondents live. It would not distinguish therefore between a high-density city centre location and a low density suburban location.

Publicly-available Census data tables from (www.nomisweb.co.uk) were used; we investigated the possibility of accessing the raw data but confidentiality constraints would have prevented more useful analysis. The relevant commuting modal share tables are broken down by driving to work (not including passengers) and public transport (of all kinds); no further breakdown was available of the remaining modes. Driving and public transport were the two modes of greatest interest because the largest changes in the travel behaviour of young adults in recent years have concerned these two modes (Chatterjee *et al.*, 2018). The two age groups separately analysed, 16 to 24 years of age and 25 to 34 years of age correspond to the categories used in several of the Census tables.

The unit of analysis used was Lower Layer Super Output Areas (LSOAs), which have an average of roughly 1500 residents; the boundaries of LSOAs mostly remained unchanged in 2011 compared to 2001 but there were a few exceptions. Some LSOAs were split, reflecting significant population growth; others were merged in areas where population fell. As the main aim was comparability over time, identical boundaries were used for both 2001 and 2011 by merging either one or the other as appropriate. In a few cases (147 out of 32,844 LSOAs in 2011) the boundaries were changed in a way that could not be directly compared; those data have been excluded from the analysis.

For that reason, the totals will differ slightly from aggregate national statistics published elsewhere.

Population densities were available for each LSOA. In addition, we used look-up tables provided by the UK Department for Transport that related each LSOA to seven categories of settlement size (London Boroughs, Metropolitan built-up areas, Other urban over 250K, Urban over 25K to 250K, Urban over 10K to 25K, Urban over 3K to 10K, Rural). We simplified the seven categories after observing similar proportions of driving and public transport within the following three categories: London, other cities with a population of over 250,000, and all other areas. These three categories partly serve as a proxy for public transport quality, which is better in the cities and considerably better in London.

Section 4.1 present results on the changing spatial distribution of young adults and the population as a whole between 2001 and 2011. Section 4.2 shows the changes in commuting modal shares of young adults and the working population as a whole, by quartiles of population density and separately by the three settlement categories. Section 4.3 uses regression analysis to further explore relationships between the proportion of an LSOA commuting by car/public transport and settlement type, population density, Census year and interactions between these variables. Section 4.4 sets the findings in a wider context by comparing them with trends for England from the National Travel Survey, which shows year-on-year changes for commuting and travel for all purposes.

4. Findings

4.1. Changes in the Spatial Distribution of Young Adults

Table 1 shows a shift in population towards the larger cities, which was fairly modest amongst the overall population (as observed by Headicar, 2013) but more pronounced amongst the 25 to 34 age group. The pattern amongst the 16 to 24 age group was closer to that of the overall population, partly because 66% of them live with their parents – a proportion that remained stable over the decade (ONS, 2016) as more full-time students were counterbalanced by fewer independent householders.

Table 1 Proportions of England's Population by Age and Settlement Type

	London	Other Cities >250,000	Elsewhere	Total
Age 16 – 24				
2001	17.9%	31.4%	50.7%	100.0%
2011	18.1%	32.3%	49.6%	100.0%
Change (percentage points)	+ 0.1%	+ 0.9%	-1.1%	
Age 25 – 34				
2001	21.7%	28.0%	50.3%	100.0%
2011	24.9%	29.4%	45.8%	100.0%
Change (percentage points)	+3.1%	+1.4%	-4.5%	
All Ages				

2001	16.6%	28.1%	55.3%	100.0%
2011	17.6%	28.4%	54.1%	100.0%
Change (percentage points)	+1.0%	+0.3%	-1.3%	

Table 2 illustrates the densification of urban areas over the decade. The 10.4% overall densification of (LSOAs in) England compares to a population increase of 7% over the decade. The population density of each LSOA was weighted by the number of people in each age group living there to produce age-weighted average densities for each settlement category and for England as a whole. This shows that young adults were already living in denser than average neighbourhoods in 2001 and the gap widened over the decade, particularly for the 25 to 34 age group and particularly for that group in London.

