LONG-TERM AND MID-TERM MOBILITY DECISIONS DURING THE LIFE COURSE

– Experiences with a Retrospective Survey –

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Long-term and mid-term mobility of people involves on the one hand decisions about their residential locations and the corresponding moves. At the same time, the places of education and employment play an important role. On the other hand the ownership of mobility tools, such as cars and different public transport season tickets, is a complementary element in this process, which also binds substantial resources. These two aspects of mobility behaviour are closely connected to one another. A longitudinal perspective on these relationships is available from people's life courses, which link different dimensions of life together. Besides the personal and familial history, locations of residence, education and employment as well as the ownership of mobility tools can be taken into account. These life course dimensions are usually not independent from one another. Events in one area are frequently connected to changes in other areas. At the same time, this longitudinal approach provides the possibility to observe developments over time.

In order to study the dynamics of long-term and mid-term mobility decisions, a longitudinal survey covering the 20-year period from 1985 to 2004 was carried out at the beginning of 2005 in a stratified sample of municipalities in the Zurich region, Switzerland.

The paper shows that there exists a strong interrelation between the two examined aspects of long-term and mid-term mobility. The residential mobility is influenced by the ownership of the different mobility tools, and vice versa. Thereby the mobility tool ownership remains comparably stable over longer periods of time. Concerning the ownership of the various mobility tools, the analyses indicate that car ownership and public transport season ticket ownership substitute one another. During the life course car ownership is highest among those who are 35 to 55 years old today. At the same time, men have noticeably more frequently a car at their disposal than women of the same age. Concerning the ownership of national and regional season tickets, the opposite trend is visible.

Key Words: Long-term and mid-term mobility decisions, Life course, Longitudinal data, Modelling of discrete decisions, Modelling of durations

1. INTRODUCTION

Long-term and mid-term mobility of people involves on the one hand decisions about their residential locations and the corresponding moves. In this context, distance and direction, frequency of moves and durations of stays as well as reasons for moving are of central interest[1]. At the same time, the places of education and employment play an important role. On the other hand, the ownership of mobility tools, such as cars and different public transport season tickets, is a complementary element in this process, which also binds substantial resources. These two aspects of mobility behaviour are closely connected to one another.

A longitudinal perspective on these relationships is available from people's life courses, which link different dimensions of life together. Besides the personal and familial history, locations of residence, education and employment as well as the ownership of mobility tools can be taken into account. These life course dimensions are usually not independent from one another. Events in one area are frequently connected to changes in other areas. At the same time, this longitudinal approach provides the possibility to observe developments over time[1-4]. Concerning the analysis of residential mobility, there is the further advantage of taking into account resident and mobile people at the same time since the respondents both stay and move during the observed period of time[1].

In order to study the dynamics of long-term and mid-term mobility decisions, a longitudinal survey covering the 20-year period from 1985 to 2004 was carried out at the beginning of 2005 in a stratified sample of municipalities in the Zurich region, Switzerland.

The paper describes residential mobility and mobility tool ownership as well as the possibilities given by the life course approach to long-term and mid-term mobility

followed by a discussion of the methodologies for analysing life course dynamics. Subsequently, the longitudinal data collected in the retrospective survey is described. The paper then concentrates on the analysis of the long-term and mid-term mobility decisions during the life course. The main focus lies on the dynamics of mobility tool ownership over the last 20 years, at the same time looking at the relationships with residential choices as well as with locations of education and employment. Besides the decisions, durations, changes and delays between changes are examined. Finally, the results are summarised in the conclusions.

2. LONG-TERM AND MID-TERM MOBILITY

Salomon and Ben-Akiva[5] regard choices of residential and occupational locations as well as mobility tool ownership and the mode of commuting as long-term and mid-term decisions, while short-term decisions on other daily mobility, e.g., with respect to trip frequency, mode, destination, route and time of the day, are based on the longer term decisions.

2.1 Residential mobility

Various variables significantly affect residential mobility. In the literature, age is most consistently reported showing an inverse relationship to the number of moves[3]. A higher education and employment status is associated with more changes in residence[6]. Changes in occupation also lead to a higher number of moves[3]. Accessibility to the places of occupation influences the residential mobility such that with increasing travel distance the probability for moving also rises[7]. At the same time, residential mobility is less dependent on absolute income and more dependent on variations in income. An increase in income encourages residential mobility, while a decrease in income seems to have no effect. The influence of the household structure is rather ambiguous[8]. Housing characteristics also play an important role, such as type, size, space adequacy and the tenure status. Renters are about twice as likely to move as owners because the transaction costs of owning are substantially higher than those of renting[3]. In this context, residential mobility is closely related to the situation on the housing market and its conditions[9,10]. Furthermore, the residential history and the different durations a person stayed in former places of residence are of some importance since prior mobility is strongly correlated to current mobility[1].

2.2 Mobility tool ownership

Mobility tools include driving licences and available cars as well as different public transport season tickets, such as national and regional tickets for different time periods and half-fare discount tickets. Through the ownership of those mobility tools people commit themselves to particular travel behaviours as they trade large one-time costs for a low marginal cost at the time of usage. Simma and Axhausen found that the ownership of the different mobility tools influences the usage of the same mode positively and the usage of the other mode negatively[11]. This means that the relationship between the private and the public transport mode is a substitutive one[11]. In general, the commitment to car availability is higher than that to season ticket ownership. In this context, the ownership of cars and the related commitment are widely covered in the literature[2,12-14], whereas the commitment to public transport is seldom considered in studies as they mostly only emphasise its supply. Models taking into account both the ownership of cars and the ownership of different public transport season tickets are rarer[11,15-17].

Different variables influence the ownership of the various mobility tools[11,16]. The relationship between age and ownership is nonlinear. Men are more likely to own driving licences and cars, whereas women show a higher public transport season ticket ownership. Education and employment status as well as income have positive effects on the driving licence and car ownership. A higher income also promotes the ownership of public transport season tickets. The location of the place of residence influences the ownership in such a way that people living in more urban areas tend to have less cars and more public transport season tickets at their disposal as they have better access to public transport in comparison to rural areas.

2.3 Long-term and mid-term mobility during the life course

The life course perspective allows the inclusion of the temporal dimension into the analysis of long-term and mid-term mobility. Decisions concerning residential mobility as well as mobility tool ownership have long-term and mid-term effects since corresponding changes involve certain amounts of resources (costs, time, etc.). Furthermore, it is possible with this approach to link different dimensions of life together as they are usually not independent from one another. Events in one area are frequently connected to changes in other areas. Analysing people's life course can contribute to the understanding of their reactions to changes occurring in their personal

and familial life, within their household as well as in the spatial structures[11]. For instance, one can analyse how a move affects mobility tool ownership and, therefore, travel behaviour. At the same time, developments over time can be observed, including time dependent aspects of decisions concerning long-term and mid-term mobility[2,3].

3. METHODS FOR THE ANALYSIS OF LIFE COURSE DYNAMICS

Life course dynamics can be described with the concepts of trajectory and transition. In this context, the life course is seen as a sequence of events. It is therefore worthwhile to understand an event and the history leading up to its occurrence. By means of event history modelling differences in timing, duration, rates of change and probabilities for the occurrence of certain events within a period of time as well as explanatory variables can be determined. In this context, the dependent variable measures the duration until an event occurs.

An essential advantage of the duration modelling approach over traditional linear regression models is its ability to account for problems with censoring. Censoring occurs when information about durations is incomplete. This is the case when subsequent events are unobserved, which means that no transition from one state to another is made within the surveyed time. Problems arise when uncensored and censored cases are treated equally since the parameters in the duration model may be under- or over-estimated. Furthermore, time-varying covariates, i.e., explanatory variables with values changing over time, can easily be included in event history modelling[18,19].

