Transportation Research Part A 89 (2016) 89–105

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Changes to commute mode: The role of life events, spatial context and environmental attitude

Ben Clark *, Kiron Chatterjee, Steve Melia

Centre for Transport & Society, Department of Geography and Environmental Management, University of the West of England, Bristol BS16 1QY, UK

ARTICLE INFO

Article history:
Received 7 May 2015
Received in revised form 9 February 2016
Accepted 5 May 2016

Keywords:
Commuting
Life events
Attitude
Spatial context
Longitudinal
Panel data

ABSTRACT

It has been suggested that commuting behaviours become habitual and that changes to commute mode are more likely at the time of major life events. However, evidence to support this has so far been limited to analyses of small-scale samples. To address this evidence gap, we use two waves of panel data from the UK Household Longitudinal Study (2009/10 and 2010/11) to identify and explain the prevalence of individual change in commute mode from year to year amongst a representative sample of the English working population (n = 15,200). One third of those that cycle or get the bus to work, and one quarter of those that walk to work, are shown to change commuting mode by the following year. Car commuting is more stable, with only one in ten car commuters changing mode by the following year. Commute mode changes are found to be primarily driven by alterations to the distance to work which occur in association with changing job or moving home. Switching to non-car commuting becomes much more likely (9.2 times) as the distance to work drops below three miles. High quality public transport links to employment centres are shown to encourage switches away from car commuting and mixed land uses are shown to encourage switches to active commuting (walking and cycling). Switches away from car commuting are found to be more likely (1.3 times) for those with a pro-environmental attitude. The attitude orientation is shown to precede the behaviour change, demonstrating evidence of 'cause and effect'. Overall, the study shows that changes in commuting behaviour are strongly influenced by life events, spatial context and environmental attitude.

1. Introduction

Transport policies in urban areas are often designed to encourage people to adopt non-car transport in order to reduce pressure on scarce road space and to improve the quality of the urban environment. Policies are particularly targeted towards managing *commuting* behaviours, as it is during the morning and evening peak commuting times that transport networks are under the most pressure. However, it has been shown that daily car commuting becomes habitual and is repeated with little or no conscious consideration of alternatives (Gardner, 2009). For this reason it is a challenge to encourage people to adopt new commuting behaviours, even if improvements are made to public transport services or to walking and cycling environments. Whilst there has been substantial research into the factors associated with commuting by different transport modes, there has been less attention given to identifying the factors associated with *changes* to commute mode, the focus of

* Corresponding author.
E-mail addresses: Ben4.Clark@uwe.ac.uk (B. Clark), Kiron.Chatterjee@uwe.ac.uk (K. Chatterjee), Steve.Melia@uwe.ac.uk (S. Melia).

http://dx.doi.org/10.1016/j.tra.2016.05.005
0965-8564/

this paper. It is important to understand what prompts people to change commute mode if effective policies and measures are to be developed to influence commuting behaviours.

The 'habit-discontinuity hypothesis' posits that habitual behaviour may become weakened when interrupted by a contextual change (Verplanken et al., 2008). It can be expected that people are more likely to change commuting mode if there is a contextual change to their life situation – for example through a *life event* like moving home. This paper examines how the likelihood of changing commute mode is influenced by life events, while also accounting for socio-demographics, transport resources, spatial context (urban form and transport supply) and environmental attitude. The paper begins with a review of existing knowledge on the determinants of commute mode decisions which clarifies the knowledge gaps and intended contributions of our study. We then introduce the data and analytical framework used to analyse changes in commuting mode. The results are presented before the paper finishes with a discussion of the implications for research and policy.

2. Literature review

The main focus of the review is on *longitudinal studies* that have investigated factors associated with *changes* to commute mode. However, to provide context we start by discussing mode choice models estimated from cross-sectional data.

2.1. Cross-sectional evidence on determinants of commute mode choice

The usual assumption made in mode choice models is that commuters evaluate the attributes of transport modes available to them and choose the option that provides the greatest overall utility (Ortúzar and Willumsen, 2011). Mode choice models include, as explanatory variables, attributes of transport modes (usually travel times and costs) and socio-demographic characteristics of individuals to recognise that tendencies to use modes may vary in the population. After including modal attributes and trip maker characteristics, there are usually unexplained preferences for particular modes and these are represented by alternative specific constants in the utility function. More recent work has sought to improve explanation of differences in individual mode preferences by incorporating *subjective variables* relating to perceptions and attitudes in mode choice models. For example, Johansson et al. (2006) found that attitudes towards flexibility and comfort, as well as pro-environmental inclination, influenced commute mode choices, in addition to instrumental modal attributes like commute time and cost.

Urban planners have an interest in how urban form influences travel behaviour and have also looked more broadly at the influence of the built environment on commute mode choices. They have shown that commute mode choice can also be influenced by land use density, mix and design (Cervero, 2002). The question has been raised, however, as to whether the built environment has a *causal* influence on commute mode choices or whether people *self-select* into residential neighbourhoods that suit their pre-existing commute mode preference. Studies of 'residential self-selection' have tended to confirm that the built environment does have an independent effect, after controlling for measures of attitudinal self-selection (e.g. Schwanen and Mokhtarian, 2005).

2.2. Longitudinal evidence on determinants of change to commute mode choice

Data sets which include repeated observations of the commuting behaviour of the same individuals over time are scarce and therefore evidence on determinants of *changes* to commute mode is limited. Panter et al. (2013) obtained repeated observations, 12 months apart, of the commuting behaviour of 655 workers in Cambridge. They tested the impact of baseline measures of personal and household characteristics, built environment characteristics (objective and subjective) and attitudes towards car use. They found uptake of walking to work was associated with not having children, perception of convenient public transport and lack of free workplace parking. Uptake of cycling to work was predicted by perception of convenient cycle routes and more frequent bus services. The study did not test the influence of *change* variables for events occurring in people's lives or any changes in external situational factors.

2.2.1. The influence of life events

Dargay and Hanly (2007) showed through a descriptive analysis of the British Household Panel Survey ($n \sim 5000$), that 17.6% of commuters changed mode between years. This figure increased to 28.1% for those who moved home, 32.7% for those that changed employer and 44.6% for those that changed both home and employer.

Oakil et al. (2011) conducted a multiple regression analysis of the relationship between a range of life events and commute mode changes. They used data from a retrospective survey capturing 21 year life histories of nearly 200 respondents in the Utrecht region (Netherlands). Switches from commuting by car were associated with changing to part time work, changing employer, and separation from a partner (one year before the commute mode change). Switches to commuting by car were associated with birth of the first child, changing employer, and separation from a partner (one year before the commute mode change). After controlling for other factors, residential relocations were not significant. Data limitations prevented an examination of the role of spatial context (i.e. urban form and transport supply).

Verplanken et al. (2008) studied the effect of residential relocations on the commuting mode of 433 university employees. They found that employees who had moved within the last year and were environmentally concerned used the car less frequently than environmentally concerned commuters who had not moved within the last year. Their interpretation of this is that residential moves allow environmentally concerned individuals to adjust their commuting behaviour in line with their values.

Qualitative research with home movers has shown variation in the extent to which they plan travel, including the journey to work, during the moving process. Most movers are not fully aware of transport opportunities until after the move (Jones and Ogilvie, 2012). It is argued therefore that the notion of residential self-selection is too deterministic.

However, there is evidence that commuting requirements are considered in home or job moves. Van Ommeren et al. (1997) found from an analysis of Dutch data (called Telepanel, collected in 1992–3) that every additional 10 km of commuting distance decreased the expected duration of the current job and current residence by more than two years. Clark et al. (2003) found (using Puget Sound Transportation Panel data over the years 1989–1997) a critical value of eight kilometers as the commute distance beyond which the likelihood of decreasing commute distance (by moving home or changing job) increases strongly. This emphasises that home and job changes are not strictly exogenous but may be motivated by a wish to reduce time spent commuting.

2.2.2. Changes to the transport system

The previously reported studies have considered the relationship between life events and changes to commuting mode. Changes to the transport system would also be expected to act as contextual changes that influence commute mode choices. There are surprisingly few studies that have directly analysed this. Bradley (1997) investigated the effect on commute mode choice of a new rail commuter line in the Netherlands. Before and after panel data for 475 commuters collected a year apart showed that 119 of the 475 car and bus commuters switched to the train. Heinen et al. (2015) investigated the change in commute mode of 470 workers in Cambridge after introduction of a guided busway with a path for walking and cycling in 2011. Seven-day travel to work diaries were obtained in 2009 and 2012. The diaries recorded the number of commute trips made by different modes. While net changes in mode share were small, they found that those living close to the new infrastructure were more likely to increase walking and cycling mode share and reduce car mode share (with no significant effect on bus use).

2.2.3. Changes to transport costs

The introduction of financial incentives or disincentives can also be expected to influence commute mode. In the 13-week field trial 'Spitsmijden', conducted in the Netherlands, 341 participants were provided with daily rewards to encourage them to avoid driving in the morning rush-hour (Ben-Elia and Ettema, 2011). To receive a reward they could drive earlier or later or avoid driving (changing mode or working from home). The results showed that about one quarter of participants avoided driving during the trial. A positive attitude towards cycling and experience of using other modes was associated with greater likelihood of not driving. However, rush hour driving returned to pre-trial levels after the incentives were withdrawn.

