A comprehensive study of life course, cohort, and period effects on changes in travel mode use

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Abstract

This paper studies changes in people's travel mode use from one year to the next. It is informed by three distinct discourses: travel behaviour change, the mobility biographies approach, and cohort analysis. The data used is the German Mobility Panel (GMP) 1994 to 2008 in which households and their members are asked three times in three subsequent years to report the trips they made over a week. The changes reported are regressed to key events over the life course, cohort effects and period effects, while various sociodemographic and spatial attributes are controlled. Due to the non-independent nature of panel observations, a cluster-robust regression approach is used. The findings suggest that behind the aggregate stability in travel mode use over time there is much change 'under the surface', induced by life course changes, individual and household sociodemographic, and spatial context. The changes found induced by life course related key events favour the notion of mobility biographies. However, taken over all key events seem to be relatively loosely associated with mode use changes. Nonetheless, various significant effects of baseline variables suggest that mode use may change even in the absence of a key event.

Keywords: travel behavior change, mobility biography, travel mode choice, key event, panel analysis

1 Introduction

Changes in individual travel behaviour have become a major field of research in transportation studies in recent years (Ampt, 2003, Cao et al., 2007; Ker, 2008). Such changes may occur on a day-to-day basis (Pendyala, 2003) or in the longer term. In the latter case they have been linked to people's life courses and conceptualised as being triggered by key events in an individual's mobility biography (Lanzendorf, 2003; Scheiner, 2003). However, behavioural changes in the long term may not just be part of individual mobility biographies, but also of collective cohort and/or period related changes, in which individual life courses are embedded.

This paper studies changes in people's travel mode specific trip rates (for convenience: mode use) from one year to the next. The data used is the German Mobility Panel (GMP) 1994 to 2008 in which households and their members are asked three times in three subsequent years to report the trips they made over a week. The changes reported are regressed to key events over the life course, cohort effects and period effects, plus various sociodemographic and spatial attributes.

The goal of this paper is to contribute to and extend the recently emerged mobility biography approach by simultaneously studying this rather comprehensive set of baseline and change variables. Knowledge about the impact of life course related key events and other variables may contribute to understanding of the effectiveness of planning schemes, particularly those which are related to such events (e.g. residential moves).

This research is informed by three distinct discourses: behavioural change, the mobility biographies approach, and cohort analysis. Within the context of this journal, the use of the mobility biographies approach is relatively novel. In the next section the state of the research is introduced. Subsequently, the data and the methodology are described, followed by the results. The paper finishes with an outlook to further research.

2 Travel behaviour change – state of the research

Travel behaviour change has long been (relatively) neglected in research, even though time geography recognised the usefulness of the life path concept for travel studies as early as the 1970s (Hägerstrand, 1975). In an early study on the dynamics of travel behaviour, Clarke et al. (1982) distinguished between three levels of dynamics: first, short-term microdynamics, capturing people’s 24 h daily activity/travel choices (see for an overview of day-to-day variability of travel Pendyala, 2003); second, macrodynamic modifiers, addressing behavioural responses to transitions and trigger events over a period of some years; third, macrodynamic processes over a lifespan which are related to aging, life-cycle stages and cohort membership.

More recently, a line of research has emerged in this context that investigates travel behaviour changes triggered by temporary interventions which aim either to break habits and make choices more deliberate, or to change actual behaviour, or both. Studies are typically either based on awareness raising concepts, e.g. by making participants reflect their travel schedules or by providing information on alternatives to the car (Kenyon and Lyons, 2003), or on the provision of public transport (PT) tickets to drivers for free (Fujii and Kitamura, 2003), or both (Bamberg et al., 2003). Other studies focus on changes in transport infrastructure, such as the temporary closure of a major road (Fujii and Gärling, 2003). The authors found that those who changed from driving to PT during the road closure continued one year later to use PT more frequently than those who did not swap.

Studying behavioural changes is key to effective travel demand management as it may help clarify the triggers that make individuals re-evaluate their habits and possibly change their

behaviour. In addition, such studies can help identify the population groups that are most resistant to change in order to effectively target others who are less resistant. The interventions studied may well be understood as key events in an individual's life. The focus in the related research is, however, not so much on life course related events, but on the effects of policy measures or other incentives on travel.

A second strand of research in this context is the mobility biography approach. This perspective focuses on changes in travel behaviour that are associated with key events and/or 'biographical processes' over a life course (Lanzendorf, 2003; Scheiner, 2003; Van der Waerden et al., 2003; Axhausen et al., 2006; Harms, 2007; Scheiner, 2007)[1]. The theoretical underpinning of this approach is that travel behaviour is relatively habitual as long as daily requirements and conditions are stable. However, an individual's behaviour may change due to adaption to new circumstances and/or learning processes. This basic idea is studied within the framework of several life domains, including household situation and the family, employment, and spatial context (particularly with respect to the residence). Changes may occur on different, but interrelated temporal scales. A household type change, for instance, is normally long-term. It may induce medium- to long-term changes in mobility, for instance in terms of residential choice and vehicle holding, and these in turn may affect short-term daily travel behaviour. Key events that have been identified as transport relevant in this approach can be categorised into three life domains:

- household and family biography, including leaving the parental home, formation of a household with a partner/founding a family, birth of children, divorce, children moving out (Goodwin, 1989; Zwerts et al., 2007, Lanzendorf 2010);
- employment biography, including the commencement of job training or university entry, entry into the labour market (Harms, 2007), change of job or education, income changes (Dargay, 2001), retirement (Ottmann, 2007);
- residential biography, including residential moves and associated changes in spatial context (Bagley and Mokhtarian, 2002; Krizek, 2003; Scheiner, 2003; Stanbridge et al., 2004; Axhausen et al., 2006).

Some commentators treat gaining a driving license or the purchase or disposal of a car as key events that may affect mobility biographies. However, a note on causality is warranted here. As these key events imply pre-decisions that can be interpreted as a form of 'self-commitment' with respect to travel mode choice (Simma and Axhausen, 2001) they may be regarded as parts of the mobility biography rather than as determinants. It should be noted that other elements in the mobility biography framework also raise questions of causality. Travel behaviour changes are typically treated as the outcome in this framework, assuming that they are induced by residential relocations, for example. However, research on residential self-selection has argued in favour of bi-directional causal relationships (Cao et al., 2007; Scheiner and Holz-Rau, 2007). For instance, travel preferences and travel choices such as the decision to own a car may trigger residential choice or workplace choice.

Processes of learning may also be induced by experience gathered over longer periods. For instance, there is ongoing debate about the effect of socialisation in childhood and adolescence on adult travel behaviour (Baslington, 2007). Travel behaviour may be shaped by learning

[1] For an overview on biographical (or life course) approaches in sociology and psychology see Mortimer and Shanahan (2006), for biographical approaches in the field of residential relocation and migration see Stovel and Bolan (2004) and Kulu (2008), for an application to tourism and long-distance travel see Frändberg (2008).

processes through which behaviour is transferred from parents, school or peer groups to children, and this behaviour may then be continued in later life (Haustein et al., 2009). An example for learning from one's own experience can be taken from the distinction between the 'young old' and the 'old old' (Rosenbloom and Ståhl, 2002). Becoming an 'old old' does not necessarily involve a distinct key event (although it may be induced by a key event, such as an accident or the decease of the partner), but may well be a slow process of learning about emerging age-related physical limitations.