In the context of duration modelling, there exist different approaches. In parametric models the underlying hazard rate or transition rate, i.e., the rate at which events occur, is parameterised in terms of the probability distribution, e.g., Weibull, Gompertz, exponential, gamma, log-logistic and log-normal distributions[20]. A semi-parametric alternative is represented by the Cox proportional hazard model[21,22]. Thereby it is not necessary to make assumptions about the particular distributional form of the duration times. This makes it preferable over its parametric alternatives[18]. In the Cox model the hazard rate for the *i*th individual is defined as follows:

$$h_i(t) = h_0(t)\exp(\beta' x_i) \qquad (1)$$

where $h_0(t)$ denotes the baseline hazard function and $\beta' x_i$ are the parameters and covariates. The hazard rate for the Cox model is proportional as the hazard ratio for two individuals i and j is written as:

$$\frac{h_i(t)}{h_j(t)} = \exp\left(\beta'(x_i - x_j)\right) \qquad (2)$$

which demonstrates that this ratio is constant over time[18]. The estimation method in the Cox model is the maximum partial likelihood method and allows to estimate the parameters β' without having to specify the baseline hazard function $h_0(t)$. This method is based on the assumption that the intervals between successive duration times contribute no information regarding the relationship between the hazard rate and the covariates, but rather the ordered duration times[18].

Event histories can consist of single events. On the other hand they can include multiple events of the same type or multiple events of different types. Cases where different kinds of events occur are often referred to as competing risks situations. There are many variants of competing risks models proposed in the literature[18,20,23-25]. A commonly applied approach is the latent duration time approach. It assumes that there are K ($k=1, 2, 3, \ldots, r$) specific events, where K denotes the number of possible outcomes, and that there exists a potential or a latent duration time associated with each event. The implementation of this model requires that K models with type specific hazards are estimated where all events other than k are treated as randomly censored. Thereby the assumption is made that the K risks are conditionally independent[18]. The latent variables approach has been extended to both parametric and semi-parametric settings. Han and Hausman propose a flexible parametric proportional hazard duration model for competing risks, which permits unrestricted correlations among the risks. The specification of the model is flexible parametric in the sense that the baseline hazard is non-parametric, while the effect of the covariates takes a particular functional form, that is typically linear, but does not have to be[24]. In this context, durations are treated as categorical by transforming the continuous intervals into an arbitrarily defined number of categories with a chosen class size, where each class needs to have at least two observations[26].

4. DATA

For the estimation of dynamic models on long-term and mid-term mobility longitudinal data is required. Essentially, there are two ways of collecting such data. The most obvious and well-recognised method is to conduct a

panel survey. Data collected this way is very reliable since events are observed as they happen. However, panel surveys are difficult and expensive to carry out as well as rather effort and time consuming. The second method approximating a panel survey is to use a retrospective approach that relies on individual's recall capacity and, therefore, is subject to the limitations of the human memory. With increasing time elapsed since an event the amount of information retained decreases in a logarithmic relationship[3,27]. People tend to remember major events, such as residential moves or personal and familial events, better. Therefore, those can be used as support for the memory by further linking different dimensions of life together and in doing so placing single events into a larger context[27]. Experiences from Hollingworth and Miller showed that a retrospective survey proved to be a favourable alternative to a panel survey[3]. They tested it as a tool for collecting longitudinal data on residential mobility and found that people's ability to recall prior residential mobility decisions and housing details is generally good.

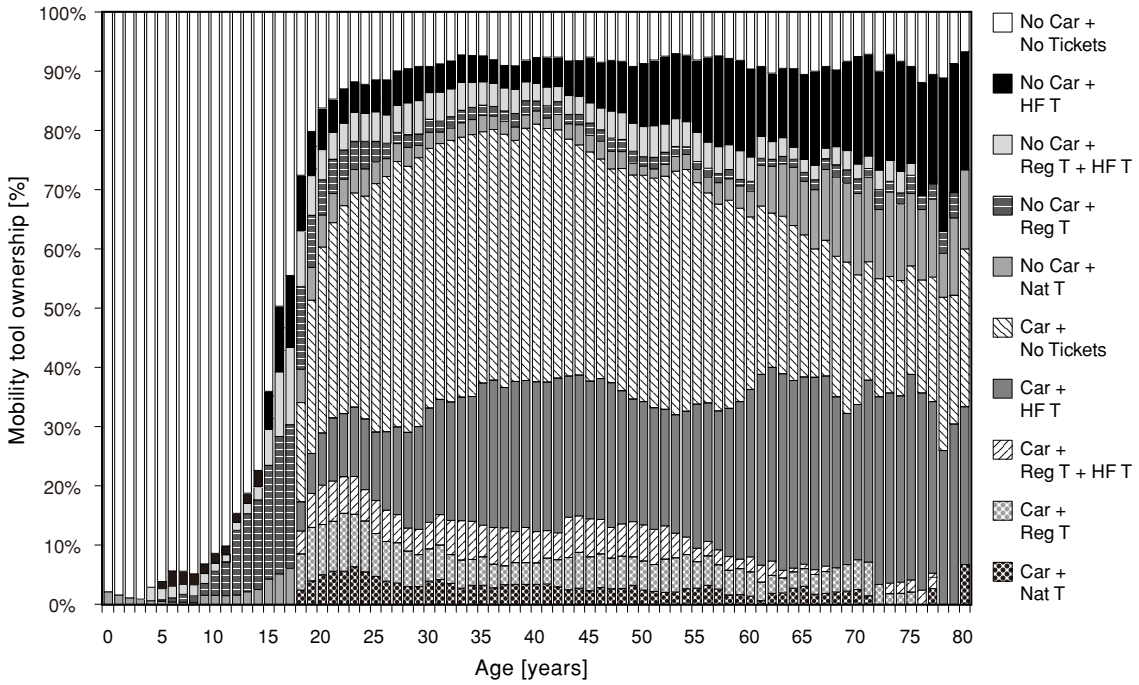
In order to collect longitudinal data concerning long-term and mid-term mobility, a retrospective survey covering the 20-year period from 1985 to 2004 was carried out at the beginning of the year 2005 in a stratified sample of municipalities in the Zurich region, Switzerland, taking different spatial and transport related municipality types into account[28]. In this context, predominantly households that moved within the last five years were sampled, including movers within the municipalities as well as arriving and departing residents.

The survey was conducted as a written self-completion questionnaire consisting of two parts, a household form and a person form. The household form asked for the current address, a short description of all persons living in the household and the household income. In the person form socio-demographic and socio-economic characteristics of the respondents were collected. The essential part of this form was a multidimensional life course calendar for the years from 1985 to 2004. This interval presents a relatively long period, but, at the same time, is still memorable for the respondents and contains the necessary effort within reasonable limits. For the 20-year period considered retrospective information about the personal and familial history, the household size as well as data on moves and corresponding places of residence was collected. Furthermore, the respondents were asked to indicate their changing ownership of cars and different public transport season tickets, such as national and regional tickets as well as half-fare discount tickets. Data on the places of education and employment, on the main mode of transport for the commuting trip as well as on the personal income was collected for the period from 1985 to 2004. Each household received two person forms that were to be filled in by persons aged 18 years and older. The questionnaire was sent out by mail to 3,600 households. The response rate amounts to only 23.1%, which is primarily due to the relative length and complexity of the questionnaire[29]. Overall 780 household forms and 1,166 person forms are available for further statistical analyses. Concerning the representativeness of the data, a comparison of the household and person sample to the entire population of Switzerland, using census data of the year 2000, indicates that the deviations are relatively small. However, it is noticeable that the sampling predominantly aimed for a higher share of households that moved recently. In spite of this, no weighting is implemented for the period from 1985 to 2004.