Table 2 Age-weighted¹ average population densities of LSOAs in England

	London	Other Cities >250,000	Elsewhere	All England
<u>Age 16 – 24</u>				
2001	83.0	51.5	26.9	44.7
2011	93.4	57.0	29.0	49.7
Percentage Change	+12.6%	+10.6%	+8.2%	+11.3%
<u>Age 25 – 34</u>				
2001	86.4	48.9	26.7	45.9
2011	101.2	53.9	30.2	54.8
Percentage Change	+17.2%	+10.2%	+13.1%	+19.5% ²
<u>All Ages</u>				
2001	78.4	46.2	23.7	39.1
2011	89.1	49.1	25.1	43.1
Percentage Change	+13.7%	+6.3%	+5.9%	+10.4%

4.2. Changes in Commuting Modes

Table 3 shows the proportions of workers (including home workers) in each age group that travelled to work as car drivers (excluding car passengers) or public transport (of all types), by the density of their home LSOAs and settlement type. The LSOAs were ranked into quartiles based on their population density in the relevant year (2001 or 2011).

Table 3 Main mode of travel to work as a percentage of all workers by age, density quartile and settlement type in England

¹ For each age group and LSOA (i) the formula was: $(\sum_i \text{Population}_i \times \text{Density}_i) / \sum \text{Population}$.

² The average for England is greater than the averages for each of the area types because there was also a shift in the population of that age group towards London and the other cities.

Commuting Modal Share by Year and Age	Density Quartiles				Settlement Type			Total
	Upper	3rd	2nd	Lower	London	Other cities*	Else-where	
Driving								
Age 16 – 24								
2001	25.4%	34.5%	37.3%	44.0%	21.2%	31.2%	40.4%	34.9%
2011	25.6%	39.1%	42.6%	49.8%	21.1%	35.8%	45.0%	38.8%
Change (% points)	+0.2%	+4.6%	+5.3%	+5.8%	-0.1%	+4.6%	+4.6%	+3.9%
Age 25 – 34								
2001	41.5%	58.6%	61.7%	67.5%	31.7%	58.7%	64.7%	56.1%
2011	32.2%	54.6%	58.9%	65.9%	22.0%	55.0%	61.8%	49.9%
Change (% points)	-9.4%	-4.0%	-2.8%	-1.6%	-9.7%	-3.7%	-2.9%	-6.2%
All Ages								
2001	42.1%	55.2%	58.2%	63.1%	36.8%	54.4%	60.3%	54.9%
2011	37.0%	55.6%	59.1%	63.4%	30.1%	55.8%	60.8%	53.9%
Change (% points)	-5.1%	+0.4%	+0.8%	+0.3%	-6.7%	+1.3%	+0.5%	-1.1%
Public Transport								
Age 16 – 24								
2001	31.6%	21.2%	17.8%	12.0%	39.5%	30.7%	12.7%	21.1%
2011	37.5%	22.0%	18.4%	11.8%	54.2%	28.9%	12.7%	22.9%
Change (% points)	+5.8%	+0.8%	+0.6%	-0.2%	+14.6%	-1.8%	0.0%	+1.8%
Age 25 – 34								
2001	25.5%	11.5%	8.8%	4.9%	34.9%	15.2%	5.3%	13.6%
2011	39.5%	18.6%	14.9%	8.7%	55.5%	19.3%	9.6%	23.1%
Change (% points)	+14.0%	+7.1%	+6.0%	+3.8%	+20.6%	+4.1%	+4.3%	+9.4%
All Ages								
2001	27.5%	14.7%	11.7%	6.7%	38.6%	17.3%	7.7%	14.9%
2011	32.0%	15.1%	11.9%	6.9%	44.4%	16.8%	7.9%	16.4%
Change (% points)	+4.5%	+0.4%	+0.3%	+0.2%	+5.8%	-0.5%	+0.2%	+1.5%

*** Cities > 250,000 people**

Overall, the 16 to 24 age group drove the least, in both years, followed by the 25 to 34 year olds. The differential effect of neighbourhood density (comparing the modal shares of the lower and upper quartiles) was strongest for the 25 to 34 age group, followed by the 16 to 24 year olds. The influence of settlement size was also strongest on the 25 to 34 age group; 25 to 34 year olds in London drove less than other London workers, whereas 25 to 34 year olds outside the main cities drove more than other workers in those places.

For public transport Table 3 shows the associations we would expect between modal share of commuting, age and neighbourhood density or settlement type. Both younger age groups commute slightly more by public transport than the population as a whole. All age groups commute more by public transport if they live in denser areas and larger settlements.