2.2.4. Information and marketing interventions

Voluntary Travel Behaviour Change (VTBC) measures encourage travellers to change the way they travel through information and marketing. Thørgersen (2006) evaluated the impact of a free one month public transport card targeted at commuters who owned a car in Copenhagen. An intervention group (n = 373) received a free public transport travel card and a control group (n = 224) did not receive the card. The study showed that it was only those in the intervention group who had moved home or changed workplace within the last three months that increased their public transport use. This highlights the potentially critical role of life events in facilitating changes to commute behaviour. Hence, while changes to the external transport context through various means have been shown to influence commuting behaviour, it appears likely that commuters are more likely to respond to these if they are also experiencing life events.

3. Knowledge gaps and data opportunity

The review provides evidence that commute mode changes are more likely for those experiencing life events. However, previous studies on life events and commute mode changes have had to rely on non-representative, small sample sizes and/or have focussed on a single or limited range of life events. Data limitations have also restricted understanding of the role of contextual factors (socio-demographics, transport resources, spatial context, attitudes) in influencing whether life events increase the likelihood of commute mode changes and the types of change. Thus the analysis presented in the next sections sought to address three research questions:

1. How many people change commute mode from one year to the next?
2. To what extent are commute mode changes associated with life events? and
3. How are socio-demographic characteristics, attitudes and (changes to) spatial context associated with commute mode changes?

The availability of two wave panel data from the UK Household Longitudinal Study (UKHLS) (established in 2009) provided an opportunity to address these questions in a single analytical framework. The breadth of information collected in UKHLS meant that a comprehensive range of life events could be considered. The UKHLS also captures distance to work and how this changes from year to year. Previous studies of life events and commute mode changes have not explicitly accounted for this. Debates around residential self-selection have been concerned with the extent to which observed relationships between commute mode choices and urban form are indirect proxies for lifestyle preferences. By linking to a number of external data sets, it has been possible to represent the spatial context in which people live and how this changes in association with residential relocations. The UKHLS also includes a measure of environmental attitude. This enabled an examination of the temporal relationship between environmental attitude and commute mode, to explicate whether environmental attitude in the base year influences whether a commute mode change occurs by the following year.

4. Theoretical framework

Most theories of consumer behaviour assume that behaviour is a result of a deliberative process (see Van Acker et al. (2010) for a review of behavioural theories that have been applied to travel behaviour research). For example, the widely used Theory of Planned Behaviour (Ajzen, 1991) posits that behavioural intention is formed by a combination of attitudes, subjective norm and perceived behavioural control with behavioural intention determining behaviour, mediated by actual control. But there has been increasing recognition that some behaviours such as travel behaviours, are habitual and are not deliberated over each time they are performed. Verplanken et al. (1997) suggested that those with strong habits automatically enact a behaviour to achieve their goals, while those with weak habits refer to situational cues and seek information to support their choice making. Ouellette and Wood (1998) showed that when behaviours are performed in unstable circumstances, behaviour is deliberative and determined by behavioural intentions, but when behaviours are well-practiced, intentions are less influential and habits dominate. Verplanken et al. (2008, p. 122) have introduced the 'habit discontinuity hypothesis' that posits that context change (where context encompasses the environment where behaviour takes place, including physical, spatial, social, and time cues) 'provides a window within which behaviour may have a higher likelihood to be (re)considered'.

Lanzendorf's (2003) dynamic Mobility Biography framework has also been used to examine how travel behaviours develop over the course of one's life in relation to changes occurring in three related life domains: the lifestyle domain (e.g. family formation, employment type), the accessibility domain (e.g. the relative locations of home and employment) and the mobility domain (e.g. car availability). In the Mobility Biographies framework, life events occurring in one domain, such as a change in employment, can be expected to potentially lead to changes in other domains, for example a change in car ownership (e.g. Clark et al., 2015) or commuting mode.

A generalised conceptual model of the relationship between life events and travel behaviour change is shown in Fig. 1. The hypothesis made is that turning points in travel behaviour, such as a change in commute mode, are triggered by a

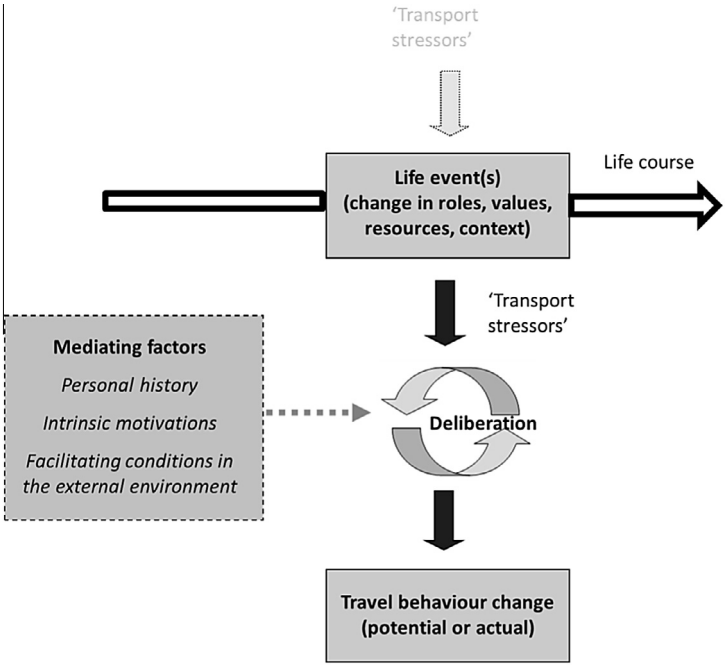

Fig. 1. General conceptual model for explaining turning points in travel behaviour.

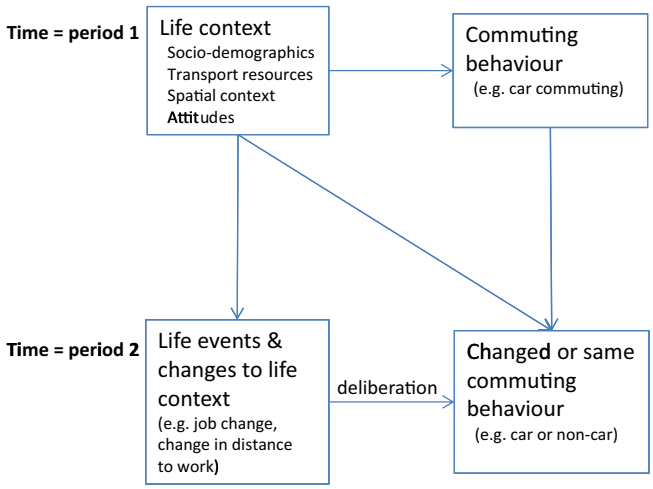

Fig. 2. Analytical framework for studying how life events influence commuting behaviour.

contextual change (a life event for the purposes of our research but this could also be a change to the transport system as discussed in the literature review). Life events can alter the roles that people perform within their family and social networks, alter the values people hold, alter the resources available for travel and alter the context for travel. These can create 'transport stressors', which entail discrepancies between the current transport circumstances and a desirable alternative (Miller, 2005), potentially triggering deliberation over travel behaviour. Life events can also change the travel mode alternatives that are available, the characteristics of travel that are considered salient and hence attitudes towards travel modes (Van der Waerden et al., 2003). Drawing on the work of Giele and Elder (1998), and later developed by Chatterjee et al. (2013), three types of mediating factor are hypothesised to influence travel behaviour outcomes following a contextual change. These are personal history (for example, experience in using travel modes), intrinsic motivations (for example, saving money or improving health) and facilitating conditions (for example, public transport availability).

The analysis of commute mode changes using two wave panel data operationalised a simplified version of this framework, as shown in Fig. 2. It is assumed that in stable circumstances, commuting behaviour becomes established in line with an individual's life context, including their socio-demographic circumstances, transport resources, spatial context and attitudes (at time period one). After experiencing a life event, deliberation over commuting behaviour will be made based on the new contextual circumstances (a combination of the circumstances that existed prior to the life event and any changes to these). Commuting behaviour (at time period two) may be unchanged (e.g. remaining a car commuter) or modified (e.g. switching to non-car commuting).

It is not shown in Fig. 2 but we recognise that life events can be a response to commuting considerations (e.g. a long commute may lead to a decision to move closer to work). They may not therefore be strictly exogenous to commuting behaviour. In the analysis that follows we are not able to take this into account (given lack of information in our data on reasons for life events) but recognition is given to this in interpreting the results. The method and results of our study are now reported.

5. Models of changing commute mode

The analysis of factors associated with changing commute mode from year to year was conducted using the first two waves of data available from the UKHLS (2009/10 and 2010/11).

5.1. UKHLS data and analytical approach

The UKHLS uses a sample that is representative of the UK population in 2009. It captures a range of social, economic and attitudinal information about the lives of members of 40,000 households. Adult household members (aged 16 or over) are interviewed once per year. Given restrictions in the availability of geographical context variables for all nations of the UK, the sample analysed was of individuals resident in England and that were in employment at both waves. This constituted 15,200 individuals.

5.1.1. Commuting modes

The UKHLS survey asks each working person how they usually get to their place of work[1]. The data confirmed the car as the most common method for travelling to work in England in 2009/10 (see Table 1).

[1] "And how do you usually get to your place of work? (if more than one mode of transport, the mode used for the part of the journey that is furthest in distance)".

Table 1
2009 commuting modal share for the English workforce.