5. RESULTS

5.1 Mobility tool ownership during the life course

The mobility tools considered in the retrospective survey are cars and different public transport season tickets, including national annual tickets (Nat T), regional annual and monthly tickets (Reg T) as well as half-fare discount tickets (HF T). National tickets allow the usage of nearly the entire public transport in Switzerland, whereas regional tickets are only valid for a certain area. The annual costs for a national ticket amount to approximately 3,000 CHF. Concerning the regional tickets, the costs strongly depend on the size of the area and the number of zones covered. For smaller zones the prices vary between 200 CHF and 400 CHF per year, while for greater zones the prices rise up to around 700 CHF. Regarding an entire public transport association with multiple zones, the annual costs are between ca. 1,000 CHF and ca. 2,000 CHF. Half-fare discount tickets, as the name suggests, provide a half-fare discount on the purchase of any ticket. They cost about 150 CHF for one year. Further mobility tools, such as bicycles, for instance, are not taken into account, since they seem more difficult to remember. In Figure 1 the ownership of mobility tools during the life course is shown. Regarding the age of the respondents there is, as expected, a strong increase in car ownership after reaching the age of 18 years. Persons aged from 25 to 50 years show the highest share with about 75%. Then a slow decrease is visible. The ownership of national tickets increases over the life course, whereas the share of regional tickets decreases. The half-fare discount tickets have growing shares. About one third of the respondents own



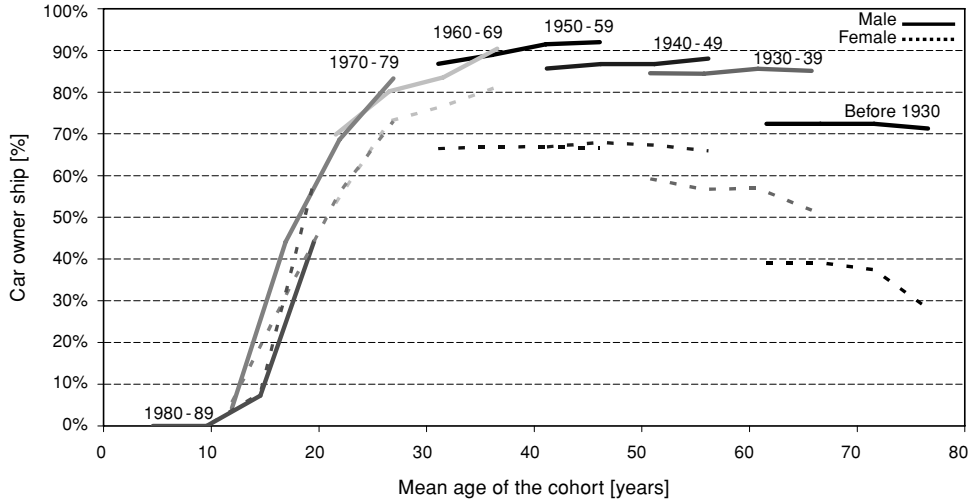
Notes: Nat T (national annual tickets), Reg T (regional annual and monthly tickets), HF T (half-fare discount tickets)

Fig. 1 Mobility tool ownership during the life course

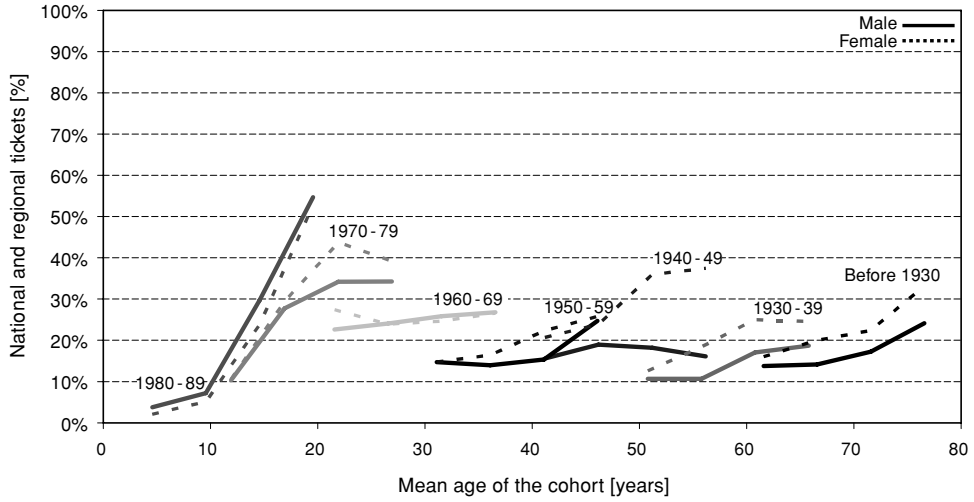
a car and public transport season tickets at the same time. Overall the ownership of mobility tools increases at the beginning and then remains relatively stable over the life course with only approximately 10% of persons not having any of the considered mobility tools at their disposal.

Below, the ownership of mobility tools is analysed by age of the respondents and their membership in birth cohorts. Thereby it is possible to take into account changes during the life course of a person as well as cohort effects which specify intra- and intergenerational similarities and varieties in one generation or between different generations[30,31]. In this context, it is assumed that people born in the same time interval and, therefore, ageing together also share a common life experience due to the fact that general changes have differing impacts for persons of unlike age and that the consequences of these changes persist in the subsequent behaviour of these individuals and, thus, of their cohorts[31]. A third temporal dimension includes period effects indicating the impact of the global context and which are independent from the persons[30,32]. Figure 2 illustrates the ownership of the various mobility tools by gender, age and birth cohort membership. For all three variables significant differences occur. The oldest cohort group comprises of people which are born before 1930. The following cohorts span a period of ten years in each case. It is noticeable that the oldest cohort group owns considerably fewer cars than the younger cohorts. Highest is the ownership among those who are 35 to 55 years old today. At the same time, men have noticeably more frequently a car at their disposal than women of the same age. However, for the younger generations this difference diminishes. Except for the oldest group, there are still increases in ownership observable over the age within the different cohorts. This means that the level of saturation is not necessarily reached yet. The same patterns are observed for Switzerland[16] and the United Kingdom[33] using national survey data and the so-called pseudo-panel approach, in which panel data is constructed by tracing cohorts in the cross-sectional data and treating the cohort averages for each point in time as observations[33]. Dargay shows that the age and cohort effects are largely explained by differences in income over the life course and differences in income between generations[33]. Concerning the ownership of national and regional season tickets, a different trend is visible compared to car ownership. The cohorts with a current age between 35 and 55 years now show the lowest ownership rates. Furthermore, women generally own more public transport season tickets than men. Therefore, both car ownership on the one side and national and regional season ticket ownership on the other side substitute one another. The ownership of half-fare

Car ownership by gender, age and birth cohort membership



National and regional ticket ownership by gender, age and birth cohort membership



Half-fare discount ticket ownership by gender, age and birth cohort membership

Fig. 2 Mobility tool ownership by gender, age and birth cohort membership

discount tickets increases relatively strongly over the life course. With the exception of the oldest cohort group, the female respondents tend to own more half-fare discount tickets than the male respondents of the same age.

In the following, various discrete choice models are estimated for the ownership of mobility tools between 1985 and 2004. For this time period observations on a semi-annual basis are included. Only persons that are 18 years and older are considered. Overall 28,808 observations are in the data set. In this context, it is necessary to take into account that each respondent appears several times as observation and, therefore, to control for unobserved characteristics of the individuals. Thus, an error term is added in the model, which allows individuals who are homogeneous in their observed characteristics to be heterogeneous in their response probabilities[34]. Within the model specification a random parameter is introduced, which is normally distributed across the entire sample, but invariant for each individual. For this parameter the standard deviation is estimated, while the mean value is set to zero[35].

In Table 1 the results of different binomial logit models for the availability of cars and the ownership of public transport season tickets during the 20-year period are represented. All relevant explanatory variables are used and a corresponding indication of their significance is shown, since estimating these models requires a lot of computational time and effort. As measure for the goodness of fit the adjusted ρ^2 is shown in the table. It is calculated as follows:

$$\rho^2 = 1 - \frac{L(\max) - K}{L(0)} \qquad (3)$$

where *L(0)* and *L(max)* represent the initial and the final log-likelihoods, respectively, and *K* denotes the number of estimated parameters[35]. Overall the goodness of fit is relatively high, only in the model for the half-fare discount ticket ownership a slightly lower ρ^2 is observed.