Life domains, key events and experiences must not be considered in isolation. For instance, residential relocations often correspond with events in employment and household biographies, such as household formation, the birth of a child or workplace change (Dieleman and Mulder, 2002). When examining the effects of residential relocation it is therefore necessary to closely consider related changes in the household context.

The mobility biography approach is individualist in nature, and thus tends to neglect generation specifics in biographies (for an exception see Heinickel and Dienel, 2006). For instance, out-migration and long-distance commuting are not just individual, but generation specific experiences shared by East German adults who were part of the labour force after the German reunification in 1990. Another example is the experience of young German families being pioneers in visiting Mediterranean tourism destinations in the 1950s and 1960s. Such collective patterns should result in cohort specific elements in mobility biographies, e.g. in cohort specific car use (Thakuriah et al., 2010).

Individualist approaches also tend to neglect structural circumstances that operate over and above individual life situations. Changing structural circumstances should result in period-specific effects in travel. They may include changing transport prices, the introduction of new and/or faster modes (high-speed trains, aeroplanes), or welfare changes over time.

Longitudinal studies allow for the distinction of age/life course, period, and cohort effects. It is not possible to simultaneously control for all these effects empirically, as the simultaneous inclusion of age, cohort and year of observation in, say, a regression model, would result in perfect multicollinearity (e.g., information on age and cohort allows a conclusion to be made on year of observation) (Glenn, 2006). However, age per se is not an impact factor for travel behaviour, but rather a proxy for other changes that are related to age, e.g. household changes, employment changes, or declining health. Thus, age as a determinant of travel may be dispensed with as soon as other, presumably more accurate impact factors are considered.

Life course events may be assumed to be more closely related to behavioural change than age. What is more, using life course events also serves to avoid multicollinearity with cohort and period effects. The analysis in this paper is based on the following hypotheses with respect to life course events, cohort and period effects.

Period effects. We expect a slight increase in car use and a decline in walking and PT use until 1999. In subsequent years, car use has been observed to stagnate or even slightly decline, while PT use has increased (BMVBS, 2010). Thus, little change in car use over the period 2000 to 2008 has to be expected, while PT use should increase.

Cohort effects. The trends described as period effects may vary by cohort. We do not know much in detail about such variation, but recent research suggests that car use may decline particularly among young adults (Kuhnimhof et al., 2011). As the period of observation is limited to 1994-2008 and, hence, does not cover a person's full lifespan, cohort effects may reflect age effects to a certain extent. Because of this overlap we expect car use to increase from one year to the next in the younger cohorts who are just about to enter the labour force, but to decrease in the older

cohorts due to age-related constraints[2]. In order to detect age v. cohort effects, models including age but excluding cohort are estimated for comparison.

Key events. Some studies on the effects of key events work with specific target groups, such as movers (Stanbridge et al., 2004) or young parents (Lanzendorf, 2010) without considering control groups. This study is based on panel data which are not limited to a certain target group. This permits testing of the effects of life course events not just in terms of the significance of change over time, but also in terms of significance against those individuals who do not experience this event and who, thus, serve as a control group. No significant change is expected for the latter. All significant effects of life course events provide evidence that life course events induce *more* change in mode use than what would happen anyway. The changes are expected to differ by type of event, and they are specified below (Section 3.5).

3 Methodology

3.1 Data

The data used is the German Mobility Panel (GMP) 1994 to 2008[3]. The GMP is a household survey with the sample organised in overlapping waves. Every household is surveyed three times over a period of three consecutive years (Chlond and Kuhnimhof, 2005), e.g. from 1994-1996, before being excluded from the survey. A trip diary is used to collect information on trips over a whole week from all household members aged ten years or over. Sociodemographic attributes for the household and its members are collected as well as spatial context attributes at the residence and at the household members' places of work or education.

An important limitation is that household income has only been recorded since 2002. Income is thus excluded from the analysis, rendering it impossible to investigate the effects of income changes. Education level and employment status are used as rough proxies for income. Another limitation is the period of observation on the individual level. Changes can only be observed as long as they occur from one year to the next. Dargay (2001) found evidence for lagged changes in car ownership after income changes. However, we study mode specific trip rates, and we expect trip rates to adapt relatively fast to life course related changes. First, because additional trip making does not require much investment (other than car ownership), and second, because changes in activity patterns and associated trips are often a direct outcome of life course events. Hence little delay is expected. In any case, this data limitation has to be kept in mind.

Coding multiple life course events results in missing values in many cases (see Scheiner, 2011 for details). As life course events are relatively rare events in an individual's life, we assume no event in cases of uncertainty. The coefficients estimated are thus based on changes among those for whom it is relatively certain an event occurred, while some of those for whom no event is assumed may in fact have experienced one. However, missing values are to a large extent due to unemployed individuals where information on access to the workplace is missing. Coding these cases as not having experienced a change in access does not yield a problem. Changes in mode use among those falsely coded as having experienced no event may be expected to take various

[2] This is not a contradiction to the observation that car use declines among young adults, compared to young adults in earlier decades. Even given this decline, car use on the individual level may increase over time, starting from a low level, as an effect of life course related changes.

[3] The GMP is conducted by the University of Karlsruhe on behalf of the Federal Ministry of Transport, Building and Urban Development (BMVBS). The data are provided for research use by the Clearingstelle Verkehr (www.clearingstelle-verkehr.de).

directions rather than being biased systematically into a particular direction. Thus, the coefficients estimated should be unbiased. However, the level of significance may be underestimated due to variance inflation among those falsely coded as having experienced no event.

The regression models are based on a sample of 11,236 out of a total of 23,520 individual weeks of report for whom complete information (other than that discussed above) is available. This sample is composed of 6,932 individuals, for 4,304 of whom two observations of change are available (from the first to the second and from the second to the third year of report).

3.2 Analysis approach

While most mobility biography studies to date focus on a particular life event, this paper uses regression modelling to detect the effects of a comprehensive set of life course events, cohort and period effects on travel mode use. Descriptive analysis of selected life course events that turned out to be significant in regression is presented as well. As biographies may be starkly gendered in many respects including travel behaviour changes (see for example Zwerts et al., 2007) and our data exhibit significant gender effects, the descriptive tables are categorised by gender.

The panel nature of the data results in non-independent (clustered) observations, thus violating a most basic assumption of statistical analysis. The use of OLS regression with such data may result in the underestimation of standard errors because the amount of independent information available is inflated. The significance of parameters may therefore be overestimated (Hedeker et al., 1994). Although it is standard practice in transport studies to ignore cluster structures in data that emerge from observing multiple trips made by one person, or from multiple persons living within the same household, the problem of non-independence is likely to be even more marked in repeat observations of the same individuals.

There are two basic ways of treating panel data in regression. Either one employs a random effects model or cluster-robust estimation based on pooled data. The former has the disadvantage that it assumes constant correlation between successive observations of the same unit. In contrast, clustered regression with pooled data allows for arbitrary correlation. The estimates are less efficient, and, similar to OLS, the standard errors may be too small when the number of clusters is finite (Wooldridge, 2003; Nichols and Schaffer, 2007). However, the cluster-robust standard error estimator converges to the true standard error as the number of clusters (not the number of observations) approaches infinity (Kézdi, 2004; Nichols and Schaffer, 2007). Given the relatively large sample and cluster number, neither of these issues should raise serious concern.