Commute mode	Percentage of English workforce (weighted) (%)	Unweighted sample counts/ percentage	
		Frequency	Percent
Car (as driver or passenger)	64.2	9561	62.9
Walk	10.0	1621	10.7
Work from home	7.8	1145	7.5
Bus/coach	5.4	1014	6.7
Train	4.5	679	4.5
Cycle	3.6	478	3.1
Underground/light rail	2.7	457	3.0
Other	1.7	245	1.6
Total	**100.0**	**15,200**	**100.0**

Table 2
People choosing the same/new commute mode by the following year, by mode.

Commute mode in 2009/10	% age of people choosing same/new commute mode by 2010/11							
	Car (%)	Walk (%)	WFH[a] (%)	Bus/coach (%)	Train (%)	Cycle (%)	Metro (%)	Other (%)
Car	91.4	2.5	2.1	1.1	1.0	0.6	0.3	1.0
Walk	13.3	76.1	1.5	4.6	1.3	1.6	0.5	1.0
WFH[a]	26.5	3.5	62.4	0.8	3.0	0.6	1.0	2.3
Bus/coach	16.6	8.4	1.1	65.8	2.7	1.7	2.5	1.4
Train	9.3	2.9	2.7	5.7	70.7	1.0	6.6	1.0
Cycle	16.3	9.0	0.8	1.7	1.9	67.4	1.0	1.9
Metro	6.8	2.0	2.4	8.3	13.1	1.5	64.3	1.5
Other	29.4	10.6	4.1	2.4	4.5	3.3	2.9	42.9

[a] WFH – Work From Home.

5.1.2. Changing commute mode from year to year

3056 (20%) of the 15,200 workers reported a change in commute mode by the following year. Table 2 shows, by mode, the percentage of people choosing the same or an alternative commuting mode. This demonstrates that car commuting is a more stable option compared to other modes. It also illustrates how the car is the most attractive alternative to users of other modes. For example over 90% of car commuters were still commuting by car the following year. By contrast, a third of cyclists had changed to an alternative mode, with the largest share (16% of cyclists) switching to commuting by car.

To set this in the context of the longer term, a separate analysis of British Household Panel Survey (predecessor to UKHLS) data for 1991–2009 was also performed. This showed that the mean duration of car commuting (among the 4098 respondents who participated in all 18 waves) was 6.3 years, while for public transport commuting it was 3.0 years and for active commuting (commuting by walking or cycling) it was 3.2 years. This highlights that people tend not to maintain non-car commuting for very long and once they have started commuting by car, they tend to remain a car commuter.

5.1.3. Analysis of changes to commuting mode

Two categories of commute mode switching were analysed: 1. *Commuting by car* (driving or getting a lift) and *changes to and from* this position and 2. *Commuting by active travel* (walking and cycling, herein referred to as active commuting) and *changes to and from* this position. There is major policy interest in the UK in encouraging commuting by alternatives to the car and in particular by active travel modes.

These commuting behaviours were analysed through a two-step regression approach. In step one a *cross-sectional model* was estimated, on the full wave one sample, to identify factors associated with the commuting states of interest: car commuting and active commuting. In step two, transition models were estimated for the changes of interest (to/from car commuting; to/from active commuting). For each worker there was one observation (a flag indicating whether a commute mode change had occurred by wave two). The dependent variables for each model are described in Table 3.

Binary logit regressions were employed for both the cross-sectional models and the transition models. The dependent variables take the value '1' for the outcome of interest (commuting by car/active travel or changing to or from these positions) or '0' otherwise. The sample included households with multiple workers (on average there were 1.4 workers per household), therefore random-effects binary logit models were fitted using the 'xtlogit' command in Stata. The random effects specification accounts for unmeasured household factors (common to workers from the same household) by introducing an error term specific to each household in addition to an error term specific to each individual. The household error term is assumed to be normally distributed across the sample. It was found that the household error term was statistically significant (although with implied intra-household correlations that were modest) and it was hence appropriate to use the random effects specification.

Table 3
Dependent variable descriptive statistics.

Variable	Wave one		Changing mode by wave two	
	n	%	*n*	%
Commute by car	9432	63.03	812	8.6
Commute by non-car	5532	36.97	916	16.6
Total	**14,964**	**100**		
Commute by active Travel	2070	13.83	465	22.5
Commute by non-active Travel	12,894	86.17	519	4.0
Total	**14,964**	**100**		

Notes: sample counts have been adjusted for missing values in the explanatory variables used in the regression models.

Explanatory variables were selected for inclusion in the models based on our assessment of the literature reviewed in this paper and the analytical framework depicted in Fig. 2. Baseline variables for individual characteristics at wave one are included in the cross-sectional models and the commute mode change models. The transition models also include life events and a number of other *change* variables to capture changes in circumstance by wave two.

5.1.4. Explanatory variables – baseline

The baseline variables include indicators for each working individual of socio-demographics, transport resources, spatial context and environmental attitude. Socio-demographic information available included gender, age, education, employment type and household size, structure and income. Transport resource information available was restricted to driver licence availability and number of household cars. A single attitude measure was available. This related to environmental attitude and was measured in the base year as a binary response to the statement "any changes I make to help the environment need to fit in with my lifestyle" (agreement or disagreement).

Spatial context variables were drawn from other data sets and linked to UKHLS via a geographic identifier of the individual's residential address – the UK census Lower Layer Super Output Area (LSOA). These linked variables are summarised in Table 4. They refer to the spatial context of the residence of the individuals in the sample, rather than providing any information about the workplace (hereafter referred to as 'residential context' when presenting results. This includes the land use characteristics and public transport supply in the vicinity of the home). However, distance to work was directly available from UKHLS. Distance to work was only collected during the first six months of the wave one survey (owing to the need

Table 4
Residential context variables.

Residential context variable	Source data set	Definition
Settlement type (London & Metropolitan, Other urban, Rural)	UK National Travel Survey categories	Degree of urbanity of area of residence
Population density	UK Census 2001	Population density in area of residence
Proportion of population economically active	UK Census 2001	–
Travel time to the nearest employment centre with at least 100 jobs by Public Transport (PT) /Walk (mins)	DfT accessibility indicators 2009	Time taken by public transport to reach closest employment centre
Number of employment centres with at least 100 jobs accessible by PT/walk (weighted by distance decay function)	DfT accessibility indicators 2009	Ease of access by public transport to major employment opportunities
Travel time to nearest town centre by PT/walk (mins)	DfT accessibility indicators 2009	Time taken by public transport to reach closest commercial centre
Number of food stores accessible by PT/walk (weighted by distance decay function)	DfT accessibility indicators 2009	Ease of access by public transport to food shops (indicator of mixed land use)
Overall Index of Multiple Deprivation (IMD) score[a]	Indices of Multiple Deprivation 2010	Overall level of social deprivation score measured with respect to income, employment, health, education, crime, access to services and living environment
Living environment IMD score[a]	Indices of Multiple Deprivation 2010	Score combining measures of poor quality housing, numbers of road casualties and air pollution
Presence of railway station in LSOA or surrounding LSOA	National Public Transport Data Repository	–
No. of bus stops in LSOA	National Public Transport Data Repository	–

Notes: All variables measured at Lower Layer Super Output Area level (typically population of 1500), except population density measured at Medium Layer Super Output Area level (typically population of 7000).

[a] A higher IMD score indicates that the area contains a greater proportion of people being classed as deprived (Department of Communities and Local Government, 2011).

Table 5
Percentage of commuters changing commute mode in association with life events.

Life event sub samples	Full sample n = 14,964		Car to non-car n = 9432		Non-car to car n = 5532		Active to non-active n = 2070		Non-active to active n = 12,894	
	n	%[a]	n	%[b]	n	%[b]	n	%[b]	n	%[b]
Switched employer	1576	10.5	971	18.2**	605	30.3**	192	59.4**	1384	8.7**
Residential relocation	1012	6.8	590	15.1**	422	23.0**	178	38.2**	834	7.9**
Had child	578	3.9	368	9.2	210	20.5	80	26.3	498	3.2
Acquired driving licence	281	1.9	72	15.3**	209	34.9**	73	52.1**	208	6.7**
Started cohabiting	278	1.9	176	14.2**	102	22.6*	42	35.7**	236	5.5
Stopped cohabiting	183	1.2	116	15.5**	67	14.9	25	16.0	158	7.6**
% age individuals switching mode overall				**8.6**[c]		**16.6**[c]		**22.5**[c]		**4.0**[c]

[a] % individuals in the full sample experiencing the life event.
[b] % of individuals in the life event sub sample that also changed commute mode e.g. 18.2% of car commuters that switched employer also changed from car to non-car commuting.
[c] % age of the commute mode subgroup that switched mode overall e.g. 8.6% of car commuters switched to non-car commuting overall.
** Life event subgroup has a higher/lower prevalence of commute mode change compared to sample average, significant at 95% level.
* Significant at 90% level.

to shorten the UKHLS interview process during wave one), but fully recorded in wave two. This led to a large number of missing values in the distance to work variable in the base year. To handle this, distance to work was coded as a categorical variable with 'no response' as a category to retain all observations in the analysis model. Models were also estimated on the work-distance subsample (n = 4288) as a robustness check for the preferred model results.

5.1.5. Explanatory variables – life events and contextual change variables

Life events: Dummy variables were coded for the range of life events summarised in Table 5. Switching employer[2] was the most frequently experienced event followed by residential relocations. For each life event subsample, Table 5 also reports the percentage of individuals that experienced different commute mode changes. This may be compared to the proportion of commute mode changers for the full sample of interest (shown in bold in the last row of Table 5) to identify whether the life event is associated with increased prevalence of commute mode change.