Table 3 highlights some notable changes that occurred between 2001 and 2011:

- The proportion of 16 – 24 year olds driving to work increased by 3.9 percentage points; the increase occurred in both settlement types outside London.
- The proportion of 25 – 34 year olds driving to work fell by 6.2 percentage points
- The proportion of all ages driving to work fell by 1.1 percentage points.
- The differential effect of neighbourhood density widened over the decade, for all age groups but particularly for the 25 to 34 year olds; those in the densest areas reduced their driving the most; the reduction in the least dense areas was much smaller.
- The fall in driving and increase in public transport use were strongest in London.

The increase in driving amongst the youngest age group was unexpected. As explained in Section 4.4 below, this only applies to commuting; the overall trend amongst this age group was towards less driving. It should be noted that the proportions shown in Table 3 are of those who were employed (including the self-employed). The employment rate amongst the youngest age group fell over the decade (from 58% to 52%), reflecting both the recession and the expansion of higher education.

Between 2001 and 2011 the 25 to 34 age group increased its commuting by public transport by 9.4 percentage points. By contrast, there was only a very small increase in public transport commuting in the general population and amongst the youngest age group. In 2001 the 16 to 24 age group made much more use of public transport for commuting than the 25 to 34s; by 2011 that difference had disappeared. The rise in public transport amongst the 25 to 34 age group was larger than the fall in car commuting (the combined 'other categories' also fell).

Much of the change in public transport use can be attributed to London, where significant improvements were made to the public transport network over the decade (Melia, 2015). When London is removed from the data (not shown) the overall increase in commuting by public transport disappears, except for the 25 to 34 age group. The effect of density is still present, although not as strong; public transport commuting still increased within the densest LSOAs. With London excluded, the rise in public transport was similar to the fall in driving amongst the 25 to 34 age group. This implies that this group was switching to public transport from all modes in London, but was only switching from driving (in smaller numbers) in other cities.

In summary, in 2011 young adults were living in denser areas and larger settlements than they were in 2001; Table 3 shows the relationship between their travel behaviour and those spatial factors was also strengthening over time. The regression analysis that follows explores those changes further.

4.3. Regression Analysis

Regression analyses were conducted to examine the extent to which the proportion of car driver commuters and public transport commuters at LSOA level were explained by spatial variables and observation year. (The Census collects only limited socio-demographic data so building a complete explanatory model of modal choice was not possible.) This was conducted for 16-24 year olds and 25-34 year olds separately for each year (2001 and 2011), resulting in four models. Results are shown in Table 4. The regression analyses were performed in Stata using the fractional logit model which entails a logit transformation of the response variable and assumes the dependent

variable follows the binomial distribution³. The following explanatory variables were used in each case:

- LSOA density
- London - dummy variable
- Other cities (> 250k) - dummy variable
- Year – dummy variable

The following interaction terms were included, to explore whether the interactions between the spatial variables were accentuating or moderating the separate impact of each:

- Density x London
- Density x other cities (> 250k)

The following interaction terms were included to assess whether the effects of each spatial factor strengthened or weakened over the decade:

- London x year
- Other cities (> 250k) x year
- Density x year

For each of the four regression models, the estimated coefficient is reported with z-value, significance level and 95% confidence interval. Also reported is the average marginal effect (dy/dx). An average marginal effect of 0.1 for a continuous variable (e.g. population density) indicates that a one unit increase predicts a +0.1 higher score on the outcome (i.e. a 10 percentage point increase in mode share) on average across the sample of observations; some examples of this will be given below. An average marginal effect of 0.1 for a categorical variable indicates that belonging to that category predicts a +0.1 higher score on the outcome (10 percentage point increase in mode share) on average across the sample of observations.

Goodness of fit statistics are included for each model after the coefficient information. The statistics are log pseudo-likelihood, AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion). They are also presented for empty models which contain no explanatory variables. The difference in log pseudo likelihood value between the empty models and full models is significant in all the models.

The regression modelling results show that density, 'London' and other 'Cities>250k' have the expected negative associations with car driving and positive associations with public transport. All of those associations are significant at the 99% confidence level. The association of 'London' is relatively stronger for 25-34 year olds than 16-24 year olds for both car driving and public transport, while the association of 'Cities>250k' is relatively stronger for 16-24 year olds than 25-34 year olds for both car driving and public transport. This emphasises that the 25 to 34 year olds are relatively less likely to use public transport in cities outside London.