Hence, we use a pooled data approach and account for clustering by using a robust estimation method controlling for autocorrelation within subjects emerging from the temporal order (sequence) of records. As the analysis is at the person level, this means that the correlation matrix of within-subject dependencies is estimated as part of the model. The SPSS procedure GEE (generalised estimating equations) is used for the analysis. This procedure has been used in few transport studies before (an exception is Heinen et al., 2011).

Concerning model specification (see Garson, 2010 for details), the autoregressive correlation type is used, because the temporal order of within-subject measurements means that values at a given point in time are a function of prior values plus error term. We work with continuous dependent variables, assuming normal distribution with untransformed variables. A graphical inspection reveals that this assumption holds true, which is not surprising as behavioural change from one year to the next is scattered around zero.

Unlike OLS regression, there is no determination coefficient available for cluster-robust regression. SPSS reports a quasi likelihood under independence criterion (QIC) which is an extension of the Akaike Information Criterion (AIC) for repeated measures (Garson, 2010). It is available in a corrected form (QICC) that penalises model complexity and small sample size. QICC works in a 'the smaller the better' form. This is reported for the final models as well as for the intercept models. However, there is no formal test of significance in model improvement available.

For comparison we estimated OLS regressions. The results are documented elsewhere (Scheiner, 2011). OLS regressions are known to be relatively robust against mild violations of assumptions. A comparison of the cluster-robust regressions with the OLS regressions shows different levels of significance in some cases. However, the two modelling approaches generally yield very similar results both for the signs and the magnitudes of the coefficient estimations, supporting the robustness of the findings. We present the cluster robust models here which many readers may be less familiar with to make sure that the specific structure of the data is accounted for.

3.3 Dependent variables

The variables studied are changes in travel mode specific trip rates from one year to the next on the person level, including five modes: car as a driver, car as a passenger, public transport, bicycle and walking. The variables are computed using mean trip frequencies per day over the week of report, taking the difference between the value in the year of interest and that in the preceding year. Changes in the fraction of trips made by a given mode among all trips a person reported having made were studied for comparison. These models yield very similar results, and they are reported elsewhere (Scheiner, 2011). They are considered for interpretation here as appropriate.

The differences between trip shares and trip rates as regards content are that mode specific trip rates reflect the frequency of use of a given mode (i.e. mode use) rather than an individual's relative inclination (i.e. choice) to use this mode. Modal split shares on the other hand reflect an individual's relative propensity to choose a particular mode, given his/her trip rate.

3.4 Explanatory variables I – baseline values

Various state and change variables in sociodemographics and spatial context at the residence and at the place of work or education (for the sake of brevity: workplace) are considered as explanatory variables. Change variables reflect life course events or changes in context (see next section). State variables reflect the baseline value observed in the year prior to change. Some of the variables used are explained in the following, as required (see Table 1 and Table 2 for the full set along with the descriptive statistics).

We use self-reported car availability rather than a more objective measure such as the number of cars per driver in the household, as the former explains a considerably higher share of variance[4]. It should be noted that car availability is endogeneous to sociodemographics (Salomon and Ben-Akiva, 1983; Scheiner and Holz-Rau, 2007; Van Acker and Witlox, 2010), which may result in biased estimations.

[4] Using the latter variable yields effects with the same signs and relative magnitudes (i.e. stronger effects for an increase than for a decrease in car availability), but with considerably lower absolute magnitudes.

With respect to cohort effects, we consider cohort plus cohort squared divided by 100 in order to capture non-linear effects. Those born in 1900 are coded as cohort zero while the younger cohorts are assigned larger values (i.e. those born in 1901 are coded as cohort one). It should be noted that the resulting variable does not perfectly correlate with age, as cohort depends exclusively on year of birth, while age also depends on year of observation.

	type*	min	max	mean	standard deviation
Dependent variables					
Change in number of trips per day made...					
... by car as a driver	C	-6.71	6.69	-0.02	1.05
... by car as a passenger	C	-3.71	3.34	-0.01	0.58
... by PT	C	-3.14	3.33	-0.01	0.41
... on foot	C	-6.57	4.75	-0.01	0.75
... by bicycle	C	-5.14	5.24	0.01	0.56
Explanatory variables					
Gender, household, family biography					
No. of children in household (< 10 yrs)	B	0	4	0.28	0.63
No. of children in household (10-13 yrs)	B	0	3	0.17	0.44
No. of children in household (14-17 yrs)	B	0	3	0.18	0.44
Spatial context at residence, residential moves					
Urbanity (variety of facilities in neighbourhood accessible on foot)	B	0	5	3.07	1.41
PT quality in neighbourhood (variety of different systems accessible on foot)	B	0	5	2.45	1.07
Change in urbanity	C	-5	5	-0.02	1.11
Change in PT quality	C	-3	3	0.00	0.71
Cohort and period					
Cohort (94 yrs in 1994 = 0)	B	5	96	54.80	18.17
Cohort, squared, div. by 100	B	0.25	92.2	33.33	20.71
Year of survey (1994 = 0)	B	0	13	6.99	3.59
Year of survey * dummy '2000 or later' (interaction)	B	0	13	5.87	4.80
Baseline values of mode use					
... by car as a driver	B	0	10.8	1.65	1.56
... by car as a passenger	B	0	10.4	0.49	0.63
... by PT	B	0	4.4	0.29	0.58
... on foot	B	0	9.4	0.79	0.90
... by bicycle	B	0	7.4	0.36	0.76

Table 1: Continuous variables used in regression: definitions and descriptive statistics

* B = baseline variable; C = change variable.

To capture period effects, the year of survey (1994 equals zero) is considered, plus an interaction term of year multiplied by a dummy taking the value one for years from 2000, and zero for years to 1999, as mode choice trends in the aggregate tended to change from this year. For comparison we ran models including age plus age squared, but excluding cohort. These models turned out as virtually identical to those including cohort. However, age effects turned out as just significant for PT use only, while cohort was strongly significant for car use as a driver and public transport use. Thus, cohort is used for further analysis.

With respect to access to the workplace, we use three different measures, all as subjectively reported by the respondents. Walking distance from the nearest PT stop to work or education is recorded in three categories in the data (< 10, 10-20, > 20 minutes). Only one dummy is used as a baseline value, indicating whether the walking distance is less than 10 minutes or not. At this threshold travel mode choice changes considerably. The PT connection to work is measured in

five categories. The two categories 'speedy direct connection' and 'one transfer required' are associated with very similar PT modal split shares and, hence, they are summarised into one dummy 'good connection'. The same is true for the categories 'slow direct connection' and 'more than one transfer required', which are therefore summarised into one dummy 'poor connection'. The last answer category is 'no PT connection available', which is used as a separate dummy. The parking situation at the workplace is recorded in four categories, out of which the two 'better' categories ('more good than difficult' and 'good') are associated with similar modal splits. Hence, they are summarised into one reference category.

The data include information on walking access in the neighbourhood to various PT systems (bus, tram, underground, regional train (S-Bahn), long-distance train) and facilities (groceries, other shopping facilities, restaurants/pubs, evening leisure facilities, sports facilities). This information is used to calculate two variables that reflect the quality of the PT supply and the degree of urbanity at the residence, i.e. here the variety of neighbourhood facilities. Both variables are based on the number of different PT systems or facilities accessible on foot. Additionally, a self-reported variable of living at a central or remote location within the city is included. This information is only available for medium sized towns and cities. Small towns and villages are coded as remote.