The probability of disposing of a car which is available at all times increases until the age of 54 years and then slowly declines. At the same time, male respondents are more often in this position than female respondents. Employment as well as income has a positive influence. The ownership of season tickets is related to a lower proportion of always available cars. In larger households these cars are less likely. With reference to the urban areas persons having their own car live more often in rural areas. Rather opposed tendencies are noticeable for partially available cars. For instance, men tend to have a car less frequently only part-time at their disposal than women. Furthermore, the monthly income has a negative effect. Persons owning public transport season tickets are in general more likely to simultaneously have a partially available car. The ownership of national and regional tickets for public transport is reduced with increasing age, while the utility for half-fare discount tickets increases. Men tend to own less public transport season tickets than women. The Swiss nationality as well as a college or university degree and being in education lead to a higher ownership of these mobility tools. Only for the national tickets the distance to the place of employment has a positive influence. Concurrent with the expectations, simultaneous car availability decreases the ownership of public transport season tickets. Persons with national or regional tickets live more often in urban areas. In the cases where the place of residence is abroad, season ticket ownership tends to be lower. The index of purchasing power is a combined index of consumer prices and exchange rates, aiming to account for variation in consumer prices and the movement of currency exchange rates over time. It measures the changes in consumer prices in a country in Euro, making an adjustment for changes in exchange rates[36]. It has a positive influence on the public transport season ticket ownership. All these results are in general consistent with other analyses concerning the ownership of mobility tools[11,16]. The high values for the standard deviation $\sum$ of the individual-specific error term indicate a substantial heterogeneity in the sample[34]. The sign of the random parameter is not relevant.

Furthermore, the ownership of the various mobility tools is assigned to six groups, which cover all possible combinations, in order to consider the different mobility tools simultaneously. With regards to these six groups, various models are estimated, including binomial and multinomial logit models, nested and cross-nested logit models as well as a probit model. A comparison of these models shows that the logit models are relatively similar to one another, with the best model being the nested logit model overall.

Table 2 presents the parameters of this nested logit model with two nests regarding the ownership and non-ownership of a car. Other possible specifications include a model with nests for national and regional tickets and no national and regional tickets as well as a model with nests for half-fare discount tickets and no half-fare discount tickets. The model shown in the table fits the data best. For the alternatives including the national and regional tickets age has a negative effect until the age of about 50 years. Afterwards the utility increases with increasing age. With regards to the other alternatives, age leads to a higher pro-

Table 1 Binomial logit models for the mobility tool ownership during the life course

Explanatory variable	Car availability: Always	Car availability: Partially	National ticket ownership	Regional ticket ownership	Half-fare discount ticket ownership
Age in years	+ 0.538*	– 0.089	– 0.474*	– 0.140*	+ 0.128*
Age in years squared	– 0.005*	– 0.000	+ 0.006*	+ 0.001	– 0.001
Gender: Male	+ 3.595*	– 0.842*	+ 0.972*	– 0.114	– 1.710*
Nationality: Swiss national	– 0.147	+ 1.724*	+ 4.309*	– 0.053	+ 3.560*
College or university degree	– 0.245	+ 2.021*	+ 2.848*	+ 1.609*	+ 2.590*
In education	+ 0.000	– 0.757*	+ 0.708*	+ 1.119*	+ 0.562*
Change in education	– 0.340*	+ 0.096	+ 0.186	+ 0.138	+ 0.185
Distance between the place of residence and the place of education in 1,000 kilometres	+ 0.227	– 0.145	+ 5.479	+ 0.468	– 3.810
In employment	+ 1.063*	– 0.317	– 0.109	+ 1.109*	+ 0.282
Change in employment	+ 0.069	+ 0.181	+ 0.017	+ 0.167*	+ 0.120
Distance between the place of residence and the place of employment in 1,000 kilometres	– 0.493*	– 0.217	+ 1.222*	– 8.174*	– 1.364*
Monthly income in 1,000 CHF	+ 0.511*	– 0.345*	+ 0.030	– 0.111	+ 0.228*
Monthly income in 1,000 CHF squared	– 0.024*	+ 0.014*	– 0.000	+ 0.011	– 0.012*
Car availability: Always			– 2.243*	– 2.370*	– 1.720*
Car availability: Partially			– 0.927*	– 0.120	– 1.039*
National ticket ownership	– 3.799*	+ 0.486			
Regional ticket ownership	– 3.076*	+ 1.220*			+ 1.080*
Half-fare discount ticket ownership	– 2.173*	+ 0.096		+ 0.878*	
Moving out of parents' house	+ 0.408	+ 0.062	+ 0.061	+ 0.020	+ 0.118
Change in residence	– 0.015	– 0.054	+ 0.212	– 0.195*	– 0.007
Birth of a person in the household	+ 0.340	+ 0.119	– 0.567	– 0.073	– 0.269
Number of persons in the household	– 0.286*	+ 0.150	– 0.163	– 0.131	– 0.009
Number of rooms in the accommodation	+ 0.078	+ 0.038	– 0.050	+ 0.065	+ 0.006
Degree of urbanisation:					
Urban (referential category)					
Urban to rural	– 0.115	+ 0.479*	– 0.436	– 0.572*	+ 0.152
Rural	+ 0.933*	– 0.379	– 1.863*	– 0.989*	+ 0.611
Place of residence abroad	+ 0.573	– 0.395	– 2.705*	– 2.104*	– 3.002*
Purchasing power index in the residential region	– 0.003	+ 0.028*	+ 0.116*	+ 0.028*	+ 0.025*
Constant	– 11.866*	– 6.331*	– 15.689*	– 3.048*	– 10.609*
Standard deviation of the individual-specific random parameter	+ 6.999*	– 5.288*	+ 7.962*	– 5.339*	– 5.550*
Number of persons: 1,043 Number of observations: 28,808	$\rho^2 = 0.759$	$\rho^2 = 0.744$	$\rho^2 = 0.859$	$\rho^2 = 0.728$	$\rho^2 = 0.582$
Initial log-likelihood *L(0)*	– 19,968.2	– 19,968.2	– 19,968.2	– 19,968.2	– 19,968.2
Final log-likelihood *L(max)*	– 4,776.2	– 5,090.3	– 2,797.8	– 5,405.0	– 8,317.8

* Level of significance ≤ 0.10

pensity to choose one of these. Overall men are considerably more likely to be mere car owners than women. With the exception of the persons with no mobility tools, being a Swiss national as well as holding a college or university degree has a positive influence. This also applies to education and employment as well as to changes occurring in education and employment. The distance between the places of residence and education increases the probability of mobility tool ownership, except for the mere half-fare discount ticket ownership, in reference to only car owners. Concerning the place of employment, the distance has in general a negative effect. A higher income enhances the simultaneous availability of cars and public transport season tickets. The birth of a person in the household as well as the household size and accommodation size increase the ownership of a car. These owners are pri-

Table 2 Nested logit model for the mobility tool ownership during the life course with two nests for car and no car

Explanatory variable	No Car + No Tickets	No Car + HF T	No Car + Nat T / Reg T	Car + No Tickets	Car + HF T	Car + Nat T / Reg T
Age in years	– 0.056	+ 0.107*	– 0.420*		– 0.081*	– 0.297*
Age in years squared	+ 0.001*	– 0.000	+ 0.005*		+ 0.002*	+ 0.003*
Gender: Male	– 1.645*	– 1.866*	– 1.532*		– 1.309*	– 2.138*
Nationality: Swiss national	– 1.264*	+ 2.656*	+ 1.530*		+ 4.678*	+ 2.943*
College or university degree	– 0.361	+ 2.162*	+ 2.308*		+ 3.663*	+ 3.206*
In education	– 0.746	+ 2.211*	+ 2.224*		+ 1.203*	+ 3.719*
Change in education	+ 0.317	+ 1.143*	+ 0.895*		+ 0.953*	+ 1.263*
Distance between the place of residence and the place of education in 1,000 kilometres	+ 5.341	– 27.082*	+ 7.436*		+ 8.128*	+ 8.036*
In employment	– 1.787*	+ 0.452*	+ 0.566*		+ 0.709*	+ 1.332*
Change in employment	– 0.810*	+ 0.286	+ 0.564*		+ 0.348	+ 1.102*
Distance between the place of residence and the place of employment in 1,000 kilometres	+ 0.292	– 0.089	– 3.598*		– 0.186	– 1.129*
Monthly income in 1,000 CHF	– 0.551*	+ 0.199*	+ 0.049		+ 0.008	+ 0.256*
Monthly income in 1,000 CHF squared	– 0.025	– 0.028*	+ 0.012*		+ 0.014*	– 0.005
Moving out of parents' house				+ 0.627*		
Change in residence				+ 0.010		
Birth of a person in the household				+ 0.815*		
Number of persons in the household				+ 0.009		
Number of rooms in the accommodation				+ 0.199*		
Degree of urbanisation:						
Urban (referential category)				+ 1.961*		
Urban to rural				+ 2.214*		
Rural						
Place of residence abroad				+ 3.148*		
Purchasing power index in the residential region				– 0.007*		
Constant	+ 2.463*	– 7.216*	+ 6.611*		– 6.798*	– 0.583
Model parameters for the two nests:						
Nest: Car						0.247*
Nest: No Car						0.305*
Number of observations: 28,808	$\rho^2 = 0.217$					
Initial log-likelihood *L(0)*	– 51,617.0					
Final log-likelihood *L(max)*	– 40,329.7					

* Level of significance ≤ 0.10
Notes: Nat T (national annual tickets), Reg T (regional annual and monthly tickets), HF T (half-fare discount tickets)

marily found in more rural areas. The scale parameters estimated in the NL model are both significant. They indicate that the correlations in the nest with the alternatives including a car are slightly smaller than in the other nest.