³ Fractional logit models were estimated using Stata command of the form: `glm y x1 ... xK, fam(bin) link(logit) robust`. See Papke and Wooldridge (1996) for further explanation of this technique.

Table 4 Results of the four regression analyses

	Regression 1:					Regression 2:				
	Proportion of 16 – 24 year olds driving to work					Proportion of 25 – 34 year olds driving to work				
	Coefficient	dy/dx	Std. Err.	z	P> z	Coefficient	dy/dx	Std. Err.	z	P> z
Density	-0.00792	-0.00178	0.00012	-64.73	0.000	-0.00656	-0.00149	0.00012	-54.94	0.000
London	-0.36868	-0.08080	0.01465	-25.17	0.000	-0.64514	-0.15392	0.01463	-44.11	0.000
Othercities	-0.29726	-0.06590	0.00873	-34.06	0.000	-0.11998	-0.02728	0.00898	-13.36	0.000
Densityyear	-0.00115	-0.00026	0.00014	-8.34	0.000	-0.00142	-0.00032	0.00014	-10.36	0.000
DensityLondon	-0.00345	-0.00077	0.00018	-19.32	0.000	-0.00376	-0.00085	0.00017	-22.14	0.000
Densityothercities	0.00192	0.00043	0.00015	12.57	0.000	0.00015	0.00003	0.00015	0.98	0.329
Year 2011	0.22788	0.05127	0.00556	41.00	0.000	-0.02441	-0.00554	0.00603	-4.05	0.000
Londonyear	-0.05219	-0.01168	0.01535	-3.40	0.001	-0.17249	-0.03976	0.01566	-11.01	0.000
Othercitiesyear	0.09658	0.02184	0.00872	11.07	0.000	0.05316	0.01202	0.00911	5.84	0.000
Constant	-0.15267		0.00440	-34.68	0.000	0.78490		0.00455	172.51	0.000

	Regression 1:		Regression 2:	
	Full model	Empty model	Full model	Empty model
Log pseudo-likelihood	-27772.63435	-29344.72096	-22000.08009	-25089.1205
AIC	0.8632571	0.911825	0.6838933	0.7795958
BIC	-709290.5	-706246	-707860.6	-701782.1

	Regression 3:					Regression 4:				
	Proportion of 16 – 24 year olds using public transport					Proportion of 25 – 34 year olds using public transport				
	Coefficient	dy/dx	Std. Err.	z	P> z	Coefficient	dy/dx	Std. Err.	z	P> z
Density	0.00599	0.00092	0.00019	31.81	0.000	0.00947	0.00103	0.00021	44.83	0.000
London	1.02511	0.19095	0.01902	53.88	0.000	1.65856	0.25563	0.02066	80.27	0.000
Othercities	0.91232	0.14925	0.01239	73.64	0.000	0.94445	0.11020	0.01377	68.61	0.000
Densityyear	-0.00023	-0.00003	0.00020	-1.13	0.256	-0.00239	-0.00026	0.00021	-11.20	0.000
DensityLondon	0.00191	0.00029	0.00022	8.81	0.000	-0.00083	-0.00009	0.00022	-3.75	0.000
Densityothercities	-0.00264	-0.00041	0.00022	-11.85	0.000	-0.00340	-0.00037	0.00023	-14.48	0.000
Year 2011	-0.01245	-0.00192	0.00946	-1.32	0.188	0.62279	0.06829	0.01120	55.59	0.000
Londonyear	0.55384	0.09677	0.01907	29.04	0.000	0.35887	0.04317	0.02053	17.48	0.000
Othercitiesyear	-0.08294	-0.01263	0.01250	-6.64	0.000	-0.27207	-0.02842	0.01390	-19.58	0.000
Constant	-2.07162		0.00771	-268.53	0.000	-3.12835		0.00908	-344.44	0.000

	Regression 3		Regression 4	
	Full model	Empty model	Full model	Empty model
Log pseudo-likelihood	-22000.08009	-25089.1205	-17007.42142	-20850.54057
AIC	0.6838933	0.7795958	0.5287623	0.6478954
BIC	-707860.6	-701782.1	-708856.8	-701270.2