Finally, we include the respective baseline value of the mode use under study in the year prior to change, as those with a high level of use of a particular mode may be expected to reduce it more than those who hardly use it anyway (Krizek, 2003).

	type*	per cent 'yes'
Gender, household, family biography		
Gender female	B	52.5%
Living with partner	B	75.9%
Birth of a child	C	2.0%
Household formation with partner	C	2.0%
Separation from partner	C	1.5%
Child moving out	C	2.1%
Social status, employment and educational biography		
Full-time employed (reference)	B	34.9%
Part-time employed	B	14.0%
Apprenticeship, trainee, in education	B	13.7%
Not employed	B	37.4%
Education level	B	
Elementary school qualification ...without apprenticeship or no qualification	B	14.3%
...plus apprenticeship	B	25.5%
Secondary school qualification level I	B	28.7%
University entrance qualification or higher (reference)	B	31.5%
Commencement of job training, apprenticeship, university entry	C	0.6%
Completion of school, apprenticeship, or university	C	6.1%
Entry into labour market	C	3.7%
Change of workplace	C	7.0%
Leaving labour market (not retirement)	C	2.2%
Retirement	C	2.8%

Access to place of work (or education) and associated changes		
Walking distance from PT stop to place of work or education is 10 minutes or more	B	12.9%
PT connection to place of work	B	
Good connection (reference)	B	64.2%
Poor connection	B	18.4%
No connection	B	17.5%
Parking situation at place of work	B	
Good / more good than difficult (reference)	B	86.0%
Difficult	B	7.5%
Very difficult	B	6.5%
Walking distance from PT stop to place of work gets...	C	
... much longer	C	1.0%
... somewhat longer	C	3.5%
... much shorter	C	1.0%
... somewhat shorter	C	3.5%
PT connection to place of work gets...	C	
... worse	C	7.3%
... much worse	C	2.7%
... better	C	7.1%
... much better	C	2.6%
Parking situation at place of work gets...	C	
... worse	C	6.2%
... much worse	C	1.7%
... better	C	5.8%
... much better	C	2.0%
License ownership and car availability, and associated changes		
Driving license held	B	79.7%
Passing driving license	C	2.3%
Loss of driving license	C	1.2%
Car availability	B	
Not available (reference)	B	29.4%
Occasionally / after agreement	B	11.9%
Regularly	B	58.7%
Increase in car availability	C	5.9%
Loss in car availability	C	5.3%
Spatial context at residence, relocation		
Municipality with < 20,000 inh (reference)	B	41.6%
Municipality with 20,000-100,000 inh	B	27.5%
Municipality with 100,000-500,000 inh	B	17.2%
Municipality with > 500,000 inh	B	13.8%
Central residential location within city	B	15.3%
Move to centre	C	2.9%
Move to periphery	C	2.8%
Move to larger municipality	C	0.9%
Move to smaller municipality	C	1.0%
n		11,236

Table 2: Dummy variables used in regression: definitions and descriptive statistics

All variables are coded as yes=1, no=0.
* B = baseline variable; C = change variable.

3.5 Explanatory variables II – life course events

A rather comprehensive set of life course events and changes in spatial context is considered. These are coded as dummies taking the value one for individuals who experienced a particular event, and zero for those who did not. Separate dummies for changes in opposite directions permit the detection of asymmetrical effects. It should be noted that some events are experienced only by relatively few individuals, which may result in non-significance even when associated changes in mode use are relatively pronounced. The rarest event in the data is the start of apprenticeship or university entry, which is experienced by 73 respondents (0.6%) (Table 2). Brief variable descriptions for the life course events under study are given in Table 3, along with their hypothesised effects on mode use (in a simplified form). We do not expect all events to have significant effects on travel mode use.

Again, some variables require brief explanations (for details see Scheiner, 2011). The walking distance from the nearest PT stop to the workplace getting 'much' longer (or shorter) means an increase (or decrease) of more than 10 minutes. With respect to the PT connection to the workplace, the three categories described above are used to compute dummy variables of change. Getting 'much better' means the connection changes from 'not available' to 'good', and vice versa. Similarly, dummy variables of change are computed for the parking situation at the workplace, in which 'getting much better' or 'much worse' implies a change into the next but one category.

Changes are also computed for the measures of urbanity and PT system quality at the residence described above. These changes may reflect residential moves or changes in urban form or in the transport system at the place of residence. A change report in the dummy 'central location of residence within the city' is also used to capture the direction of a move (towards a more central or a more remote location). Finally, moving to a larger or smaller municipality is captured by dummies which are calculated from a change in municipality size (recorded in six categories).

4 Results

4.1 Descriptive analysis

In the following some descriptive statistics of mode use change associated with life course events are presented. The events are selected based on their significance in regression. As expected, those who did not experience a key event over the year under study show little change in mode use (Table 4). To facilitate interpretation, the table also includes state variables of trip frequencies for the total sample.

The birth of a child is associated with both more driving and more walking, confirming expectations, as babies do not just need to be driven, but also to be taken for walks. These changes are accompanied by a decrease in the use of all other modes, especially the bicycle. The changes are strongly gendered, and they mainly refer to women, whereas for men a child's birth does not seem to have that much of an effect on mode use, except that their cycling and PT use declines.

The formation of a household with a partner has been hypothesised to result in little change in mode use. However, this event turns out to result in fewer trips made as a car driver and more cycling. Taking gender into account suggests some kind of change in driving workshare. While men drive less and make more trips as passengers after household formation, it is the other way round for women.

Key event	Variable description	Hypothesised effect on… Car use	PT use	NMT use
Household biography				
(Leaving the parental home)	Impossible to model, as the parent household rather than the descendant household would be traced further	0	0	0
Household formation with partner	Household type change from single household or single parent to couple or family	0	0	0
Birth of a child	Increase in number of children under 10 years of age	+	–	+
Separation from partner	Household type change from couple or family to single or single parent	0–	0+	0+
Child moving out	Decrease in household size plus household type change from family to family or couple or from single parent to single parent or single household	0–	0	0
Employment biography				
Commencement of job training, apprenticeship, or university entry	Change from employment or unemployment to job training, apprenticeship, school or university	–	+	0
Entry into the labour market	Change from non-employment job training, apprenticeship, school or university to employment	+	–	–
Change of job or education	Self-reported change	0+	0–	0–
Leaving the labour market (not retirement)	Change from employment to non-employment (not retirement)	–	0+	+
Change in access to place of work or education	Walking distance from PT stop to workplace:			
	Increase	+	–	0–
	Decrease	–	+	0+
	PT system quality			
	Increase	–	+	0+
	Decrease	+	–	0–
	Parking places at workplace			
	Increase	+	–	0–
	Decrease	–	+	0+
Retirement	Change into retirement or change into non-employment for those aged 60+	–	0+	+
Spatial mobility				
Change in driving license status	Change in self-reported license possession			
	Gain	+	–	–
	Loss	–	+	+
Change in car availability	Change in self-reported car availability			
	Increase	+	–	–
	Decrease	–	+	+
Residential move	Move to inner city	–	+	+
	Move to periphery	+	–	–
	Move to larger municipality	–	+	+
	Move to smaller municipality	+	–	–
Spatial change at residence (or move)	Increase in urbanity	–	0+	+
	Increase in PT quality	–	+	0+
(Entry into 'old age')	Impossible to model, as 'old age' does not imply a fixed age threshold	–	0	+

Table 3: Life course events in regression: definitions and hypothesised effects

NMT: non-motorised transport.
+ increase; 0+ slight increase; – decrease; 0– slight decrease; 0 no change hypothesised.