Table 3 shows a corresponding cross-nested logit model, differentiating between four nests for car, national and regional tickets, half-fare discount tickets as well as no mobility tools. This model very much resembles the nested logit model, especially concerning the way in which the explanatory variables influence the choices of the alternatives. Therefore, the corresponding results of the CNL model are not commented on again. At the same time, the majority of the estimated model parameters describing the cross-nested structure are significant. The highest correlations occur among the alternatives in the nest regarding the half-fare discount tickets. The parameters indicating the degree at which an alternative belongs to a certain nest is, concurrent with the expectations, always largest for the alternatives that merely include the mobility tool defining the nest and, thus, do not belong to any other nest. The group owning a car and a half-fare discount ticket is primarily part of the nest for cars and to a lesser extent part of the nest for the half-fare discount tickets. In contrast to that, the respondents having a car as well as national and regional tickets at their disposal predominantly belong to the nest for national and regional

Table 3 Cross-nested logit model for the mobility tool ownership during the life course with four nests for car, national and regional tickets, half-fare discount tickets and no mobility tools

Explanatory variable	No Car + No Tickets	No Car + HF T	No Car + Nat T / Reg T	Car + No Tickets	Car + HF T	Car + Nat T / Reg T
Age in years	+ 0.085*	– 0.009	– 0.135*		– 0.035*	– 0.067*
Age in years squared	– 0.001*	+ 0.000*	+ 0.001*		+ 0.000*	+ 0.000*
Gender: Male	– 1.044*	– 1.136*	– 1.693*		– 0.718*	– 0.489*
Nationality: Swiss national	– 0.735*	+ 0.824*	+ 0.453*		+ 1.766*	+ 1.009*
College or university degree	– 0.295*	+ 0.841*	+ 0.906*		+ 1.341*	+ 1.153*
In education	+ 0.250*	+ 0.340*	+ 1.352*		+ 0.162	+ 0.662*
Change in education	– 0.003	+ 0.190	+ 0.383*		– 0.015	+ 0.068
Distance between the place of residence and the place of education in 1,000 kilometres	+ 2.740	+ 5.090*	+ 3.334		– 0.879	+ 4.372
In employment	– 1.378*	– 0.187*	– 0.316*		+ 0.094	+ 0.642*
Change in employment	– 0.218	– 0.007	+ 0.280*		+ 0.043	+ 0.268*
Distance between the place of residence and the place of employment in 1,000 kilometres	– 0.474	– 0.746	– 1.025		– 0.668	– 25.292*
Monthly income in 1,000 CHF	– 0.322*	– 0.232*	– 0.105*		+ 0.013	+ 0.117*
Monthly income in 1,000 CHF squared	– 0.017	+ 0.009*	+ 0.008*		+ 0.000	– 0.016*
Moving out of parents' house				+ 0.043		
Change in residence				– 0.032		
Birth of a person in the household				+ 0.276*		
Number of persons in the household				– 0.101*		
Number of rooms in the accommodation				+ 0.153*		
Degree of urbanisation:						
Urban (referential category)				+ 1.002*		
Urban to rural				+ 1.025*		
Rural						
Place of residence abroad				+ 2.084*		
Purchasing power index in the residential region				– 0.011*		
Constant	– 0.389	– 0.387*	+ 1.180*		– 1.268*	– 0.289
Model parameters for the four nests as well as for the six groups:						
Nest: Car						0.963
Car + No Tickets						1.324*
Car + HF T						0.617*
Car + Nat T / Reg T						0.000*
Nest: National and regional tickets						0.578*
No Car + Nat T / Reg T						1.476*
Car + Nat T / Reg T						0.971*
Nest: Half-fare discount tickets						2.057*
No Car + HF T						1.082*
Car + HF T						0.289*
Nest: No mobility tools						1.000
No Car + No Tickets						0.867*
Number of observations: 28,808	$\rho^2 = 0.177$					
Initial log-likelihood *L(0)*	– 51,617.0					
Final log-likelihood *L(max)*	– 42,383.3					

* Level of significance ≤ 0.10

Notes: Nat T (national annual tickets), Reg T (regional annual and monthly tickets), HF T (half-fare discount tickets)

tickets and not at all to the nest for cars. Nevertheless, the adjusted ρ^2 is considerably lower in the CNL model than in the NL models.

5.2 Durations in long-term and mid-term mobility

In the following the method of event history modelling is applied to the retrospective data on the one hand for the residential mobility and the changing locations of edu-

cation and employment as well as on the other hand for the ownership of the different mobility tools. In Figure 3 the distribution of the residential, education and employment durations during the last 20 years is shown. Overall 4,155 residential, 1,290 education and 2,589 employment durations are observed between 1985 and 2004. On average these durations are 5.0, 3.9 and 4.8 years long with a standard deviation of 4.8, 3.0 and 4.8 years, respectively. Approximately 70% of all the durations are up to five years long. Figure 4 shows the observed durations of car availability and public transport season ticket ownership. For about one third of these durations cars are always available over the whole period from 1985 to 2004. In this context, the other duration lengths are relatively evenly distributed. Partial car availability is more often indicated for shorter periods of time with over 50% being less than five years long and over 80% being less than ten years long. The ownership of national and regional tickets shows a left-skewed distribution, where the highest shares occur for durations shorter than five years. To a lesser extent this also applies to the half-fare discount ticket ownership. Overall the ownership of the different mobility tools is relatively stable over time, especially the availability of cars, whereas the slightly more variable ownership of season tickets during the period from 1985 to 2004 points to a weaker commitment to public transport. This stability in

