Locations, commitments and activity spaces

paper presented at the Survive Workshop, Bonn, December 2001

Working Paper

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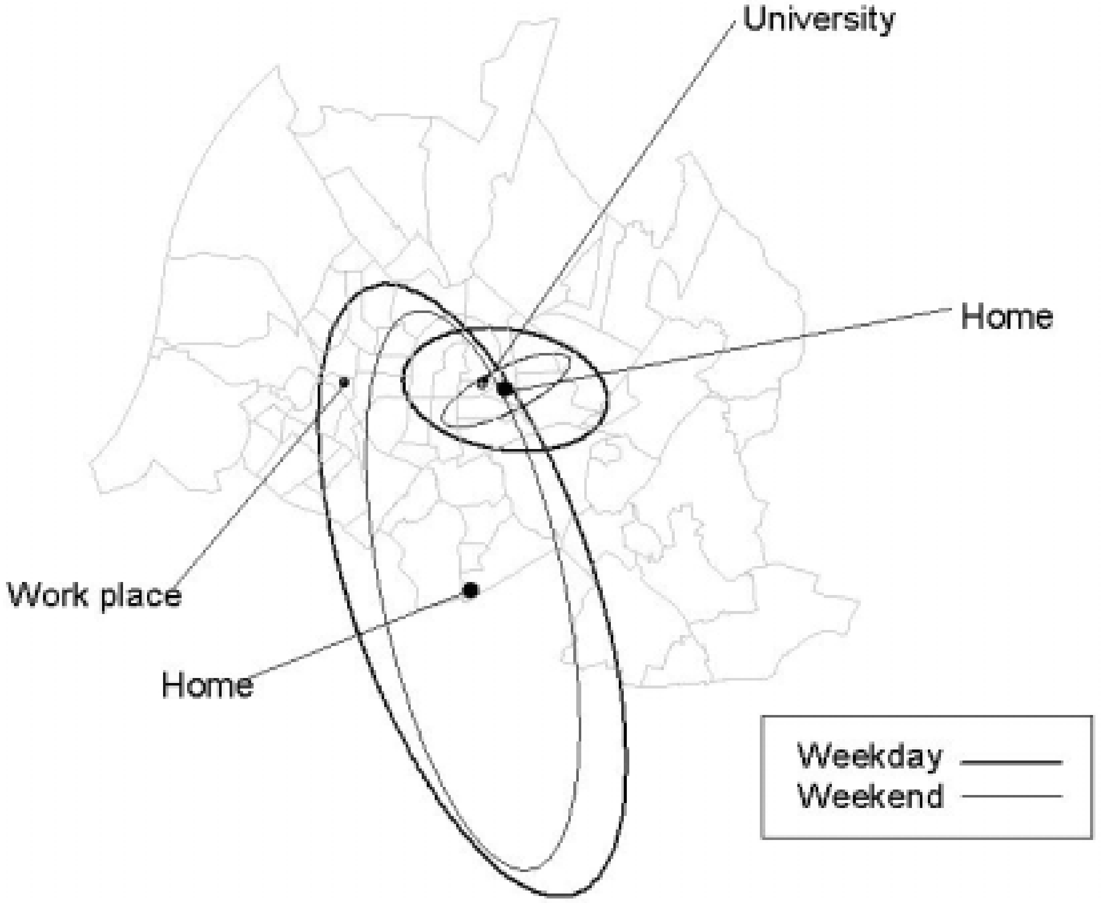
Publication date:
2001

Permanent link:
https://doi.org/10.3929/ethz-a-004339396

Originally published in:
Arbeitsberichte Verkehrs- und Raumplanung 96



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Arbeitsbericht Verkehrs- und Raumplanung 96 **Dezember 2001**

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Vortrag für den Survive Workshop, Bonn, Dezember 2001

Orte, Verpflichtungen und Aktivitätenräume

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Dezember 2001

Kurzfassung

Die Wechselwirkungen zwischen Wohnstandort, Arbeitsplatz, Besitz an Mobilitätswerkzeugen und Verkehrsverhalten sind in den letzten Jahren in den Vordergrund der Fachdiskussion gerückt. Dieser Aufsatz beleuchtet einige Aspekte dieser Diskussion, die in der vorwiegend amerikanischen Diskussion untergegangen sind: die Rolle des Zeitkartenbesitzes für den PW-Besitz und die Rolle der Erschliessung mit dem Öffentlichen Verkehr und der Nähe zur alten Wohnung bei der Wohnstandortwahl.

Die Modelle, die hier vorgestellt werden, verwenden Daten aus dem Mobiplan – Projekt, das im Jahr 2000 verschiedene Befragungen zum Umzugs- und Verkehrsverhalten in Halle und Karlsruhe durchgeführt hat.

Die Modelle zeigen, dass a) Haushalte die Anzahl der PW und der Zeitkarten aufeinander abstimmen und dass die Zeitkarte als Ersatz für einen weiteren Wagen funktioniert; und dass b) die Entfernungen zu alter Wohnung, zu den Zentren und zu Arbeit und Ausbildung einen signifikanten Einfluss auf die Wohnstandortwahl haben.