Number of observations in each of the four regressions: 64367

The regression outputs in Table 4 also show the following:

- **Density** - the negative association between density and driving strengthened over the decade for both age groups. For example, the dy/dx measure for density in Regression 1 indicates that an additional 10 people per hectare in 2001 was predicted to lead to a reduction of 1.8 percentage points in the proportion driving to work. By 2011 an additional 10 people per hectare was predicted to lead to a reduction of 2.0 percentage points in the proportion driving to work (obtained by adding dy/dx *Density* and dy/dx *Densityyear*). By contrast the positive association between density and commuting by public transport remained stable for the 16 to 24 age group but weakened for the 25 to 34 age group, between 2001 and 2011.
- **Settlement type** - living in London was associated with less driving to work and more use of public transport and the associations strengthened over the decade, for both of the age groups and for both modes of transport. Living in other cities was also associated with less driving to work and more use of public transport (compared to 'elsewhere') but this association weakened over the decade.
- **Interactions between density and settlement type** - the interaction between density and London *accentuated* the separate negative association between each and driving, for both age groups. In other words, the density association was stronger in London than it was elsewhere. The same was also true of the interaction between density and London and its association with public transport for the 16 to 24 age group. However, the interaction between density and London *moderated* the separate positive association of each with commuting by public transport for the 25 to 34 age group. In other words, there was some overlap between the London association and the density association: the total association was weaker than the two separate associations would suggest. The interaction between density and other cities *moderated* the negative associations with driving for both age groups and the positive associations with public transport for the 25 to 34 age group only (the interaction was not statistically significant for the 16 to 24 age group). In other words, there was some overlap between the settlement type association and the density association: the total association was weaker than the two separate associations would suggest.
- **Time trends** - the year dummy in Regression 1 indicates a 5.1 percentage point increase in the proportion of 16 to 24 year olds driving to work by 2011 (after accounting for other factors). A model with only the year dummy indicates there was a 4.2 percentage point increase in the proportion driving. In this second model the year dummy acts as a proxy for all factors that changed over the decade – including the spatial factors. This suggests that the spatial influences identified above *moderated slightly* the increase in driving (which occurred for other reasons). The year dummy for Regression 2 indicates a 0.6 percentage point decrease in the proportion of 25 to 34 year olds driving in 2011. A model with only the year dummy indicates there was a 2.6 percentage point decrease in the proportion driving. This suggests that the spatial influences identified above *explain much of the decreased tendency for 25-34 year olds to drive to work in 2011*. In Regression 3 the year dummy coefficient for 2011 is not statistically significant. A model only with the year dummy indicates there was a 1.9 percentage point increase in the proportion of 16 to 24 year olds using public transport by 2011. This suggests that the spatial influences identified above *explain all of the increased tendency for 16-24 year olds to use public transport* (subject to a general caveat about the limited range of variables in the model; the spatial factors are likely to be acting as proxies for other factors in some cases). The year dummy for Regression 4 indicates a 6.8 percentage point

increase in the proportion of 25 to 34 year olds using public transport in 2011. A model with only the year dummy indicates there was a 6.2 percentage point increase in using public transport. This suggests that the spatial influences identified above *moderated slightly* the increase in public transport (which occurred for other reasons). This is probably because of greater modal shift to other modes, such as walking, in larger settlements and denser areas.

The indicators for goodness of fit show that adding the nine explanatory variables caused a large improvement in the fit of the models compared to the 'empty models'. It can also be noted that the z values of the above coefficients indicated strong relationships; nearly all were significant at the 99% confidence level.

4.4. Comparison with the National Travel Survey (NTS)

Table 3 above showed an increase in driving to work by people aged 16 to 24 between the years 2001 and 2011, which was unexpected. To provide some broader context to this finding, a comparison was made with the NTS, which collects data for commuting and for other purposes. Whereas the Census asks about usual mode of travel to work, the NTS collects seven-day travel diaries so the two are not directly comparable. As the NTS sample sizes are considerably smaller than the Census some of the year-on-year fluctuation will be due to sampling error but the annual figures will also reflect the influence of factors which fluctuate in the short-term (e.g. fuel prices).