With respect to employment biography events, entry into the labour market is associated with more driving (particularly for men) and less walking. While men appear to change their mode use from walking, cycling or using PT exclusively towards driving when commencing a job, women seem to change from walking to driving or using PT.

A decrease in walking distance from the PT stop to work results in an increase in PT use, but also in more cycling and walking. This suggests that the changes in egress time (walking distance from the stop) are not so much due to changes in the PT system, but rather in the location of work. In any case, decreases in walking distances are associated with considerably less driving, particularly among women. The effect on driving is even more notable as the figures presented include all trips, rather than just the commute. On the other hand, strong increases in walking distances (from less than 10 minutes to more than 20 minutes) are associated with more driving, particularly among men. A control analysis categorised by trip purpose shows that about two thirds of the driving trips saved by more proximate PT stops are due to trips to work or education, while one third is due to other trips (no table). This analysis also suggests that a closer PT stop affects men's travel mode use on trips to work/education as much as women's. However, men seem to compensate less driving to work with more driving for other purposes, while women tend to reduce their driving for other purposes likewise.

Relatively pronounced effects can also be seen for changes in the parking situation at the workplace, as long as these changes are substantial. When the parking situation gets much more difficult, people (particularly men) drive less. Instead, men use cars more often as passengers, or they cycle, while women tend to use PT more often. When the parking situation gets much easier, people (particularly women) drive more, and they less frequently use PT as well as cars as passengers, and they walk less.

Gaining a driving license is a key event for most individuals. Similar to car purchase or disposal, it is not just an impact factor for travel mode use, but it may be endogeneous to mode use. Young people may not just drive because they have gained a license, but may be eager to get licensed because they want to drive. This said, gaining a driving license is strongly positively associated with driving, and negatively with riding in a car as a passenger, using PT, and cycling. All these associations are more pronounced for men than for women.

Similarly, changes in car availability show the expected effects on mode use. The frequency of driving increases with the level of car availability, and for all other modes it is the other way round. The effects of car disposal on driving outbalance the effects on all other modes taken together. Thus, the disposal of a car seems to be associated with a general decrease in travel. This may be due to the mobility the car provides or to other changes associated with car disposal, e.g. loss in physical capabilities or other aspects of health. Subsequently the results of multiple regressions are described.

		Car (driver)	Car (pass)	Public transport	On foot	Bicycle	n
Birth of a child	M	-0.02	0.02	-0.10	0.00	-0.08	120
	F	0.13	-0.18	-0.05	0.20	-0.26	130
	All	0.05	-0.08	-0.07	0.10	-0.17	250
Household formation with partner	M	-0.24	0.07	-0.01	-0.04	0.11	125
	F	0.05	-0.07	0.00	-0.01	0.07	115
	All	-0.11	0.01	0.00	-0.03	0.09	240
Entry into the labour market	M	0.24	-0.02	-0.10	-0.10	-0.10	178
	F	0.12	-0.06	0.10	-0.16	0.04	260
	All	0.17	-0.04	0.01	-0.14	-0.02	438

Walking distance from PT stop to workplace							
Strong decrease	M	-0.01	0.13	0.08	0.16	0.01	56
	F	-0.29	-0.10	0.20	0.11	0.18	60
	All	-0.14	0.03	0.14	0.14	0.09	116
Decrease	M	-0.01	0.08	0.05	-0.06	0.01	223
	F	-0.12	-0.07	0.02	0.05	0.01	212
	All	-0.06	0.01	0.04	-0.01	0.01	435
Increase	M	-0.06	0.09	0.01	-0.05	-0.04	210
	F	-0.01	-0.13	0.01	-0.11	0.03	206
	All	-0.03	-0.02	0.01	-0.08	-0.01	416
Strong increase	M	0.21	-0.02	-0.10	-0.12	0.04	63
	F	0.10	-0.01	-0.20	-0.07	-0.06	66
	All	0.16	-0.01	-0.14	-0.10	0.00	129
Parking situation at the workplace gets...							
...much more difficult	M	-0.24	0.10	-0.02	0.05	0.11	108
	F	-0.12	-0.04	0.14	-0.04	-0.08	93
	All	-0.19	0.04	0.05	0.01	0.02	201
...more difficult	M	0.03	0.10	0.01	-0.04	-0.02	390
	F	0.00	-0.10	0.05	0.00	-0.02	348
	All	0.02	0.01	0.02	-0.02	-0.02	738
...easier	M	-0.10	0.05	-0.02	-0.03	-0.04	357
	F	0.05	-0.11	0.00	0.00	0.06	337
	All	-0.03	-0.03	-0.01	-0.02	0.01	694
...much easier	M	0.10	0.06	-0.20	-0.06	0.05	121
	F	0.34	-0.23	-0.16	-0.24	-0.02	113
	All	0.21	-0.08	-0.18	-0.14	0.02	234
Decrease in car availability	M	-0.31	0.06	0.04	-0.02	0.02	303
	F	-0.16	-0.01	0.05	0.04	0.00	340
	All	-0.23	0.03	0.05	0.01	0.01	643
Increase in car availability	M	0.24	-0.09	-0.07	-0.03	-0.03	318
	F	0.26	-0.11	-0.07	-0.07	-0.07	395
	All	0.25	-0.10	-0.07	-0.05	-0.05	713
Gaining a driving license	M	0.85	-0.22	-0.21	-0.04	-0.21	130
	F	0.56	-0.04	-0.06	-0.06	-0.12	151
	All	0.70	-0.12	-0.13	-0.05	-0.16	281
Reference groups							
None of the key events studied in	M	-0.04	-0.01	0.01	-0.06	0.03	954
regression occurred	F	-0.02	0.00	0.01	-0.02	-0.01	1,096
	All	-0.03	0.00	0.01	-0.04	0.01	2,050
Total sample	M	-0.03	-0.01	-0.01	-0.02	0.00	5,738
	F	0.01	-0.02	0.00	-0.02	0.00	6,382
	All	-0.01	-0.01	0.00	-0.02	0.00	12,120
State variables (daily trip frequencies)	M	1.86	0.32	0.30	0.72	0.38	5,745
Total sample	F	1.19	0.62	0.36	0.91	0.36	6,390
	All	1.50	0.47	0.33	0.82	0.36	12,135

Table 4: Changes in mean trip frequencies per day after experiencing various life course events, categorised by gender

M: male, F: female.

4.2 Multivariate analysis

Baseline variables effects

Perhaps surprisingly, a number of baseline variables significantly affect changes in mode use (Table 5). The number of children in the household positively affects driving. This holds both for children aged 10 or younger and children aged 14 to 17. Being female is associated with decreased driving and increased trip-making as a car passenger. Women also tend to have an increased frequency of walking. Living as a couple is associated with decreased walking and driving frequencies, and increased trips as a car passenger. Employment status is significant to a certain extent, most pronounced in terms of decreased driving for those still in education. Those with low education levels tend to decrease both their driving and walking, and those with medium education levels tend to decrease their cycling.

While these sociodemographic associations are generally in line with what one would expect for travel mode use at a given point in time, the interpretation of their effects on changes in mode use is less obvious. One may hypothesise, say, that couples decrease their driving from one year to the next more than those living without a partner, because they have more options to organise their workshare more efficiently in order to react to increasing fuel prices – but we do not yet know whether this is true or not. Apparently there are changes in mode use over an individual's life course that are associated with particular life situations, but not necessarily with certain key events.