The comparison indicates that, of the life events tested, residential relocations, employment switches and gaining a driving licence were most strongly associated with increased prevalence of changing commute mode to/from car/active commuting. It is also once again apparent that switching away from non-car and active commuting is far more prevalent than switching towards non-car or active commuting in association with a life event. Having a child is not found to be significant, although many workers who have a child leave the workforce and are therefore excluded from any analysis of commute mode change.

Change in distance to work: Change in distance to work between waves one and two associated with a residential move or job change was included as a variable. Given that the work distance variable included a large number of missing values in wave one, it was necessary to code change in work distance as a categorical variable (including missing as a category to retain all observations). A single distance change threshold was defined for each type of commute mode switch. Sensitivity tests indicated that changes from three miles or over to below three miles most strongly predicted switches to non-car commuting and to active commuting, while changes from two miles or less to over two miles most strongly predicted switches to car commuting and non-active commuting.

Contextual change variables: A number of continuous variables were included to capture changes in residential context (such as an increase in population density) and change in household income between waves one and two. Note that a change in residential context could only occur in association with a move to a new neighbourhood as all spatial context data was statically defined i.e. no information was available on whether land uses or the transport system were themselves changed from one year to the next.

The preferred regression models are presented in Tables 6 and 7. Note that these tables also report descriptive statistics for all explanatory variables (counts and percentages for categorical variables and means and standard deviations for continuous variables). A commentary and interpretation of the results is provided next in Sections 5.2 and 5.3.

5.2. Regression analysis: car commuting and switches to/from this

5.2.1. Predictors of commuting by car

Transport resources available within the household (and specifically opportunity to use a car) and *commute distance* variables have the strongest effects on the likelihood of commuting by car at wave one. Commuting by car increases in likelihood with having a driving licence, having greater access to household cars and as the distance to work increases, but only up to 25 miles (after which the data shows that rail competes with car). The *residential context* has a strong effect with living in areas

[2] This does not include people working at a new location, but for the same employer.

Table 6
Logistic regression models of car commuting and switches to and from this.

Dependent variable	Wave 1 Commute by car				Switch from car to non-car				Switch from non-car to car			
Name	n/*mean*[a]	%/*SD*[b]	Odds ratio	*P* > *z*	n/*mean*[a]	%/*SD*[b]	Odds ratio	*P* > *z*	n/*mean*[a]	%/*SD*[b]	Odds ratio	*P* > *z*
CHANGE VARIABLES (wave 1 to wave 2)												
Life events												
Residential relocation	1012	6.76			590	6.26	1.803	0.000	422	7.63	1.684	0.006
Had child	578	3.86			368	3.90	1.127	0.582	210	3.80	1.164	0.537
Starting cohabiting	278	1.86			176	1.87	1.092	0.760	102	1.84	1.559	0.211
Stopped cohabiting	183	1.22			116	1.23	2.317	0.008	67	1.21	0.748	0.533
Switched employer	1576	10.53			971	10.29	2.538	0.000	605	10.94	2.479	0.000
Acquired driving licence	281	1.88			72	0.76	0.369	0.015	209	3.78	16.649	0.000
Change in residential context												
Change in land use characteristics												
Change in MSOA population density (persons/HA)	*−0.10*	*7.59*			*0.01*	*6.20*	1.017	0.007	*−0.27*	*9.50*	1.003	0.622
Change in no. of emp. centres with 100+ jobs by PT/walk	*−0.01*	*0.23*			*−0.01*	*0.24*	0.934	0.786	*0.00*	*0.22*	0.956	0.888
Change in no. of foodstores accessible by PT/walk	*−0.01*	*0.27*			*−0.01*	*0.27*	1.059	0.788	*0.00*	*0.26*	0.753	0.305
Change in PT availability												
Change in travel time to nearest employment centre by PT/walk (mins)	*0.01*	*1.39*			*0.01*	*1.51*	0.918	0.020	*0.02*	*1.17*	1.106	0.052
Change in travel time to nearest town centre by PT/walk (mins)	*0.01*	*1.39*			*0.02*	*2.96*	1.035	0.058	*0.02*	*2.96*	0.996	0.858
Change in rail station proximity (gain=+1, loss = −1)	*0.00*	*0.15*			*0.00*	*0.15*	0.982	0.942	*0.00*	*0.16*	0.584	0.071
Change in number of bus stops in LSOA	*0.01*	*3.94*			*0.01*	*3.11*	1.003	0.812	*0.02*	*5.05*	0.992	0.441
Change in commute distance												
Change in commute distance: missing	10,738	71.76			7256	76.93	1.656	0.000	3482	62.94	1.600	0.000
Change in commute distance to: below 3 mi (to non-car), above 2 mi (to car)					141	1.60	9.155	0.000	292	5.28	30.179	0.000
Ref: no change in commute distance					2035	21.58			1758	31.78		
Other change												
Change in monthly household income (£1000)	*0.24*	*2.41*			*0.22*	*2.35*	1.017	0.346	*0.29*	*2.52*	0.994	0.756
BASELINE LIFE CONTEXT VARIABLES (wave 1)												
Household structure												
Household size 1 person	1582	10.57	1.444	0.001	915	9.70	0.821	0.302	667	12.06	1.174	0.458
Household size 3 people	3361	22.46	0.749	0.001	2174	23.05	0.966	0.807	1187	21.46	0.984	0.918
Household size 4+ people	5326	35.59	0.609	0.000	3412	36.17	0.985	0.925	1914	34.60	0.842	0.332
Ref: Household size 2 people	4695	31.38			2931	31.08			1764	31.89		
Live with a partner	10,703	71.52	0.982	0.804	7029	74.52	0.888	0.360	3674	66.41	1.303	0.084
Child present in the household	7025	46.95	1.696	0.000	4566	48.41	1.183	0.212	2459	44.45	1.126	0.438
Gender and age												
Female	7963	53.21	1.177	0.002	5011	53.13	0.876	0.154	2952	53.36	0.752	0.006
16–24	1255	8.39	1.038	0.733	671	7.11	1.127	0.513	584	10.56	2.198	0.000
25–29	1422	9.50	1.298	0.006	846	8.97	0.893	0.480	576	10.41	1.796	0.001
30–44	5967	39.88	1.207	0.002	3861	40.94	0.823	0.063	2106	38.07	1.143	0.280
60 plus	1134	7.58	1.302	0.010	708	7.51	1.316	0.107	426	7.70	0.879	0.522
Ref: 45–59	5186	34.66			3346	35.47			1840	33.26		
Education level												
Degree	4603	30.76	0.551	0.000	2653	28.13	1.339	0.064	1950	35.25	0.495	0.000
Other higher	2025	13.53	0.793	0.020	1389	14.73	1.000	0.999	636	11.50	0.542	0.002
A level	3053	20.40	0.732	0.001	1990	21.10	1.158	0.334	1063	19.22	0.759	0.101
GCSE	3155	21.08	0.827	0.030	2058	21.82	1.171	0.283	1097	19.83	0.758	0.094
Ref: Other or no qualification	2128	14.22			1342	14.23			786	14.21		
Employment type and income												
Management & professional	6471	43.24	1.142	0.072	4303	45.62	1.009	0.943	2168	39.19	0.802	0.143
Intermediate	2111	14.11	0.918	0.303	1370	14.53	0.885	0.408	741	13.39	0.747	0.088
Small employers & own account	1383	9.24	0.760	0.007	707	0.00	1.681	0.001	676	12.22	1.279	0.156
Lower supervisory & technical	1087	7.26	1.317	0.010	757	91.97	0.772	0.158	330	5.97	1.423	0.091
Ref: Semi routine	3912	26.14			2295	24.33			1617	29.23		
Full time employed	11,013	73.60	1.235	0.001	7164	24.05	0.896	0.308	3849	69.58	1.018	0.884
Monthly household income (£1000)	*4.23*	*2.85*	0.944	0.000	*4.30*	*2.79*	1.033	0.071	*4.12*	*2.96*	0.982	0.399
Attitudes												
Pro-environmental behaviour needs to fit in with lifestyle (yes)	7912	52.87	1.228	0.000	5143	54.53	0.755	0.002	2769	50.05	0.884	0.240
Pro-environmental behaviour needs to fit in with lifestyle (non response)	2025	13.53	1.274	0.003	1203	12.75	0.993	0.957	822	14.86	1.017	0.913

(*continued on next page*)

Table 6 (*continued*)