Figure 2 shows the proportion of trips as car driver made by the 16 to 24 age group for the period 1995 to 2014. This shows a longer-term trend towards less driving amongst that age group. (For the 25 to 34 age group, not shown, the NTS shows a stronger downward trend in driving for work and other purposes, consistent with the Census analysis.)

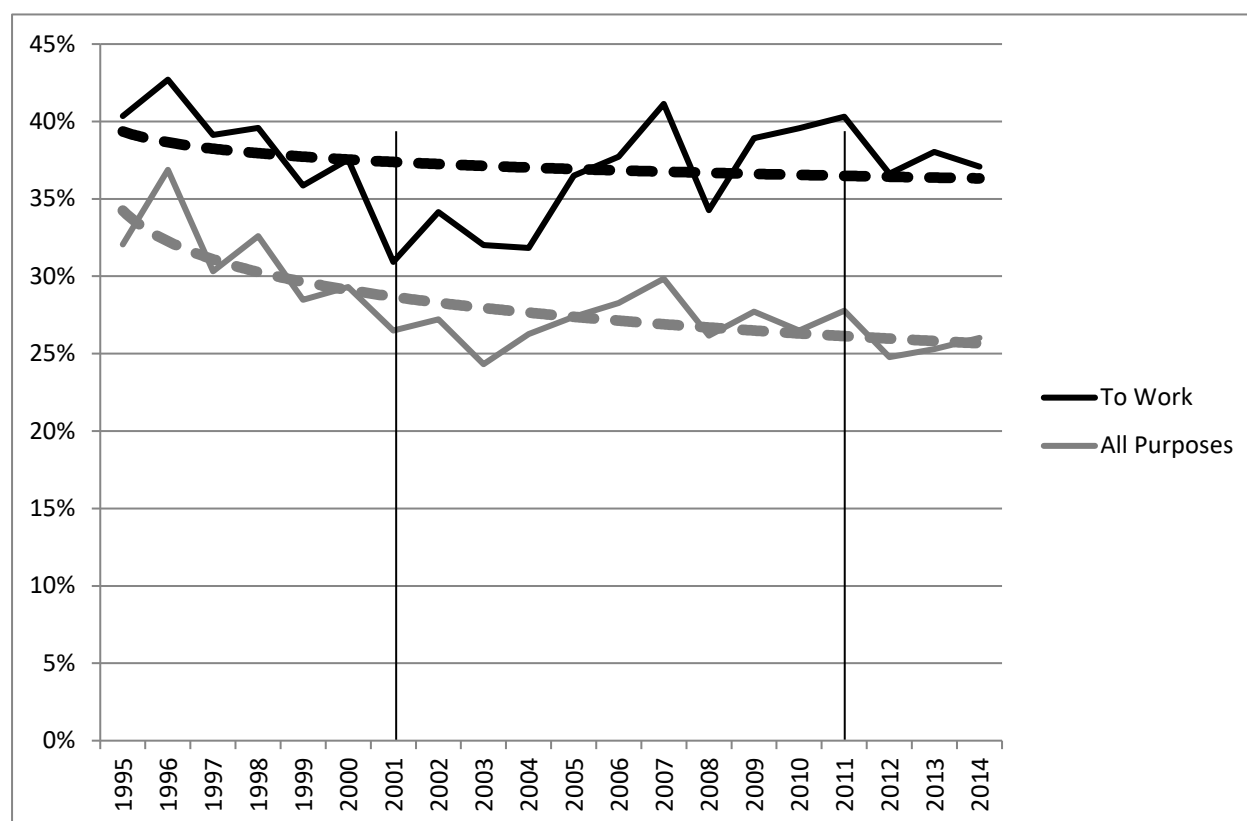


Figure 2: Proportion of Trips by 16 – 24 year olds as Car Driver from the NTS (dashed lines are logarithmic trendlines)

The 'All Purposes' line shows a fluctuation around a downward trend, with the rate of decrease slowing over time. The 'Driving to Work' line shows a weaker downward trend, levelling out in more recent years. The two curves have been diverging over time, suggesting less driving, but *relatively* more driving to *work* amongst the shrinking proportion of the 16 to 24 age group who were in employment. The measure of commuting modal share shown in Figure 2 (proportion of trips reported via seven-day diary) is not the same as the Census ('usual mode of travel') but the individual year data shows that the modal share of driving to work increased (by 9 percentage points) between 2001 and 2011, as it did in the Census (by 4 percentage points). Some possible reasons for these diverging findings will be discussed below.