Similarly, access to the workplace has some significant effects. A poor PT connection is associated with declining PT use, and a difficult parking situation at the workplace leads to significantly reduced driving and more PT use. Again, while these observations are in line with expections for baseline mode use, there is no obvious reason to expect, for instance, a decline in car use when the parking situation was already difficult in the baseline year. Perhaps these findings reflect learning processes over time. They may be considered relatively strong (particularly the effect of a very difficult parking situation on changes in driving), as the effects on all trips are under study here, rather than effects on just the commute.

Driving license holdership and car availability both have significant effects on changes in mode use. License holders and car owners tend to increase their driving frequency more than others. For license holding, this is at the expense of using the car as a passenger, while for car ownership it is at the expense of PT ridership, walking and cycling.

Municipality size also has some significant effects. The positive effect of living in a large city on PT use and the negative effect on driving are most pronounced. On a more micro-spatial level, urbanity and central locations are associated with increased walking and (somewhat) decreased car use, while PT quality positively affects PT use and cycling. Again, these effects of spatial context may reflect learning processes. Individuals living in cities, and particularly those living in inner-city neighbourhoods with well-established PT services, may be more adaptive to increasing fuel prices or other changes, as they have more alternatives available.

Cohort effects are only minor, but are nonetheless significant. Cohort is positively associated with driving and negatively with PT use. That is to say, subsequent cohorts drive more and use PT less than their predecessors. The effects of 'cohort squared' - negative (not significant) on driving and positive on PT use – suggest that the cohort specific changes are smoothing over time. As outlined above, the cohort effects found here may to a certain extent reflect age.

		Car (driver)			Car (passenger)			Public transport			On foot			Bicycle		
		B	Exp (B)	Sig.	B	Exp (B)	Sig.	B	Exp (B)	Sig.	B	Exp (B)	Sig.	B	Exp (B)	Sig.
Intercept		-0.01	0.99	0.88	0.06	1.06	0.29	0.24	1.28	0.00	0.22	1.24	0.00	0.03	1.03	0.59
Gender, household, family biography																
Gender female	B	-0.12	0.89	0.00	0.14	1.16	0.00	0.00	1.00	0.83	0.03	1.03	0.03	-0.01	0.99	0.38
No. of children in household (< 10 yrs)	B	0.07	1.07	0.00	-0.01	0.99	0.09	0.00	1.00	0.63	0.01	1.02	0.17	0.02	1.02	0.01
No. of children in household (10-13 yrs)	B	-0.01	0.99	0.58	-0.01	0.99	0.25	0.01	1.01	0.51	0.00	1.00	0.88	0.03	1.03	0.03
No. of children in household (14-17 yrs)	B	0.10	1.11	0.00	0.02	1.02	0.07	-0.01	0.99	0.37	-0.04	0.96	0.01	-0.01	0.99	0.36
Living with partner	B	-0.05	0.96	0.02	0.08	1.09	0.00	-0.02	0.98	0.02	-0.06	0.94	0.00	0.00	1.00	0.80
Birth of a child	C	-0.03	0.97	0.71	-0.08	0.92	0.03	-0.04	0.96	0.07	0.14	1.15	0.01	-0.12	0.88	0.00
Household formation with partner	C	-0.08	0.92	0.26	0.13	1.14	0.00	0.01	1.02	0.53	-0.04	0.96	0.41	0.04	1.04	0.15
Separation from partner	C	-0.07	0.94	0.36	-0.03	0.97	0.39	0.05	1.05	0.14	0.06	1.06	0.29	-0.01	0.99	0.78
Child moving out	C	-0.10	0.90	0.11	-0.03	0.97	0.31	0.04	1.04	0.06	-0.01	0.99	0.71	0.05	1.05	0.29
Social status, employment and educational biography																
Employment (reference: full-time)	B															
Part-time employed	B	0.06	1.06	0.07	-0.01	0.99	0.53	0.00	1.00	0.74	0.04	1.04	0.07	0.03	1.03	0.09
Apprenticeship, trainee, in education	B	-0.17	0.84	0.00	0.05	1.05	0.11	0.01	1.01	0.64	0.05	1.05	0.19	0.00	1.00	0.95
Not employed	B	-0.01	0.99	0.71	0.02	1.02	0.24	-0.04	0.97	0.01	0.04	1.05	0.06	0.01	1.01	0.40
Education level (reference: university entrance qualification or higher)	B															
Elementary school qualification without ...apprenticeship or no qualification	B	-0.09	0.91	0.01	0.01	1.01	0.54	0.01	1.01	0.59	-0.07	0.94	0.01	0.01	1.01	0.76
...plus apprenticeship	B	-0.03	0.97	0.19	0.02	1.02	0.08	-0.01	0.99	0.08	-0.03	0.97	0.07	-0.04	0.96	0.00
Secondary school qualification level I	B	0.01	1.01	0.79	-0.01	0.99	0.46	-0.01	0.99	0.22	-0.02	0.98	0.24	-0.04	0.96	0.00
Commencement of apprenticeship, university entry	C	-0.14	0.87	0.38	0.06	1.07	0.40	0.03	1.03	0.66	-0.07	0.93	0.40	-0.02	0.98	0.84
Completion of school or apprenticeship	C	0.00	1.00	0.94	0.01	1.01	0.50	-0.01	0.99	0.56	0.01	1.01	0.73	-0.02	0.98	0.40
Entry into labour market	C	0.25	1.29	0.00	-0.03	0.97	0.27	0.01	1.01	0.73	-0.07	0.93	0.10	-0.03	0.97	0.31
Change of workplace	C	0.01	1.01	0.84	-0.02	0.98	0.29	0.01	1.01	0.76	-0.04	0.96	0.13	0.01	1.01	0.79
Leaving labour market (not retirement)	C	0.04	1.05	0.61	0.01	1.01	0.82	-0.07	0.93	0.00	0.12	1.13	0.02	-0.05	0.96	0.16
Retirement	C	-0.06	0.95	0.29	0.00	1.00	0.99	-0.01	0.99	0.67	0.05	1.05	0.22	0.06	1.06	0.07