Dependent variable	Wave 1 Commute by car				Switch from car to non-car				Switch from non-car to car			
Name	n/*mean*[a]	%/*SD*[b]	Odds ratio	*P* > *z*	n/*mean*[a]	%/*SD*[b]	Odds ratio	*P* > *z*	n/*mean*[a]	%/*SD*[b]	Odds ratio	*P* > *z*
Ref: Pro-environmental behaviour needs to fit in with lifestyle (no)	5027	33.59			3086	32.72			1941	35.09		
Transport resources												
No. of household cars	*1.53*	*0.83*	3.038	0.000	*1.76*	*0.71*	0.798	0.003	*1.14*	*0.87*	1.462	0.000
Driving licence availability	12,634	84.43	10.207	0.000	8998	95.40	0.178	0.000	3636	65.73	5.647	0.000
Commute distance												
Commute distance: missing	10,677	71.35	37.366	0.000								
Commute distance: 2 to under 5 mi	913	6.10	44.248	0.000								
Commute distance: 5 to under 10 mi	732	4.89	54.699	0.000								
Commute distance: 10 to under 25 mi	699	4.67	63.879	0.000								
Commute distance: 25+ mi	287	1.92	28.604	0.000								
Ref: Commute distance: under 2 mi	1656	11.07										
Residential context												
Settlement type												
Area: Inner London	990	6.62	0.251	0.000	205	2.17	1.776	0.082	785	14.19	0.432	0.012
Area: Outer London	1644	10.99	0.386	0.000	759	8.05	1.138	0.544	885	16.00	0.590	0.040
Area: Metropolitan areas	2254	15.06	1.086	0.471	1471	15.60	0.718	0.084	783	14.15	1.357	0.198
Area: Large urban (250k+)	1665	11.13	1.027	0.827	1087	11.52	0.926	0.695	578	10.45	1.274	0.333
Area: Medium urban (25k–250k)	3894	26.02	0.939	0.529	2647	28.06	1.002	0.989	1247	22.54	1.376	0.130
Area: Small urban (10k–25k)	1100	7.35	0.982	0.877	783	8.30	0.923	0.681	317	5.73	1.750	0.026
Area: Very small urban (3k–10k)	772	5.16	0.833	0.170	548	5.81	1.061	0.778	224	4.05	1.297	0.339
Ref: Area: Rural	2645	17.68			1932	20.48			713	12.89		
Land use characteristics												
MSOA population density (persons/HA)	*31.33*	*31.66*	0.994	0.000	*24.98*	*24.54*	1.002	0.508	*42.15*	*38.72*	0.997	0.255
No. of emp centres with 100+ jobs by PT/walk	*7.10*	*1.00*	1.068	0.157	*6.99*	*0.99*	0.943	0.453	*7.29*	*0.99*	1.298	0.006
No. of foodstores accessible by PT/walk	*3.40*	*1.01*	0.940	0.159	*3.27*	*0.99*	1.132	0.098	*3.62*	*1.01*	0.998	0.979
PT availability												
Travel time to nearest employment centre by PT/walk (mins)	*9.65*	*5.50*	0.997	0.638	*9.98*	*5.36*	0.989	0.324	*9.09*	*5.69*	1.019	0.080
Travel time to nearest town centre by PT/walk (mins)	*16.67*	*10.95*	1.003	0.393	*17.57*	*11.26*	1.005	0.324	*15.15*	*10.23*	1.007	0.274
Rail station in LSOA or neighbouring LSOA	5234	34.98	0.891	0.035	3164	66.45	1.113	0.248	2070	37.42	0.850	0.136
Number of bus stops in LSOA	*10.85*	*11.41*	0.995	0.070	*11.14*	*9.60*	0.998	0.719	*10.36*	*13.96*	0.991	0.091
Social environment												
LSOA proportion economically active	*0.64*	*0.09*	3.250	0.004	*0.65*	*0.09*	0.596	0.453	*0.63*	*0.10*	1.680	0.509
LSOA overall Index of Multiple Deprivation score	*20.50*	*14.60*	1.019	0.000	*18.89*	*13.94*	0.992	0.144	*23.23*	*15.27*	1.009	0.123
LSOA living environment Index of Multiple Deprivation score	*21.25*	*16.27*	0.989	0.000	*18.69*	*15.17*	1.009	0.011	*25.61*	*17.13*	0.999	0.738
Other												
Ethnic minority boost sample household	1768	11.82	1.025	0.774	771	8.17	1.203	0.237	997	18.02	1.429	0.022
Constant			0.001	0.000			0.366	0.202			0.001	0.000
Household level variance components			**Value**	**SE**			**Value**	**SE**			**Value**	**SE**
sigma_u			0.817	0.092			0.894	0.214			1.079	0.231
Rho			0.169*	0.031			0.195*	0.075			0.261*	0.083
Goodness of fit statistics												
Wald statistic	1398.11^				259.45^				234.54^			
Wald statistic degrees of freedom	47				58				58			
n/%	**14,999**	**100**			**9432**	**63.03**			**5532**	**36.97**		
Successes	**9452**	**63.02**			**812**	**8.6**			**916**	**16.6**		

Notes:
Grey shading indicates significance at 95% level.
A Level: Advanced Level (taken at 18).
Emp: Employment.
GCSE: General Certificate in Secondary Education (taken at 16).
LSOA: UK Census Lower Layer Super Output Area level.
MSOA: UK Census Medium Layer Super Output Area level.
mi: Miles.
PT: Public Transport.
[a] Frequencies for categorical variables are shown in non-italics. Means for continuous variables are shown in italics.
[b] Percentages for categorical variables are shown in non-italics. Standard deviations for continuous variables are shown in italics.
* Indicates rho is significantly different to 0 at 95% level.
^ Wald statistic is significant at 95% level, indicating improved model fit compared to null model.

with greater access to alternatives to the car (i.e. London, higher population density, proximity to rail, poorer living environment – which may be associated with living close to major transport links) reducing likelihood of commuting by car. Living in areas of higher deprivation (see variables under 'social environment' in Table 6) is associated with higher likelihood of car commuting (after controlling for other factors). We hypothesise that this is because perceptions of non-car alternatives are less positive in areas of higher deprivation. For example, Anable (2010) found that perceptions of the walking and cycling environment were least positive in the most deprived areas based on a survey of 12,000 households in Scotland, UK.

After accounting for other factors, *higher economic status*, as indicated by educational qualifications and income, is associated with reduced likelihood of car commuting. One possible explanation for this is higher status jobs being located in larger urban areas that are less accessible by car. With respect to *employment type*, the self-employed and those working for small employers ('small employers and own account' in Table 6) are less likely to commute by car (as the data indicates that these groups have greater tendency to work from home) and those in lower supervisory and technical roles have increased likelihood of commuting by car. *Gender and life stage* (which is reflected by 'age' and 'household structure' in Table 6) are relevant with the likelihood of car commuting greater for females, having children present in the household and being aged 25–44 or 60 or over (after accounting for other factors such as car access and distance to work). This suggests that those with caring and household responsibilities prefer to use a car. *Attitudes* are found to play a role with willingness to act to protect the environment associated with lower likelihood of car use.

5.2.2. Predictors of switching to/from commuting by car

The transition models indicate that a *change in commute distance* most strongly predicts switching to/from car commuting. Increases in distances have a stronger effect than reductions in distance e.g. an increase from two miles or less to at least two miles increases the likelihood of switching to car by 30 times, while a decrease from three miles or more to less than three miles increases likelihood of switching to non-car commuting by only nine times. Such changes occur either when moving home or changing employer. These are frequently experienced events (e.g. 10% of the sample changed employer – see Table 5) and are therefore of great significance for commuting.

Residential relocations are likely to result in a change in residential context (land use and public transport provision) to a greater or lesser extent. The transition models show that residential relocations involving an *increase in population density* and *reduced travel time to the nearest employment centre by public transport and walking*[3] (see 'change in residential context' variables in Table 6) increase the likelihood of switching to non-car commuting, highlighting the importance of public transport availability/connectivity in reducing car commuting. Beyond their impacts via commute distance and residential context changes, changing employer and moving home, as *life events* in themselves, are also associated with increased likelihood of changing to and from car commuting. Odds ratios for switching from car to non-car are 1.8 in association with residential relocation and 2.5 in association with switching employer. Odds ratios for switching from non-car to car are 1.7 in association with residential relocation and 2.5 in association with switching employer. These findings should be treated with caution, however, given the large number of missing values for the change in commute distance variable. Sensitivity tests estimating transition models only on the subset of cases without missing commute distance values demonstrated that changes in distance to work and residential context remained significant, as did switching employer, but the residential relocation event was no longer significant. The increased likelihood of changing to and from car commuting with a change of employer, regardless of the change in commute distance, is likely to be due to it bringing about a change in the attractiveness of commuting by different modes in ways that are not captured by the data (no information was available on the transport attributes of the workplace). It could also simply be due to it prompting deliberation about how to get to work which would not occur otherwise.

With respect to other observable life events, *acquiring a driving licence* is found to strongly predict a switch to car commuting – it is worth noting that a licence may be acquired with travel to work in mind. *Stopping cohabitating* increases likelihood of switching from car to non-car. This may relate to the loss of access to a car which has been found to often occur in this circumstance (see Clark et al., 2015). The results also show that age and educational levels influence the propensity to switch to and from car commuting. *Those aged 16–29 are more likely than other age groups to switch towards car commuting*, indicating that young adults tend to move towards car commuting in their early years in the labour force. On the other hand highly educated individuals are less likely to switch to car commuting, suggesting that they take on jobs and residential locations that do not suit car commuting (whether this is willingly or not is not known).

After controlling for the possible confounding effects of residential context and socio-economic characteristics, *attitudes* and specifically a willingness to act to protect the environment in the base year, increases likelihood of switching from car to non-car (increases odds by a factor of 1.32), but is not found to affect the opposite switch. This suggests that attitude plays an active role for car commuters considering alternatives. Insight into the temporal sequence is notable here. The pro-environmental attitude exists *before* the commute mode change, confirming that attitude *precedes* behaviour change and does not simply adjust to the new behaviour.