The analysis in this section has looked purely at the proportion of trips by each mode. The trend in driving *distances* for all purposes (from the NTS) over the decade was also downwards, whereas commuting journeys grew longer, due at least in part to structural changes in the labour market, particularly affecting part-time workers (Le Vine *et al.*, 2016). The Census analysis showed similar trends of increasing distances for the different age groups of workers.

5. Discussion and Conclusions

5.1. Re-urbanisation and the Changing Travel Patterns of Young Adults

The findings support the hypothesis that between 2001 and 2011 re-urbanisation contributed to reduced rates of driving and increased use of public transport by the working population as a whole and particularly amongst the 25 to 34 age group. Spatial factors explain a large proportion of the variation in commuting behaviour within the two younger age groups; young adults in denser areas and in larger settlements are less likely to drive to work and more likely to commute by public transport.

The apparent increase in commuting by car amongst the 16 to 24 age group between 2001 and 2011 was unexpected. Figure 2 suggests that it was at least partly due to (unexplained) short-term fluctuations in the specific years of the Census. The medium-term trend in car driving for all purposes revealed by the NTS was one of gentle decline. The divergence between the trends for travel in general and for commuting will partly reflect the fall in the proportion of that age group in employment (so the share of commuting in their total travel was declining). Other people in this age group would be either in education, unemployed or economically inactive, all of which tend to be associated with lower levels of driving. Across the population as a whole, higher educational attainment is associated with lower levels of driving to work, after controlling for income and a wide range of spatial and socio-demographic variables (Clark *et al.*, 2016). Rising participation in higher education might therefore remove from the young workforce more of the social and attitudinal groups likely to choose non-car travel.

The regression analysis showed that two spatial factors (density and settlement type) explained most of the change between 2001 and 2011 in driving to work of 25-34 year olds at LSOA level. These factors did not explain the change in public transport use of this age group, however. This implies that other factors were responsible for the changes in public transport use. In contrast, spatial factors did not explain the change in driving to work amongst the 16-24 age group (possibly because of the change in the character of those

working in this age group as explained above). However, it did explain most of the increase in public transport commuting amongst that group.

It should be understood that population density and settlement size act partly as a proxy for a wider range of spatial factors that directly influence individual travel decisions, such as: distance to relevant destinations and proximity to public transport. There is also likely to be some correlation with non-spatial factors such as presence of children in the household, which is usually associated with lower density suburban areas.

The analysis shows that young adults urbanised between 2001 and 2011; in 2011 they were more likely to live in larger settlements and denser neighbourhoods compared to 2001. This was more the case for 25-34 year olds than for 16-24 year olds and the rest of the working population. The literature briefly reviewed in Section 2.2 provides some insights into the factors behind these changes.

At the same time, the relationship between spatial characteristics (density and London) and travel behaviour strengthened amongst those age groups. The difference between the commuting mode choices of young adults in London, and in dense areas of other large cities, compared to their peers living elsewhere has widened. Different hypotheses can be put forward for this, including improvements to public transport in large cities, employment in large cities increasingly located in areas better served by public transport and more constrained for car commuting, rising housing costs making car ownership too expensive for young adults and growing constraints on parking or road capacity making car ownership or use inconvenient.

The large increase in the public transport share for commuting amongst the 25 to 34 age group from 14% to 23% (and the small increase in the general population from 15% to 16%) was particularly concentrated in London where it increased from 35% to 56%. Again, there are multiple possible reasons for this. In 2000 London elected a city-wide Mayor, exercising wide transport powers, for the first time. The Mayor and other leaders of London interviewed by Melia (2015) explained that accommodating the city's increasing population by increasing road capacity would have been impossible. Instead, they decided to improve public transport, increase subsidies to buses in particular and introduce a congestion charge in central London. Several Inner London boroughs also reduced the availability of parking for residents. It is possible that there have also been changes in the socio-demographic and lifestyle characteristics of young people in London. However, similar changes would have been expected for young people in other large urban areas but they have not seen the same scale of increase in public transport use.