Access to place of work or education and associated changes															
Walking distance from PT stop to work 10 minutes or more	B	-0.02	0.98	0.59	-0.04	0.96	0.02	-0.01	0.99	0.30	-0.03	0.97	0.20	-0.01	0.99	0.41
PT connection (reference: good)	B															
Poor connection	B	0.03	1.03	0.38	0.00	1.00	0.90	-0.02	0.98	0.04	-0.02	0.98	0.30	-0.02	0.98	0.28
No connection	B	0.03	1.03	0.34	-0.01	0.99	0.58	-0.05	0.95	0.00	-0.02	0.98	0.40	0.00	1.00	0.93
Parking situation at work (reference: good or more good than difficult)	B															
Difficult	B	-0.05	0.95	0.18	0.00	1.00	0.97	0.05	1.05	0.00	-0.01	0.99	0.78	0.00	1.00	0.99
Very difficult	B	-0.11	0.89	0.00	0.00	1.00	0.99	0.06	1.07	0.00	-0.01	0.99	0.68	0.00	1.00	0.92
Walking distance from PT stop gets...	C															
... much longer	C	0.05	1.05	0.58	-0.01	0.99	0.78	-0.08	0.93	0.06	-0.13	0.88	0.00	-0.05	0.95	0.12
... somewhat longer	C	-0.02	0.98	0.68	-0.05	0.95	0.07	0.03	1.03	0.15	-0.05	0.95	0.10	-0.02	0.98	0.48
... much shorter	C	-0.15	0.86	0.11	0.05	1.05	0.33	0.10	1.11	0.07	0.14	1.15	0.05	0.11	1.12	0.08
... somewhat shorter	C	-0.06	0.94	0.32	0.02	1.02	0.41	0.06	1.06	0.02	-0.01	0.99	0.75	0.00	1.00	0.98
PT connection gets...	C															
... worse	C	0.02	1.02	0.66	0.04	1.04	0.05	0.01	1.01	0.57	-0.06	0.94	0.01	-0.04	0.96	0.03
... much worse	C	0.04	1.04	0.53	0.03	1.03	0.36	-0.02	0.98	0.38	0.03	1.03	0.51	0.01	1.01	0.84
... better	C	-0.02	0.98	0.58	0.00	1.00	0.81	-0.02	0.98	0.29	-0.01	0.99	0.82	0.01	1.01	0.46
... much better	C	0.04	1.04	0.55	-0.04	0.96	0.14	0.01	1.01	0.49	0.02	1.02	0.59	-0.02	0.98	0.54
Parking situation gets...	C															
... worse	C	0.01	1.01	0.82	0.00	1.00	0.83	0.02	1.02	0.31	-0.04	0.96	0.12	-0.01	0.99	0.60
... much worse	C	-0.19	0.83	0.01	-0.01	0.99	0.71	0.07	1.07	0.06	0.02	1.02	0.59	0.00	1.00	0.99
... better	C	0.07	1.07	0.12	0.01	1.01	0.63	-0.05	0.95	0.00	0.00	1.00	0.95	0.01	1.01	0.60
... much better	C	0.18	1.19	0.04	0.03	1.03	0.43	-0.13	0.87	0.00	-0.11	0.90	0.03	0.01	1.01	0.71
License holding and car availability and associated changes																
Driving license holding	B	0.15	1.16	0.00	-0.12	0.89	0.00	-0.03	0.97	0.17	-0.05	0.95	0.07	0.02	1.02	0.36
Achievement of driving license	C	0.72	2.06	0.00	-0.15	0.86	0.00	-0.14	0.87	0.00	-0.06	0.94	0.22	-0.11	0.89	0.00
Loss of driving license	C	-0.04	0.97	0.68	0.06	1.06	0.14	0.08	1.08	0.05	0.01	1.01	0.84	0.00	1.00	0.90
Car availability (reference: no)	B															
Occasionally / after agreement	B	0.10	1.10	0.00	0.06	1.07	0.00	-0.05	0.95	0.00	-0.01	0.99	0.59	-0.06	0.94	0.01
Regularly	B	0.41	1.51	0.00	0.02	1.02	0.30	-0.10	0.90	0.00	-0.06	0.94	0.00	-0.08	0.92	0.00
Increase in car availability	C	0.33	1.39	0.00	-0.04	0.96	0.09	-0.09	0.92	0.00	-0.06	0.94	0.04	-0.03	0.97	0.29

Loss in car availability	C	-0.33	0.72	0.00	0.05	1.06	0.02	0.07	1.07	0.00	0.06	1.06	0.05	0.03	1.03	0.17
Spatial context at residence, relocation																
Municipality size category (reference: < 20,000 inh)	B															
20,000-100,000 inh	B	0.01	1.01	0.55	0.03	1.03	0.00	-0.01	0.99	0.30	-0.02	0.98	0.14	0.02	1.02	0.10
100,000-500,000 inh	B	0.00	1.00	0.92	0.00	1.00	0.90	0.03	1.03	0.02	0.01	1.01	0.67	-0.02	0.98	0.09
> 500,000 inh	B	-0.07	0.93	0.01	-0.03	0.97	0.05	0.09	1.09	0.00	-0.04	0.97	0.09	-0.01	0.99	0.45
Central residential location within city	B	-0.03	0.97	0.19	-0.04	0.96	0.00	-0.01	0.99	0.52	0.12	1.12	0.00	-0.03	0.97	0.07
Urbanity (Variety of facilities in neighbourhood accessible on foot)	B	-0.02	0.98	0.01	-0.01	0.99	0.08	0.00	1.00	0.06	0.04	1.04	0.00	0.01	1.01	0.00
PT quality in neighbourhood (variety of different systems accessible on foot)	B	0.00	1.00	0.65	0.00	1.00	0.49	0.01	1.01	0.01	0.01	1.01	0.16	0.01	1.01	0.01
Move to centre	C	-0.01	0.99	0.83	-0.01	0.99	0.72	0.02	1.02	0.52	-0.07	0.93	0.07	-0.06	0.94	0.08
Move to periphery	C	0.05	1.05	0.34	0.02	1.02	0.40	-0.02	0.98	0.42	-0.17	0.85	0.00	0.07	1.07	0.09
Move to larger municipality	C	-0.18	0.84	0.06	-0.03	0.97	0.57	0.02	1.02	0.68	0.04	1.05	0.62	-0.06	0.94	0.25
Move to smaller municipality	C	-0.02	0.98	0.75	0.01	1.01	0.83	0.07	1.08	0.12	-0.09	0.92	0.11	-0.05	0.95	0.35
Change in urbanity	C	-0.01	0.99	0.12	-0.01	0.99	0.08	0.00	1.00	0.19	0.03	1.03	0.00	0.00	1.00	0.66
Change in PT quality	C	0.00	1.00	0.79	0.00	1.00	0.82	0.01	1.01	0.13	0.01	1.01	0.19	0.01	1.01	0.21
Cohort and period																
Cohort (94 yrs in 1994 = 0)	B	0.009	1.009	0.00	0.003	1.003	0.15	-0.003	0.997	0.04	0.001	1.001	0.62	0.001	1.001	0.46
Cohort, squared, div. by 100	B	-0.004	0.996	0.19	-0.002	0.998	0.27	0.003	1.003	0.02	-0.002	0.998	0.41	-0.001	0.999	0.51
Year of survey (1994 = 0)	B	-0.004	0.996	0.67	0.004	1.004	0.38	0.001	1.001	0.88	0.006	1.006	0.33	0.003	1.003	0.49
Year of survey * 2000 or later	B	-0.006	0.994	0.31	-0.004	0.996	0.18	0.000	1.000	0.93	-0.002	0.998	0.59	-0.002	0.998	0.56
Baseline value of mode use																
Frequency of trips (by mode under study)	B	-0.32	0.73	0.00	-0.42	0.66	0.00	-0.29	0.75	0.00	-0.34	0.71	0.00	-0.22	0.80	0.00
(Scale)		0.88			0.25			0.14			0.45			0.27		
QICC		9,995			2,933			1,695			5,170			3,198		
QICC (intercept model)		12,410			3,735			1,930			6,308			3,581		
R^2 (adjusted, from OLS regressions)		20.7			25.1			19.0			19.9			14.7		
n (observations)		11,236			11,236			11,236			11,236			11,236		
n (individuals)		6,932			6,932			6,932			6,932			6,932		

Table 5: Cluster-robust regression models of changes in daily trip rates

B = baseline variable; C = change variable.