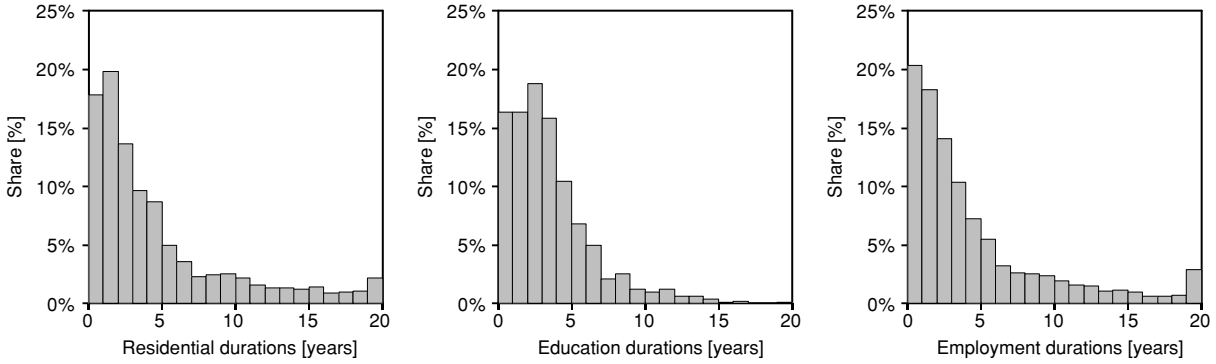


Fig. 3 Distribution of the residential, education and employment durations

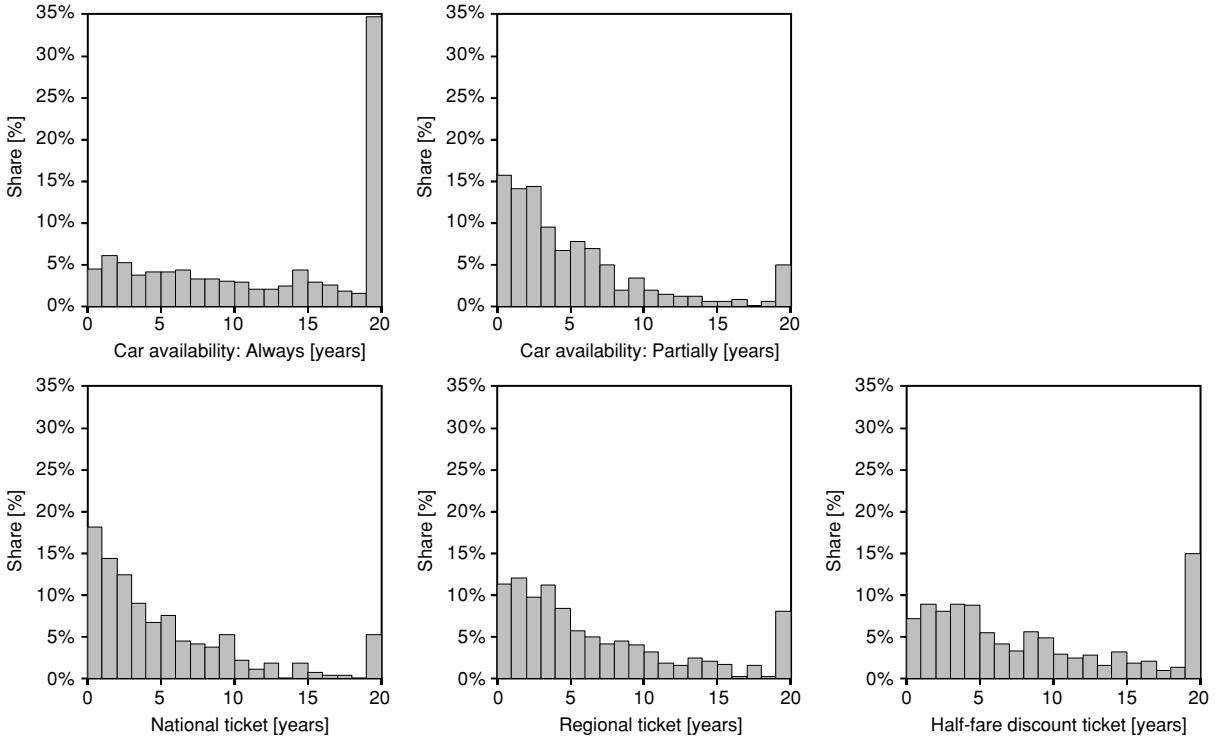


Fig. 4 Distribution of the car availability and public transport season ticket ownership durations

mobility tool ownership over longer periods of time is also found in other studies[11,37]. The distribution of mobility tool ownership durations is to a lesser extent left-skewed compared to the durations concerning the places of residence, education and employment. The various groups of observed durations are significantly different from one another. The shortest periods are observed between moves as well as between changes in education and employment, whereas always available cars and half-fare discount tickets stand at the other end of the spectrum.

In order to compare the different types of durations, competing risks models for the residential, education and employment durations on the one hand as well as for the car availability and public transport season ticket ownership durations on the other hand are estimated. The latent duration time approach is applied, which means that for each specific type of duration a model is estimated, treating the others in this context as right censored[18,20]. Table 4 presents the results of the different competing risks models for the residential, education and employment durations, grouping the observations for these three types together. All explanatory variables shown are significant at a level of at least 0.10. Their selection is based on a forward stepwise inclusion method using the significance of the change in the log-likelihood as entry or removal criteria. In the table the hazard ratios are given, which are equivalent to the exponential hazard parameters[20]. For continuous variables they indicate the percentage change of the hazard rate, whereas for dichotomous variables they equal the proportion of the two corresponding hazard rates. As a measure of how good the different models are and how well the corresponding durations can be predicted with the set of covariates, respectively, generalised R^2's are given at the bottom of the table[20]. The generalised R^2 is calculated, as proposed by Cox and Snell, as follows:

$$R^2 = 1 - \exp\left(-\frac{2(L(\max) - L(0))}{N}\right) \quad (4)$$

where $L(0)$ and $L(max)$ represent the initial and the final log-likelihoods, respectively, and N is the sample size. In the estimated models shown in the table the durations are relatively well predictable by the given explanatory variables.

The variable indicating that the duration is left censored has, concurrent with the expectations, a strong positive influence. With increasing age the hazard of changes occurring in residence, education and employment decreases. In this context, men are by about 9.5% less likely to move than women. Respondents holding a college or university degree tend to move more frequently. Persons in education and employment show a lower probability to change the place of residence. At the same time, education leads to a considerably lower hazard in employment, and vice versa. A longer duration in education at the beginning of the period shortens the various durations, whereas a longer duration in employment prolongs the corresponding duration in employment. Changes in education and employment during the observed period have a negative influence on the propensity to move. The education and employment durations show opposite effects concerning the number of changes. Respondents with many changes in education are less likely to change education, but more likely to change employment. For the changes in employment it is the other way around. The distances between the places of residence, education and employment increase the probability of changes in education and employment, respectively. The residential durations are negatively affected by the monthly income. The ownership of the different mobility tools leads to higher hazards regarding spatial mobility. Simultaneous changes of the places of residence, education and employment strongly increase the probability of variations. The duration a person already lives in a place has a positive influence on the residential duration, which is primarily connected to the cases where left censoring occurs, and a negative influence on the durations in education and employment. The number of births as well as the size of the household and the accommodation reduces the various risks. Abroad the durations in residence, education and employment tend to be by over 40% shorter than in Switzerland. The index of purchasing power in the residential region has a hazard ratio that is smaller than one. In Table 5 the hazard ratios of the different competing risks models for the mobility tool ownership durations are shown, when all mobility tools are grouped together. Again, left censoring has a strongly positive effect on the durations. With increasing age the respondents tend to own mobility tools longer. This is especially true for older persons. The share spent in education during the observed periods has a negative influence on the hazard for always available cars. Changes in residence, education and employment decrease the probability of variations in the ownership of mobility tools, whereas in the case that these changes occur simultaneously, the probability is considerably increased. Higher fuel prices lead to reduced hazards. Contrary to the expectations, this also applies to the ownership of the different mobility tools in the competing risks situation. This means that the longer respondents hold one mobility tool the less likely they are to change the ownership of any

Table 4 Hazard ratios of the competing risks duration models for the residential, education and employment durations

Explanatory variable *(Average values for the observed durations)*	Residential durations	Education durations	Employment durations	Education and employment durations
Left censoring of the duration	0.598	0.428	0.316	0.320
Age in years	1.043	1.125		1.025
Age in years squared	0.999	0.997	0.999	0.999
Gender: Male	0.905			
Nationality: Swiss national		1.308		1.240
College or university degree	1.211			
Share in education during the period	0.605		0.087	
Duration in education at the beginning of the period in years	1.072	1.070	1.074	
Changes in education during the period	0.891	0.013	1.130	0.556
Distance between the place of residence and the place of education in 1,000 kilometres		1.241		1.205
Share in employment during the period	0.660	0.116		
Duration in employment at the beginning of the period in years	1.025	1.055	0.974	0.977
Changes in employment during the period	0.832	1.196	0.032	0.340
Distance between the place of residence and the place of employment in 1,000 kilometres			1.289	1.328
Monthly income natural logarithm	1.182	0.839		
Car availability: Always			1.526	1.241
Car availability: Partially			1.855	1.460
National ticket ownership	1.420	1.750	1.928	1.715
Regional ticket ownership		1.242	1.455	1.331
Half-fare discount ticket ownership		1.375	1.254	1.264
Simultaneous change of the place of residence and the places of education or employment	2.125	2.213	2.030	1.682
Moving out of parents' house		0.640	0.582	0.592
Duration in residence at the beginning of the period in years	0.943	1.046	1.032	1.036
Changes in residence during the period	0.001		0.832	
Number of births in the household	0.735	0.381	0.526	0.479
Number of persons in the household	0.952		0.865	0.928
Number of rooms in the accommodation	0.882			
Place of residence abroad	1.495		1.486	1.428
Purchasing power index in the residential region	0.975	0.975	0.966	0.968
Number of observations	6,880	6,880	6,880	6,880
Number of censored observations	4,408	5,894	5,377	4,391
R^2 (generalised)	0.402	0.346	0.313	0.325
Initial log-likelihood *L(0)*	– 19,492.5	– 7,952.1	– 12,199.9	– 20,152.0
Final log-likelihood *L(max)*	– 17,722.9	– 6,493.8	– 10,908.0	– 18,800.3

other mobility tool, pointing to a relative stability in mobility tool ownership. The number of births in the household affects the various durations positively. National tickets are owned for shorter periods of time generally by Swiss nationals, persons with a college or university degree and persons living in non-urban areas.