[3] Note these are continuous variable in the model, and the odds ratios (which are close to 1) should be interpreted with this in mind. For example, 'Change in travel time to nearest employment centre by PT/walk' indicates a 0.918 reduction in likelihood of switching to non-car commuting for every additional minute of journey time. This is equivalent to a significant 0.425 reduction in likelihood for a 10 min increase in journey time.

Table 7
Logistic regression models of active commuting and switches to and from this.

Dependent variable	Wave 1 commute by active travel				Change from active to non-active				Change from non-active to active			
Name	n/ *mean*[a]	%/ *SD*[b]	Odds ratio	*P* > *z*	n/ *mean*[a]	%/ *SD*[b]	Odds ratio	*P* > *z*	n/ *mean*[a]	%/ *SD*[b]	Odds ratio	*P* > *z*
CHANGE VARIABLES (wave 1 to wave 2)												
Life events												
Residential relocation	1012	6.8			178	8.6	2.007	0.018	834	6.5	1.717	0.002
Had child	578	3.9			80	3.9	0.761	0.480	498	3.9	0.743	0.295
Starting cohabiting	278	1.9			42	2.0	1.209	0.716	236	1.8	0.816	0.548
Stopped cohabiting	183	1.2			25	1.2	0.357	0.228	158	1.2	1.371	0.373
Switched employer	1576	10.5			192	9.3	11.050	0.000	1384	10.7	2.564	0.000
Acquired driving licence	281	1.9			73	3.5	7.421	0.000	208	1.6	0.567	0.071
Change in residential context												
Change in land use characteristics												
Change in MSOA population density	*−0.10*	*7.6*			*−0.21*	*8.5*	0.999	0.933	*−0.08*	*7.4*	1.005	0.307
Change in no. of emp centres with 100+ jobs by PT/walk	*−0.01*	*0.2*			*0.00*	*0.2*	1.521	0.415	*−0.01*	*0.2*	0.505	0.007
Change in no. of foodstores accessible by PT/walk	*−0.01*	*0.3*			*−0.01*	*0.3*	0.538	0.206	*−0.01*	*0.3*	1.524	0.054
Change in PT availability												
Change in travel time to nearest employment centre by PT/walk (mins)	*0.01*	*1.4*			*0.03*	*1.1*	1.377	0.001	*0.01*	*1.4*	0.933	0.076
Change in travel time to nearest town centre by PT/walk (mins)	*0.01*	*1.4*			*0.03*	*3.3*	0.994	0.848	*0.02*	*2.9*	0.984	0.340
Change in rail station proximity (gain = +1, loss = −1)	*0.00*	*0.2*			*−0.01*	*0.2*	0.899	0.825	*0.00*	*0.2*	1.085	0.746
Change in number of bus stops in LSOA	*0.01*	*3.9*			*−0.10*	*7.4*	0.997	0.848	*0.03*	*3.1*	1.003	0.818
Change in commute distance												
Change in commute distance: missing	10,738	71.8			1627	78.6	1.321	0.172	9111	70.7	1.266	0.046
Change in commute distance to: below 3 mi (to active), above 2 mi (to non-active)					41	2.0	31.364	0.000	184	1.4	4.674	0.000
Ref: No change in commute distance					402	19.4			3599	27.9		
Other change												
Change in monthly household income (£1000)	*0.24*	*2.4*			*0.26*	*2.2*	1.026	0.463	*0.24*	*2.4*	0.977	0.358
BASELINE LIFE CONTEXT VARIABLES (wave 1)												
Household structure												
Household size 1 person	1582	10.6	0.762	0.035	226	10.9	0.862	0.646	1356	10.5	0.950	0.800
Household size 3 people	3361	22.5	1.337	0.005	464	22.4	0.986	0.956	2897	22.5	0.839	0.287
Household size 4+ people	5326	35.6	1.641	0.000	749	36.2	0.803	0.432	4577	35.5	1.152	0.409
Ref: Household size 2 people	4695	31.4			631	30.5			4064	31.5		
Live with a partner	10,703	71.5	1.018	0.837	1329	64.2	0.904	0.638	9374	72.7	1.012	0.933
Child present in the household	7025	47.0	0.763	0.006	977	47.2	1.185	0.476	6048	46.9	1.199	0.228
Gender and age												
Female	7963	53.2	1.044	0.505	1232	59.5	0.871	0.396	6731	52.2	1.055	0.613
16–24	1255	8.4	0.916	0.476	267	12.9	4.054	0.000	988	7.7	1.116	0.567
25–29	1422	9.5	0.806	0.059	215	10.4	2.210	0.008	1207	9.4	1.041	0.817
30–44	5967	39.9	0.883	0.103	770	37.2	1.477	0.052	5197	40.3	0.859	0.215
60 plus	1134	7.6	0.645	0.001	122	5.9	0.799	0.569	1012	7.9	0.727	0.165
Ref: 45–59	5186	34.7			696	33.6			4490	34.8		
Education level												
Degree	4603	30.8	1.028	0.804	535	25.9	0.958	0.881	4068	31.6	1.062	0.743
Other higher	2025	13.5	1.020	0.866	240	11.6	0.878	0.673	1785	13.8	1.061	0.767
A level	3053	20.4	0.929	0.491	409	19.8	0.806	0.432	2644	20.5	1.211	0.267
GCSE	3155	21.1	1.051	0.621	521	25.2	1.103	0.696	2634	20.4	1.233	0.206
Ref: Other or no qualification	2128	14.2			365	17.6			1763	13.7		
Employment type and income												
Management & professional	6471	43.2	0.517	0.000	637	30.8	1.200	0.413	5834	45.3	0.697	0.011
Intermediate	2111	14.1	0.623	0.000	277	13.4	1.162	0.546	1834	14.2	0.737	0.054
Small employers & own account	1383	9.2	0.267	0.000	87	4.2	2.071	0.059	1296	10.1	0.867	0.444
Lower supervisory & technical	1087	7.3	0.750	0.017	166	8.0	1.821	0.043	921	7.1	0.720	0.107
Ref: Semi routine	3912	26.1			903	43.6			3009	23.3		
Full time employed	11,013	73.6	0.697	0.000	1304	63.0	1.293	0.170	9709	75.3	0.715	0.004
Monthly household income (£1000)	4.23	2.9	0.991	0.515	3.63	2.4	0.994	0.868	4.33	2.9	0.953	0.067
Attitudes												
Pro-environmental behaviour needs to fit in with lifestyle (yes)	7912	52.9	0.775	0.000	1030	49.8	1.006	0.969	6882	53.4	0.796	0.036
Pro-environmental behaviour needs to fit in with lifestyle (non response)	2025	13.5	0.710	0.001	288	13.9	1.484	0.099	1737	13.5	1.150	0.329

Table 7 (*continued*)

Dependent variable	Wave 1 commute by active travel				Change from active to non-active				Change from non-active to active			
Name	n/ *mean*[a]	%/ *SD*[b]	Odds ratio	*P* > *z*	n/ *mean*[a]	%/ *SD*[b]	Odds ratio	*P* > *z*	n/ *mean*[a]	%/ *SD*[b]	Odds ratio	*P* > *z*
Ref: Pro-environmental behaviour needs to fit in with lifestyle (no)	5027	33.6			752	36.3			4275	33.2		
Transport resources												
No. of household cars	1.53	0.8	0.515	0.000	1.08	0.8	1.234	0.083	1.60	0.8	0.655	0.000
Driving licence availability	12,634	84.4	0.305	0.000	1248	60.3	2.161	0.000	11,386	88.3	0.428	0.000
Commute distance												
Commute distance: missing	10,677	71.4	0.745	0.002								
Commute distance: 2 to under 5 mi	913	6.1	0.590	0.000								
Commute distance: 5 to under 10 mi	732	4.9	0.157	0.000								
Commute distance: 10 to under 25 mi	699	4.7	0.024	0.000								
Commute distance: 25+ mi	287	1.9	0.000	0.995								
Ref: Commute distance: under 2 mi	1656	11.1										
Residential context												
Settlement type												
Area: Inner London	990	6.6	0.656	0.056	183	8.8	1.674	0.340	807	6.3	0.541	0.072
Area: Outer London	1644	11.0	0.697	0.037	166	8.0	1.514	0.346	1478	11.5	0.643	0.092
Area: Metropolitan areas	2254	15.1	1.001	0.996	319	15.4	1.237	0.590	1935	15.0	0.802	0.331
Area: Large urban (250k+)	1665	11.1	1.415	0.026	276	13.3	1.189	0.670	1389	10.8	0.888	0.617
Area: Medium urban (25k–250 k)	3894	26.0	1.602	0.000	645	31.2	0.921	0.814	3249	25.2	1.257	0.233
Area: Small urban (10k–25k)	1100	7.4	1.442	0.017	160	7.7	1.345	0.455	940	7.3	1.085	0.732
Area: Very small urban (3k–10k)	772	5.2	1.453	0.029	97	4.7	1.032	0.944	675	5.2	0.877	0.652
Ref: Area: Rural	2645	17.7			224	10.8			2421	18.8		
Land use characteristics												
MSOA population density (persons/HA)	*31.33*	*31.7*	1.005	0.002	*37.66*	*34.2*	0.999	0.739	*30.31*	*31.1*	1.002	0.441
No. of emp centres with 100+ jobs by PT/walk	*7.10*	*1.0*	0.723	0.000	*7.22*	*1.0*	1.521	0.006	*7.08*	*1.0*	0.915	0.342
No. of foodstores accessible by PT/walk	*3.40*	*1.0*	1.265	0.000	*3.67*	*1.0*	0.830	0.184	*3.36*	*1.0*	1.223	0.020
PT availability												
Travel time to nearest employment centre by PT/walk (mins)	9.65	5.5	0.980	0.022	8.67	4.2	1.026	0.263	9.81	5.7	0.985	0.270
Travel time to nearest town centre by PT/walk (mins)	16.67	11.0	0.993	0.071	14.86	10.1	1.015	0.144	16.97	11.0	1.005	0.442
Rail station in LSOA or neighbouring LSOA	5234	35.0	1.020	0.773	745	36.0	1.186	0.323	4489	34.8	1.054	0.631
Number of bus stops in LSOA	10.85	11.4	1.008	0.003	11.17	16.8	0.999	0.834	10.80	10.3	1.006	0.157
Social environment												
LSOA proportion economically active	*0.64*	*0.1*	0.339	0.031	*0.63*	*0.1*	3.269	0.336	*0.65*	*0.1*	0.291	0.108
LSOA overall Index of Multiple Deprivation score	*20.50*	*14.6*	0.982	0.000	*23.83*	*15.7*	1.008	0.356	*19.96*	*14.3*	0.988	0.040
LSOA living environment Index of Multiple Deprivation score	*21.25*	*16.3*	1.014	0.000	*25.63*	*17.6*	0.995	0.419	*20.54*	*15.9*	1.010	0.010
Other												
Ethnic minority boost sample household	1768	11.8	0.674	0.000	257	12.4	1.939	0.010	1511	11.7	0.826	0.253
Constant			21.356	0.000			0.001	0.000			0.299	0.187
Household level variance components			**Value**	**SE**			**Value**	**SE**			**Value**	**SE**
sigma_u			1.135	0.103			1.345	0.423			0.739	0.363
Rho			0.281*	0.037			0.355*	0.144			0.142	0.120
Goodness of fit statistics												
Wald statistic	733.84^				57.46				249.30^			
Wald statistic degrees of freedom	47				58				58			
n/%	**14,999**	**100**			**2070**	**100**			**12,894**	**100**		
Successes	**2074**	**13.8**			**465**	**22.5**			**519**	**4.0**		