The year of survey is not significant in any case. There is also no evidence for a non-linear trend, reflecting the end of growth in car travel around the year 2000. Finally, strong negative effects of baseline values in mode use suggest that increases in the use of a particular mode are relatively weak among those who already used this mode frequently in the baseline year. For instance, each additional trip driven results in 0.32 more driving trips being reduced.

Change variables effects – life course events

Changes in behaviour may be expected to occur not so much as an outcome of life situations per se but rather in response to changing life situations. Overall, however, the effects of key events are limited. Nonetheless, there are several significant and notable effects. To begin with household biography, the birth of a child results in decreasing car use as a passenger, PT use (just fails to reach significance), and cycling, while walking increases. Interestingly, driving does not increase. Founding a household with a partner leads to increasing car use as a passenger, pointing towards shared trips. A child moving out of the household yields somewhat more PT use among the other household members, but the effect just fails to reach significance (significant for percentage of PT trips, without table). This may be due to a reduction in the number of cars in the household when a child who is moving out takes one car away.

Entering the labour market results in more driving and decreasing shares of trips made as a car passenger, on foot or by bicycle (not significant for trip frequencies). These effects may be caused by tighter time budgets and the increase in income that tends to be associated with entering the workforce. Graduating from school or completing an apprenticeship, starting an apprenticeship, and changing the workplace yield no significant effects.

Leaving the labour market (without retiring) results in more walking and less PT use. Retirement has no significant effects on mode specific trip frequencies, but in terms of modal shares it is associated with less driving and more non-motorised travel.

Concerning access to the workplace, there are some notable observations. First, a change in walking distance from the nearest PT stop to work has two significant effects: walking frequency drops when walking distance increases considerably, and vice versa. The effect on walking frequency rather than on frequency of PT use suggests that this may not be due to changes in PT supply, but to workplace relocations and associated changes in spatial context. Second, the PT connection to work yields no significant effects, except that a decrease in PT quality leads to less walking and cycling and more trips made as a car passenger (just significant). Again, this points towards workplace relocations. Third, when parking at the workplace gets considerably more difficult, respondents drive less and use PT more often (just fails to reach significance). Conversely, when parking gets considerably easier, respondents drive more, use PT less frequently and walk less frequently.

As expected, gaining a license has a strong positive effect on driving, but negative effects on using the car as a passenger, using PT, and cycling. The effects of losing one's license are notably weaker. Only PT use increases significantly. Similarly, changes in car availability strongly affect the use of all modes (cycling is only significant when modal shares are studied). The effects on driving are very strong and outbalance all other modes taken together. This suggests that a decline in car availability is associated with generally decreased levels of travel, and vice versa. However, endogeneity of car availability may be at play here. Hence, having a car available may perhaps not be a cause for, but rather an outcome of enhanced mobility levels. Car availability was measured here as reported by respondents. Interestingly, this measure yields stronger effects on mode use changes than changes in the number of cars a household owns. This suggests that self-reported availability of a car does not only reflect car purchase (or disposal), but also reallocations of the car(s) a household owns within the household.

Residential relocations show very limited effects. Moving to the periphery is associated with a drop in walking. On a more small-scale level, increasing urbanity leads to more walking, while the shares (but not the frequencies) of car use as a driver or passenger decrease.

5 Conclusions

This paper has investigated changes in travel mode specific trip rates from one year to the next using descriptive statistics and multiple regressions. A cluster-robust estimation methodology has been used to account for the clustered nature of the data.

The results show that behind the aggregate stability in travel mode use over time there is much change 'under the surface', induced by life course changes, individual and household sociodemographics, and spatial context. The changes found induced by life course related key events favour the notion of mobility biographies. However, in total key events seem to be relatively loosely associated with changes in mode use. Besides the effects of key events, various significant effects of baseline variables have been found which suggest that mode use may change even without any key event. These moderate associations between mode use and key events are somewhat counterintuitive in that we expected to find stronger connections.

Three reasons may be offered for interpretation. Firstly, the period of observation of any household is relatively short. Changes in mode use induced by key events may be delayed (Dargay, 2001). For instance, after household formation involving two adults each owning their own cars, the decision to keep only one car may be postponed until one of the two cars is depreciated, rather than disposing of one of the vehicles immediately. Secondly, mode choice is known to involve strongly habitual elements (e.g., Bamberg et al., 2003; Fujii and Kitamura, 2003). These may prevent people from changing their behaviour even when circumstances change. Thirdly, weak effects and low levels of variance explanation (see R^2 values from OLS regressions in Table 5) suggest high levels of freedom of choice. Even if these are associated with more opportunities of choice and, hence, more change, this may not yield strong effects, as freedom of choice may result in changes in various and unexpected directions. Thus, from a statistical perspective, mode choice behaviour may seem arbitrary and random, but those opting for a particular mode are likely to have good reasons for doing so. In a welfare society such as Germany with a high level of car ownership, the level of structural determination in mode choice is very low (Scheiner, 2006).

Nevertheless, some notable effects may support the effectiveness of planning schemes. First, walking frequency drops when walking distance from the nearest PT stop to work increases considerably, and vice versa. Second, when parking at the workplace gets easier, respondents drive more, use PT less frequently and walk less frequently. Conversely, when parking gets more difficult, respondents drive less. Such effects may seem obvious given previous research, but anyway suggest that travel demand management and other concepts may have a significant impact on mode use.

This paper suggests various directions for future research. First, it is too early at this stage to draw general conclusions for the mobility biography approach. The life course related effects we found are relatively minor. However, the idea of mobility biographies includes a much broader spectrum of topics and methodological approaches than those examined in this paper. Three topics may serve for illustration. A first field is made up of mobility changes induced by learning processes from an individual's own experience (e.g. after an accident) or within social network contexts, e.g. in school, from peer groups or parents (including travel socialisation), Second, another important issue are habits and expectations in terms of acceptable or even 'normal' forms and levels of mobility associated with the affiliation to a specific generation and cultural context.

The rising level of airplane travel abroad due to global exchange among students and the growing number of long-distance commuters (Sandow and Westin, 2010) may serve as examples. This calls for cross-generational and cross-cultural comparative approaches to mobility biographies. Third, extended mobility and travel needs may emerge in the life course due to multi-local families after divorce, when families stretch beyond an individual's household. Methodological approaches may be widely spread ranging from in-depth narrative or guided interviews to complex statistical modelling (e.g. structural equation modelling, Bayesian networks) and from collecting retrospective data to panel surveys.

Second, our analysis could easily be extended to other measures of travel behaviour, such as travel distances, trip durations, trip chain complexity and the like. As biographical key events may not be expected to have significant effects on all measures of travel behaviour likewise, a set of hypotheses would have to be developed carefully for each.

Third, it would be worthwhile extending the analysis of change to longer periods to capture delayed effects (e.g., Dargay, 2001). People may react to changing circumstances slowly, because changes in some respects are superimposed on the steady habits of daily life in other respects. People may also react in very different ways to changing circumstances, rendering it difficult or even impossible for researchers to capture significances in behaviour.

Fourth, an example may serve to illustrate differences in reactions. Our descriptive analysis shows that men and women may be affected by life course related key events differently. This suggests gendered analysis using interaction terms, which will be the subject of forthcoming papers. Such an analysis using a comprehensive set of key events faces an extremely large range of explanatory variables. This paper may also contribute to efforts to distinguish less relevant from more significant key events for future research.

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