5.3 Changes in long-term and mid-term mobility

Furthermore, the changes occurring during the life course are analysed. Figure 5 shows the alterations in the places of residence, education and employment. Thereby five years are grouped together. Most moves occur between the ages of 20 and 35 years, with a maximum of about 15%. Afterwards the share of moves gradually de-

Table 5 Hazard ratios of the competing risks duration models for the car availability and public transport season ticket ownership durations

Explanatory variable *(Average values for the observed durations)*	Car availability: Always	Car availability: Partially	National ticket ownership	Regional ticket ownership	Half-fare discount ticket ownership
Left censoring of the duration	0.388	0.250	0.114	0.309	0.233
Age in years	0.919	1.175	1.298	0.932	0.966
Age in years squared		0.996	0.995		
Nationality: Swiss national			2.598		
College or university degree			1.795		
Share in education during the period	0.332			1.775	
Duration in education at the beginning of the period in years	1.064	1.139			
Changes in education during the period		0.741	0.708	0.776	
Distance between the place of residence and the place of education in 1,000 kilometres			1.614		
Share in employment during the period				1.985	
Duration in employment at the beginning of the period in years		1.086			
Changes in employment during the period		0.832	0.619	0.863	0.809
Distance between the place of residence and the place of employment in 1,000 kilometres			5.600		
Monthly income natural logarithm		0.738			
Fuel price in 0.01 CHF per litre (lead free 95)	0.954	0.956		0.958	0.950
Car availability: Always			0.173	0.295	0.286
Car availability: Partially			0.328	0.296	0.261
National ticket ownership	0.283	0.546			
Regional ticket ownership	0.276	0.441			0.303
Half-fare discount ticket ownership	0.474	0.565		0.664	
Simultaneous change of the place of residence and the places of education or employment	2.284	2.677	1.929	1.918	1.857
Moving out of parents' house		0.564			
Duration in residence at the beginning of the period in years	0.964			0.978	
Changes in residence during the period	0.537	0.618	0.722	0.584	0.679
Number of births in the household	0.639	0.755	0.336	0.563	0.533
Number of persons in the household	0.802				
Number of rooms in the accommodation	0.844			0.913	
Degree of urbanisation:					
Urban (referential category)					
Urban to rural			0.646		
Rural			0.538		
Number of observations	2,685	2,685	2,685	2,685	2,685
Number of censored observations	2,550	2,440	2,558	2,387	2,415
R^2 (generalised)	0.100	0.203	0.116	0.235	0.172
Initial log-likelihood *L(0)*	– 975.5	– 1,833.2	– 956.4	– 2,190.6	– 1,969.0
Final log-likelihood *L(max)*	– 833.4	– 1,528.0	– 791.4	– 1,831.7	– 1,715.6

creases. For the changes in the place of employment the curve is very similar at a lower level. Between the ages of 60 and 65 years the influence of retirement becomes visible. Variations in education occur, concurrent with the expectations, earlier during the life course. This share reaches a maximum for persons aged from 15 to 20 years. Figure 6 presents the changes in the ownership of the different mobility tools. In comparison to the spatial

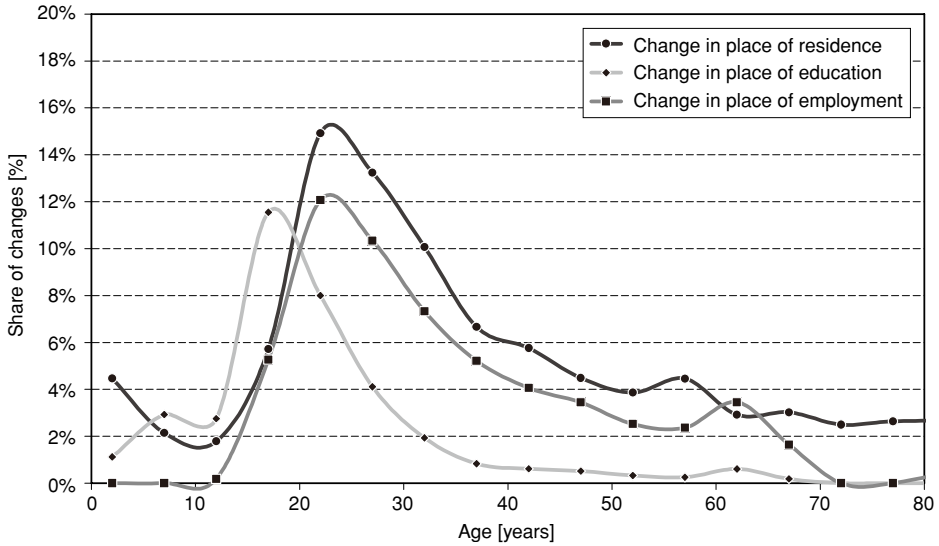


Fig. 5 Changes in residence, education and employment during the life course

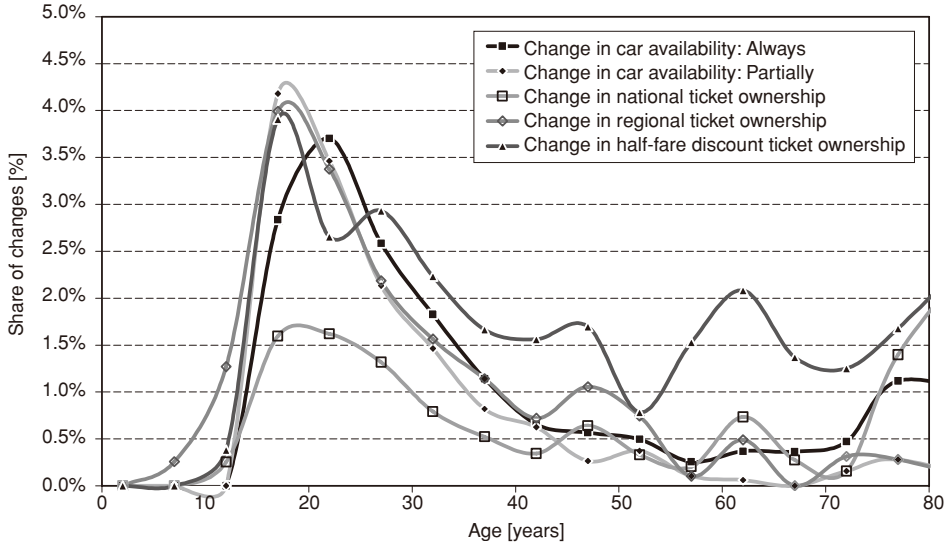
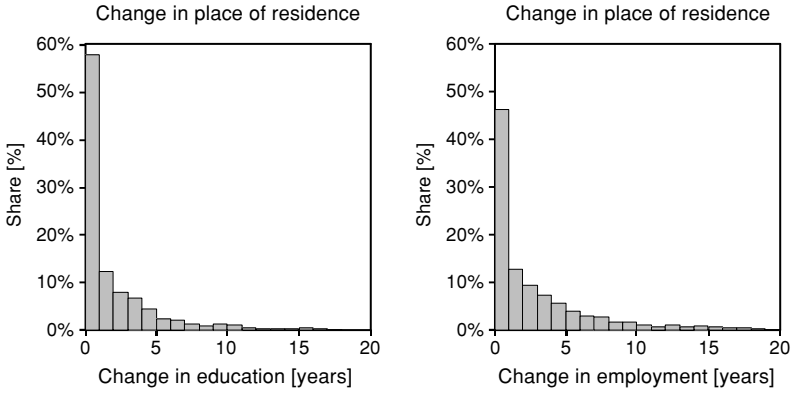


Fig. 6 Changes in car availability and public transport season ticket ownership during the life course

changes, the shape of the curves regarding mobility tool ownership is overall very similar, but ranging only up to 5% instead of up to 20%. For the ownership of always and partially available cars the two maxima are slightly offset from one another, with always following partially car availability. After the age of 40 years both curves become flat. There are some persons who give up their car as they get older, but this happens only to a lesser extent. For the national tickets the share of variations is noticeably lower, with the highest values being surveyed between the ages of 15 and 30 years. Regional tickets behave very similar to the partially available cars with a maximum for persons aged around 18 years. The half-fare discount tickets show larger variations with increasing age compared to the other mobility tools.