Notes:
Grey shading indicates significance at 95% level.
A Level: Advanced Level (taken at 18).
Emp: Employment.
GCSE: General Certificate in Secondary Education (taken at 16).
LSOA: UK Census Lower Layer Super Output Area level.
mi: Miles.
MSOA: UK Census Medium Layer Super Output Area level.
PT: Public Transport.
[a] Frequencies for categorical variables are shown in non-italics. Means for continuous variables are shown in italics.
[b] Percentages for categorical variables are shown in non-italics. Standard deviations for continuous variables are shown in italics.
* Indicates rho is significantly different to 0 at 95% level.
^ Wald statistic is significant at 95% level, indicating improved model fit compared to null model.

5.3. Regression analysis: active commuting and switches to/from this

5.3.1. Predictors of active commuting

The wave one cross-sectional model (Table 7) confirms that many of the factors that predict car/non-car commuting also predict active/non-active commuting. In common with car commuting, *commute distance* and *transport resources* (specifically opportunity to use a household car) have the strongest effects. Active commuting is most likely for those living within two miles of work, with the likelihood reducing for those within two to five miles (0.6 times the likelihood of those within two miles) and reducing sharply for longer distances. Having a driving licence and access to a larger number of household cars reduces the likelihood of active commuting.

The *residential context* has a strong effect, but different characteristics influence propensity for active commuting in comparison to car commuting. Living in *mixed land use areas* (as indicated by higher population density, higher number of local food stores, fewer large employment centres (with 100+ jobs) nearby,[4] poorer living environment – which is associated with living close to major transport links) and *good access to bus services* (living close to more bus stops, and shorter public transport journey times to employment centres) increase likelihood of active commuting. Access to a local rail station (which reduces likelihood of car commuting) does not have an effect. This suggests that the nature of the local built environment is important to active commuting. The results show that those living in more deprived areas (with a higher overall index of multiple deprivation) have a lower likelihood of active commuting. As mentioned previously, this may stem from less positive perceptions of the walking and cycling environment. Active commuting is more likely in non-metropolitan urban areas than metropolitan areas (including London) and rural areas after considering other factors such as commute distance and car ownership.

In contrast to car commuting, education level, income and gender are not important, but *employment type* is found to have a stronger effect. Those working in higher categories of employment (e.g. management roles) and those working for small employers or in self-employment ('small employers and own account' in Table 7) are less likely to commute by active travel. The *attitude* relationship is as expected with *willingness to act to protect the environment* being associated with increased likelihood of active commuting.

5.3.2. Predictors of switching to/from active commuting

The *life events* identified as important for switching to/from car commuting also hold for switching to/from active commuting. Employment changes and residential relocations that alter the *commute distance* are the strongest predictor of switches to and from active commuting. An increase from two miles or less to at least two miles increases the likelihood of switching to non-active travel by 31 times, while a decrease from three miles or more to less than three miles increases likelihood of switching to active travel by only five times. This suggests that active commuting is very unlikely to be sustained when the distance to work increases beyond two miles.

The type of alteration to residential context (land use and public transport availability), which may occur in association with a house move, is also shown to be significant. Starting active commuting is more likely in association with *residential moves to mixed land use areas* (as indicated by more local food stores and fewer local large employment centres with 100 or more jobs). As with switches to/from car commuting, sensitivity tests estimating transition models only on the subset of cases without missing commute distances demonstrated that changes in commute distance and residential context remained significant, as did changing employer, but the residential relocation event was no longer significant.

In contrast to switches to/from car commuting, *education level* is not found to be important but *employment type* is important. Those in management/professional jobs are less likely to switch to active commuting than other employment categories. Consistent with switches to/from car commuting, younger adults *aged 16–29* are more likely than other age groups to curtail active commuting. With respect to *attitudes*, it is found that willingness to act to protect the environment increases likelihood of starting active commuting (increasing odds by a factor of 1.26), but it is not found to affect the opposite switch. This suggests that attitude plays a role for those considering active commuting and insight into the temporal sequence is once again notable here – the pro-environmental attitude is shown to *precede* the pro-environmental behaviour change.

6. Discussion

6.1. Empirical insights

We now summarise the key empirical findings and their implications for research and policy, by returning to the research questions set out in section three:

1. How many people change commute mode from one year to the next?
2. To what extent are commute mode changes associated with life events? and
3. How are socio-demographic characteristics, attitudes and (changes to) spatial context associated with commute mode changes?

[4] Living near large employment centres is indicative of single use employment rather than mixed land use.

In relation to the role of life events (question two), employment changes and residential relocations have been shown to increase the likelihood of commute mode changes occurring, primarily by altering the distance to work. Distance increases are more likely to prompt a switch *to* car commuting (odds increased by a factor of 30) than distance reductions are to prompt a switch *from* car commuting (odds increased by a factor of nine). Employment changes are found to have an *independent effect* after controlling for distance to work changes. Residential relocations as events in themselves have a weaker effect, but may indirectly exert a further influence through changes to the local context for travel (discussed later).

In relation to question three, our cross-sectional *socio-demographic* and *residential context* relationships were on the whole consistent with previous studies. There has been less evidence of their association with commute mode *changes* and in this respect we have confirmed Panter et al.'s (2013) finding that certain socio-demographic characteristics also increase likelihood of particular commute mode changes. In particular holding a degree reduces likelihood of switching to car commuting. We also found that different employment roles are associated with different types of commuting behaviour changes.

It has also been confirmed that different types of *change* to *residential context* encourage different types of commute mode switching. Specifically moves to mixed land use areas encourage switches to active commuting, while moves involving shorter journey times to employment by public transport encourage switches away from car commuting.

With respect to *attitudes*, the models indicate that a 'willingness to protect the environment' *precedes* a behavioural change towards non-car and active commuting and makes it more likely by about 1.3 times, after controlling for socio-demographic characteristics, residential context and occurrence of life events. This attitude measure did not predict switches towards car commuting which suggests that at least some people with environmental concerns actively seek to modify their commuting behaviour. The temporal sequence confirms that attitudes do not simply adjust to match new behaviours once they are established.

6.2. Relationship to theory

Overall these empirical findings are supportive of the conceptual framework put forward in Fig. 1. They show that life events relating to residential and employment location are associated with increased likelihood of commute mode changes. Factors relating to the built environment (facilitating conditions) and pre-existing attitudes (intrinsic motivation) are shown to play a role in this process. But it cannot be determined whether there was a wish to change commute mode prior to changing home or job, or whether the deliberation over commute mode only occurred afterwards. It is quite possible that reflection over commuting behaviour occurs both before and after.

6.3. Opportunities for further research

We looked at whether life events and commute mode changes occurred in the same one year period. Oakil et al. (2011) examined whether there were lagged or lead effects between life events and commute mode change but their sample was relatively small. This is an area that would certainly benefit from further research as additional waves become available in the UKLHS.

We have also not been able to examine the longer term trajectories of commuting with only two waves of data. It would be interesting to see whether the length of time spent commuting by a particular mode affects the likelihood of a switch taking place (with and without the occurrence of life events). Past commuting behaviour is known to be a strong predictor of current behaviour (Dargay and Hanly, 2007), indicating that behaviours learnt in the past may exert a strong influence on how people adapt to new situations following life events. This could also be investigated with longer history data. More waves of data will also enable an examination of whether relationships are stable over time or are specific to certain periods.