In summary, the range of variables included in this analysis is limited, so the causal explanations advanced here can only be tentative. It would be interesting for analysis to be conducted using NTS data to look at changes in driving of young people over time and how this relates to changes in socio-demographics characteristics. Nevertheless, the analysis reported in this paper provides evidence of a strong association between spatial factors and the commuting mode choices of young adults. It suggests that the nature of that relationship has been strengthening over time for 25-34 year olds, the group which has seen largest reductions in driving to work. The trends are stronger for that group than for the 16 to 24 year-olds, whose participation in the labour force has been declining.

5.2. Residential Self-Selection and the Impact of Planning Policy

A critical contested question in the literature, and for policy makers, is whether planning policies that constrain the sprawl of cities and encourage densification reduce (or constrain increases in) rates of driving and encourage travel by other modes. As discussed in Section

2.4 and illustrated in Figure 1, there is little doubt that planning policies in England (as well as socio-economic factors) were an important cause of the re-urbanisation that occurred over the decade of this study. This coincided with a modest shift towards less driving to work and more use of public transport amongst the population as a whole (shown in Table 3), following several decades of increasing car use. Although causality cannot be proven, this analysis supports the argument that changes in planning policy did indeed make a contribution to that modal shift, as measured by the Census usual mode of driving to work.

Where a policy change causes a shift of population from areas where people drive more (low density suburbs) towards areas where people drive less (dense urban areas) that policy change will also cause a reduction in driving (compared to a counterfactual of no policy change) *unless* there is some countervailing mechanism whereby the policy simultaneously causes unintended increases in driving.

Residential self-selection is one possible countervailing mechanism, one which is often advanced as a reason why such policies might not succeed. Table 5 sets out a ‘thought experiment’ to illustrate this analysis.

Possible Outcomes	Indicators of Success or Failure
1. Policy achieves modal shift objectives:	Modal share of driving falls. Travel behaviour differential between dense areas and less dense areas widens or remains stable.
2. Policy fails (due to residential self-selection):	Modal share of driving rises. Travel behaviour differential between dense areas and less dense areas narrows.

Table 5 Potential outcomes of a planning policy that causes re-urbanisation

Table 5 starts from the premise that planning policy has achieved its direct objective to increase the proportion of the population living in dense urban areas, where there is less driving. The first row illustrates the expected outcomes of the policy if it were to achieve its travel objectives and the second row illustrates what would happen if residential self-selection were to frustrate those objectives – because people were reluctantly moving towards the centre of cities, whilst trying to maintain their preferred (suburban) travel behaviour.

As shown in Table 3, in England between 2001 and 2011 the modal share for driving to work fell slightly (following several decades of increases). The modal share differential (for driving to work) between the densest and the least dense areas widened by over 5 percentage points for the total population and 8 percentage points for the 25 to 34 age group. This is consistent with a policy that achieved its modal shift objective. Can we conclude, therefore that the policy caused modal shift? There are three possible hypotheses:

- 1) The policy contributed to modal shift.
- 2) The travel behaviour differential would have widened even more rapidly without the policy change (for reasons other than residential self-selection).
- 3) Rates of driving would have fallen (or risen less rapidly) in the low density density suburbs without the policy change and this difference would have been equal to, or greater than, the reductions caused by the policy in the denser urban areas.

Although this analysis cannot rule out hypotheses 2) and 3), the scale of the widening differentials between the dense urban areas and the rest suggests that they are much less plausible than the simple explanation that the policy change contributed to modal shift. The reasons why urbanisation would widen the travel behaviour differential are fairly clear. With more people living in dense areas road capacity and parking constraints are likely to

discourage driving and it also becomes easier to improve access to, and frequency of, public transport. In London where these trends have been strongest, the authorities have noted that road capacity constraints have been a significant factor in the shift away from driving (TfL, 2011). Improvements in London's public transport systems were also more extensive than elsewhere in the country over this time period (Melia, 2015).

In most of the literature on the land use-transport relationship residential self-selection is treated as a potential barrier to planning policies that aim to reduce car driving. The evidence presented in this paper illustrates a different possibility. In England during the early 2000s three factors combined to support those policy aims: planning policies which concentrated new housing in denser urban areas, the preferences of people aged 25 to 34 for inner urban living (reported by Thomas *et al.*, 2015b) and the changing travel behaviour of that age group, so planning policy 'worked with the grain' of those trends and preferences; residential self-selection facilitated rather than hindered the process.

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