Figure 7 shows the distribution of the delays following a change in the place of residence until the next change in the places of education and employment on the one hand as well as in car availability and public transport season ticket ownership on the other hand. Around 50% of all moves are connected to a change in education and employment within the first year following a change in the place of residence. After that the shares of the longer delays observed strongly decrease. This also applies to the

Distribution of the delays following a move until the next change in the places of education and employment



Distribution of the delays following a move until the next change in car availability and public transport season ticket ownership

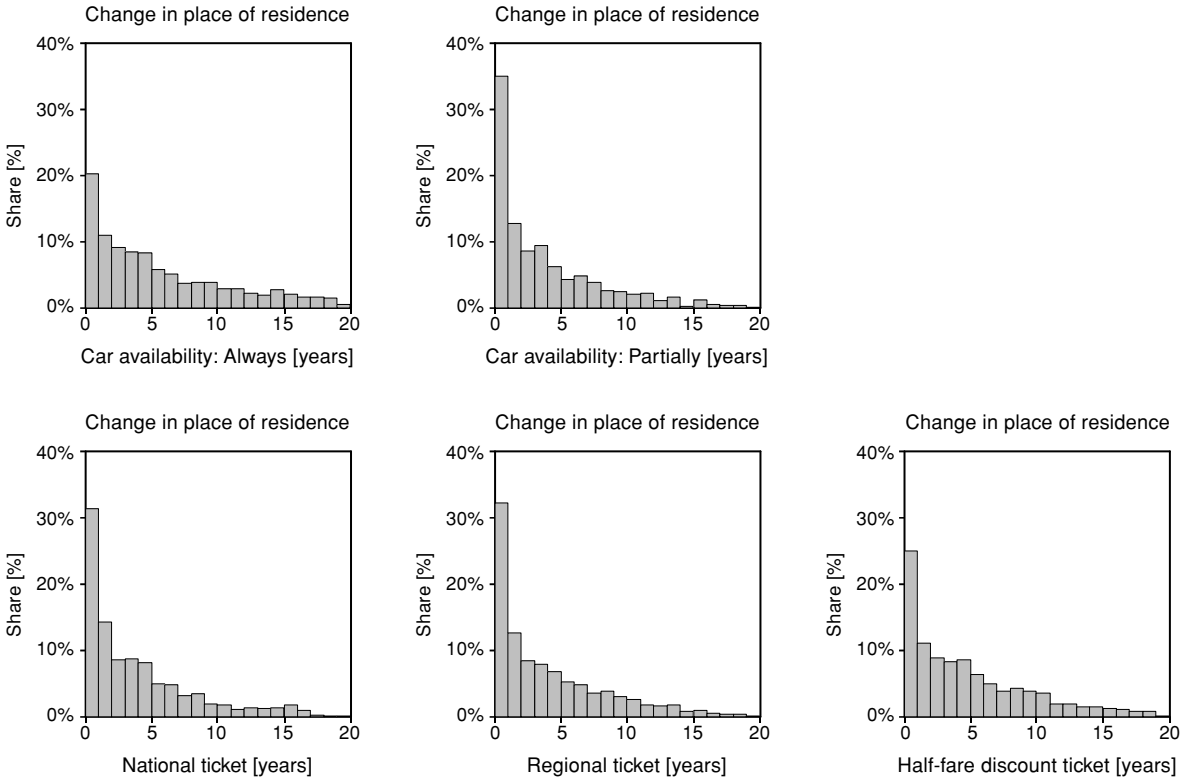


Fig. 7 Changes in car availability and public transport season ticket ownership during the life course

various mobility tools, but the shares are lower overall. Respondents with always available cars show the most stable behaviour. In this group changes after a change in residence occur for only about 20% of the persons within the first year, whereas this share amounts to about 30% to 35% for persons with partially available cars. For the national and regional tickets approximately one third of all the delays are shorter than one year. The changes in half-fare discount ticket ownership show trends comparable to the always available cars. Again, the shares of the longer durations until the next change in mobility tool ownership decrease strongly after the first year. Analogue, the durations until the next changes after variations in the places of education and employment as well as in car availability and public transport season ticket ownership are very similar. Very strongly connected to one another are education and employment changes as well as changes among the different mobility tools.

Further analysis in this context concentrates on duration models for the delays between events in the different life course dimensions, for instance, the propensity to move after another event occurs. Corresponding results concerning the delays until the next change in car availability and public transport season ticket ownership after moving as well as after changing education or employment are not shown here, but can be found in another publication[38].

6. CONCLUSIONS

During the life course car ownership is highest among those who are 35 to 55 years old today. At the same time, men have noticeably more frequently a car at their disposal than women of the same age. Concerning the ownership of national and regional season tickets, the opposite trend is visible. This means that car ownership on the one side and national and regional season ticket ownership on the other side substitute one another. The ownership of half-fare discount tickets increases relatively strongly over the life course. Overall car availability has a negative influence on the ownership of public transport season tickets.

A comparison of the various discrete choice models for the mobility tool ownership shows that the logit models are relatively similar to one another, with the best model being the nested logit model with two nests regarding the ownership and non-ownership of a car.

The analyses concerning long-term and mid-term mobility show that approximately 70% of all residential, education and employment durations observed during the period from 1985 to 2004 are only up to five years long. In contrast, the ownership of the different mobility tools is relatively stable over time, especially the availability of cars.

In the competing risks models for the residential, education and employment durations the hazard of changes occurring decreases with increasing age. In this context, men are by about 9.5% less likely to move than women. Respondents holding a college or university degree tend to move more frequently. Persons in education and employment show a lower probability to change the place of residence. Changes in education and employment during the observed period have a negative influence on the propensity to move. The distances between the places of residence, education and employment increase the probability of changes in education and employment, respectively. The residential durations are negatively affected by the monthly income. The ownership of the different mobility tools leads to higher hazards regarding spatial mobility. The competing risks models for the car availability and public transport season ticket ownership durations show similar results. With increasing age the respondents tend to own mobility tools longer. Changes in residence, education and employment decrease the probability of variations in the ownership of mobility tools, whereas in the case that these changes occur simultaneously, the probability is considerably increased. Higher fuel prices lead to reduced hazards. Contrary to the expectations, this also applies to the ownership of the different mobility tools in the competing risks situation. This means that the longer respondents hold one mobility tool the less likely they are to change the ownership of any other mobility tool.

Around 50% of all moves are connected to a change in education and employment within the first year following a change in the place of residence. This also applies to the various mobility tools, but to a slightly lesser extent.

In summary, one can say that there exists a strong interrelation between the two examined aspects of long-term and mid-term mobility. The residential mobility is influenced by the ownership of the different mobility tools, and vice versa. Thereby the mobility tool ownership remains comparably stable over longer periods of time.

However, to deepen the understanding of long-term and mid-term mobility and the decision processes involved, further analyses are necessary. As example, developments in duration modelling include the estimation of more flexible hazard models with the form of discrete choice models that allow for inter-individual and intra-individual variability of people, which can be applied to the retrospective data[39,40].

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