The data set we developed only had indicators of life events experienced by our survey sample and not transport interventions. It would be valuable to examine the interaction between life events and transport interventions, although longitudinal data on both life events and policy interventions is clearly challenging to generate.

6.4. Policy implications

Employment changes: The results showed that people are more likely to change commuting behaviour when they start working for a new employer. For example, nearly one in five car commuters switched to non-car commuting when they changed employer. Although this study did not examine the impact of VTBC measures, the findings imply that they are likely to be most effective when aimed at new employees (as they will be contemplating their commuting options to a greater extent than established employees) – for instance by issuing travel packs, or temporary free bus passes. Such measures may be particularly appropriate for new, young adult entrants to the labour market given the earlier observation that young adults tend to move towards car commuting as their careers mature.

Residential relocations: People are also more likely to change how they commute to work when they move home. For example, 15% of car commuters switched to non-car commuting at the time of a residential relocation. As with employment changes, this would suggest that VTBC measures (e.g. travel packs explaining available transport options in the local area) would be most effective when residents move into a new home. In particular, those moving into new build developments are a targetable group for such interventions.

Whilst we have observed a greater prevalence of commute mode change occurring amongst the group of employees experiencing these life events, it is notable that the majority (e.g. 72% of car commuters that switched employer) *maintained* the same commute mode after the life event. The decision to *not* change mode at the time of a life event may involve a similar level of deliberation as the decision to change mode (see Fig. 1). Further research is required to identify the potential for mode changes amongst stable commuters and their likely response to VTBC measures.

Land use planning: The findings also suggest that the built environment has an important mediating role to play in enabling commuting by non-car modes when people move home or change employer. The regression models indicated that shorter journey times by public transport to employment sites (following a house move) encourages non-car commuting. This supports the case for investment in measures to reduce journey times by public transport to employment centres. This may be achieved by providing faster services, or reducing the need to change services. The regression models also revealed that indicators of mixed land uses (e.g. proximity to food stores) were associated with increased likelihood of switching to active commuting. Hence planning policies concerned with encouraging active commuting might prioritise mixed developments with short distances (less than two miles) between residential areas, amenities (shops) and employment opportunities.

Social deprivation: Residents of more socially deprived neighbourhoods were found to be more likely to commute by car and less likely to commute by active modes after controlling for other factors. This study provides no insight into why this might be the case and this is certainly an area that demands further research. We speculate that residents of deprived neighbourhoods are less positive about their walking and cycling environment and public transport services and that measures to improve these will be helpful in addressing this.

7. Concluding remarks

Previous studies of the factors influencing commute mode changes have had to rely on comparatively small data sets. This has limited the potential to jointly examine the effects of a range of life events, spatial contexts and attitudes. The large sample size and breadth of survey content in the UKHLS provided a new opportunity to jointly investigate these factors in a single analytical framework. Through this it has been demonstrated that commute mode changes are primarily driven by alterations to the distance to work which occur in association with residential relocations and employment switches. Non-car commuting becomes much more likely as the distance to work drops below three miles. The benefits of *longitudinal* data in providing stronger evidence of 'cause and effect' have also been demonstrated. A pro-environmental attitude has been shown to *precede* switches away from car commuting and towards active commuting. After controlling for attitudes, spatial context is confirmed to retain an independent effect with high quality public transport links to employment centres shown to encourage switches away from car commuting and mixed land uses shown to encourage switches to active commuting. This suggests an effect of the built environment on commute mode that is not merely associated with residential self-selection.

Information was not available about transport interventions experienced by the survey participants and future research should seek to identify how life events interact with transport interventions to influence commuting behaviour. Nevertheless, the research has provided firm evidence that life events are a key factor to be considered in travel behaviour studies and in transport policies concerned with promoting changes to commuting behaviour.

Acknowledgements

The research was supported by the Economic and Social Research Council under the Secondary Data Analysis Initiative (Grant Number ES/K00445X/1). It was conducted in partnership with the Institute for Social and Economic Research, University of Essex (with thanks to Professor Heather Laurie and Dr. Gundi Knies) and the UK Department for Transport (with thanks to Deirdre O'Reilly, Ben Savage, Tom Gerlach, John Screeton, Louise Taylor and Samuel Omolade).

References

Ajzen, I., 1991. The theory of planned behaviour. Organ. Behav. Hum. Decis. Process. 50, 179–211.
Anable, 2010. Monitoring and Evaluation of the Smarter Choices, Smarter Places Programme: Analysis of Walking and Cycling Activity and its Relationship to Socio-Economic Status. Working Paper 2010/01. Transport Scotland, Glasgow.
Ben-Elia, E., Ettema, D., 2011. Changing commuters' behavior using rewards: a study of rush-hour avoidance. Transp. Res. Part F: Traffic Psychol. Behav. 14 (5), 354–368.
Bradley, M., 1997. A practical comparison of modeling approaches for panel data. In: Golob, T.F., Kitamura, R., Long, L. (Eds.), Panels for Transportation Planning, vol. 197. Kluwer, Boston, pp. 281–304.
Cervero, R., 2002. Built environments and mode choice: toward a normative framework. Transp. Res. Part D 7, 265–284.
Chatterjee, K., Sherwin, H., Jain, J., 2013. Triggers for changes in cycling: the role of life events and modifications to the external environment. J. Transp. Geogr. 30, 183–193.
Clark, B., Chatterjee, K., Melia, S., 2015. Changes in level of household car ownership: the role of life events and spatial context. Transportation. http://dx.doi.org/10.1007/s11116-015-9589-y.
Clark, W., Huang, Y., Withers, S., 2003. Does commuting distance matter? Commuting tolerance and residential change. Regional Sci. Urban Econ. 33, 199–221.
Dargay, J., Hanly, M., 2007. Volatility of car ownership, commuting mode and time in the UK. Transp. Res. Part A 41 (1), 934–948.

Department of Communities and Local Government, 2011. English Indices of Deprivation 2010 – Guidance Document. Department of Communities and Local Government, London, UK.
Gardner, B., 2009. Modelling motivation and habit in stable travel mode contexts. Transp. Res. Part F 12, 68–76.
Giele, J., Elder, G., 1998. Methods of Life Course Research: Qualitative and Quantitative Approaches, first ed. Sage publications, London, UK.
Heinen, E., Panter, J., Mackett, R., Ogilvie, D., 2015. Changes in mode of travel to work: a natural experimental study of new transport infrastructure. Int. J. Behav. Nutr. Phys. Act. 12. http://dx.doi.org/10.1186/s12966-015-0239-8.
Johansson, M., Heldt, T., Johansson, P., 2006. The effects of attitudes and personality traits on mode choice. Transp. Res. Part A 40, 507–525.
Jones, C., Ogilvie, D., 2012. Motivations for active commuting: a qualitative investigation of the period of home or work relocation. Int. J. Behav. Nutr. Phys. Act. 9 (109). http://dx.doi.org/10.1186/1479-5868-9-109.
Lanzendorf, M., 2003. Mobility biographies. A new perspective for understanding travel behaviour. In: Anon. 10th International Conference on Travel Behaviour Research, Lucerne 10th August 2003. The International Association for Travel Behaviour Research.
Miller, E., 2005. An integrated framework for modelling short and long run household decision making. In: Timmermans, H. (Ed.), Activity Based Analysis, first ed. Elsevier Ltd, Oxford, pp. 175–201.
Oakil, A., Ettema, D., Arentze, T., Timmermans, H., 2011. A longitudinal analysis of the dependence of commute mode switching decisions on mobility decisions and life-cycle events. In: 16th International Conference of Hong Kong Society for Transportation Studies. 17–20 December 2011, Hong Kong.
Ortúzar, J., Willumsen, L., 2011. Modelling Transport, fourth ed. Wiley, Chichester.
Panter, J., Giffin, S., Dalton, A., Ogilvie, D., 2013. Patterns and predictors of changes in active commuting over 12 months. Prev. Med. 57, 776–784.
Ouellette, J., Wood, W., 1998. Habit and intention in everyday life: the multiple processes by which past behavior predicts future behavior. Psychol. Bull. 124 (1), 54.
Schwanen, T., Mokhtarian, P., 2005. What affects commute mode choice: neighbourhood physical structure or preferences towards neighbourhoods? J. Transp. Geogr. 13, 83–89.
Thørgersen, J., 2006. Understanding repetitive travel mode choices in a stable context: a panel study approach. Transp. Res. Part A 40, 621–638.
Van Acker, V., Van Wee, B., Witlox, F., 2010. When transport geography meets social psychology: toward a conceptual model of travel behaviour. Transp. Rev. 30 (2), 219–240.
Van der Waerden, P., Timmermans, H., Borgers, A., 2003. The Influence of key events and critical incidents on transport mode choice switching behaviour: A descriptive analysis. In: Paper presented at 10th International Conference on Travel Behaviour, Lucerne, Aug. 2003.
Van Ommeren, J., Rietveld, P., Nijkamp, P., 1997. Commuting: in search of jobs and residences. J. Urban Econ. 42, 402–421.
Verplanken, B., Aarts, H., Van Knippenberg, A., 1997. Habit, information acquisition and the process of making travel mode choices. Eur. J. Soc. Psychol. 27, 539–560.
Verplanken, B., Walker, I., Davis, A., Jurasek, M., 2008. Context change and travel mode choice: combining the habit discontinuity and self-activation hypotheses. J. Environ. Psychol. 28 (2), 121–127.