Schlagworte

Wechselwirkung; Standortwahl; Mobilitätswerkzeuge; Pkw-Besitz; Zeitkartenbesitz; Verkehrsverhalten; Mobiplan; Mobidrive

Zitierungsvorschlag

Axhausen K.W., D.M. Scott, A. König und. C. Jürgens (2001) Locations, commitments and activity spaces, Vortrag bei dem Survive Workshop, Bonn, Dezember 2001, *Arbeitbericht Verkehrs- und Raumplanung*, **96**, IVT, ETH Zürich.

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December 2001

Abstract

This paper argues the case, that self-selection effects are pervasive in spatial and transport-related decision making. This argument is not new, but the recent interest in appropriate models of change and of daily behaviour under constraints brings it to forefront of interest again. Using descriptive examples and two choice models (set of mobility tools of a household and housing location choice) the paper demonstrates these effects empirically.

While the statistically proper solution is the development of self-selection models, which make the decisions about the constraints endogenous to the system, this strategy is difficult in this context due to the long time-horizons/long histories of the relevant decisions. In this paper the constraints were described with variables reflecting those previous decisions. In the model of the mobility tool choice: housing location (type of location, distance to nearest public transport stop; housing costs; distances to work and shopping); in the model of residential choice: distance to previous residential location, type of previous location, distances to work and education). All are significant and have the expected signs.

Keywords

Interactions; Residential Location; Car Ownership; Season Ticket Ownership; Choice Model; Mobiplan

Preferred citation style

Axhausen K.W., D.M. Scott, A. König und. C. Jürgens (2001) Locations, commitments and activity spaces, paper presented at Survive Workshop, Bonn, December 2001, *Arbeitbericht Verkehrs- und Raumplanung*, **96**, IVT, ETH Zürich.

1 Commitments, activity spaces and travel behaviour

Ever since transport analysts have tried to model travel behaviour formally, they have been aware of the constrained nature of the choices travellers make. Still, the degree to which these constraints have been incorporated into the models developed varies widely. The main difficulties are, in our assessment, the different time scales at which and for which the travellers decide.

Daily travel behaviour is influenced by two groups of constraints: the position of the person in the life cycle and by her/his life-style choices. While the position in the life cycle has elements of choice with regards to partnership, marriage, children and responsibilities in the care of others (e.g. care of relatives, in particular of the grandparent generation), transport analysts normally accept these as given and as uninfluenced by the service levels of the transport system. The life-style decisions are mostly reasoned and deliberate choices, in particular those of main interest to travel behaviour analysts:

- residential location;
- workplace location and number of hours worked;
- car[1] driving licence ownership, including further licences, such as might be required for heavy motorcycles or trucks;
- car availability and ownership, including the membership in commercial or co-operative car sharing schemes;
- bicycle ownership; and
- public transport season ticket and discount card ownership, whereby season tickets give free travel at the point of use for a defined period, area and pre-payment and a discount card gives an agreed fare reduction for a defined period, area and pre-payment. Examples are the Swiss *Halbtaxabo* (€ 110 for two years) or the German *Bahncard* (€ 65 (second class) and € 135 (first class) for one year), which give a 50% discount on all trains of the national railroad plus, in the case of Switzerland, varying rebates on other local public transport networks. The prices of yearly season tickets vary, but the Swiss personal *Generalabonnement,* which gives free travel on the whole heavy rail network and most other forms of public transport, costs sFr 4'400 (first class) and sFr 2'800 (second class)[2]. The German equivalent, which is restricted to the heavy rail network costs DM 10'150 (first class) and DM 6'500 (second class).

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[1] Car should be read to mean all motorised vehicles: motorcycles, cars, light trucks etc.

[2] Prices as of November 2001.

Each of these choices has a particular profile of search and transaction costs on the one hand and expected amounts of sunk costs on the other hand, which discourage the too frequent reconsideration of these choices. Consider the case of home ownership, which normally combines high search costs (i.e. time and scheduling effort), high transactions costs (i.e. realtor, legal and banking fees, purchase taxes and registration duties) and potentially large sunk costs for previous housing improvements, such as curtains, kitchens and gardens. Equally, the case of car ownership, where the search and transaction costs can be low, but the owner nearly always has to accept a markdown during the sale of her previous vehicle.

A similar logic, but with differently denominated generalised costs, applies to commitments and choices in the personal and family context (see, on the other hand, Becker [1976] for a radical economic viewpoint of these processes). In the case of housing and work, the economic and social issues come together and can reinforce the commitments: think of the inherited parental home, the links of friendship in the workplace, the sentimental ties to a house, that one has designed or built oneself.

This view, that the longer-term commitments to one's life-style choices constrain daily and shorter-term choices, implies two points, which have substantial consequences for modelling practise:

- all observations of daily behaviour are confounded by the self-selection of the travellers into life-style groups, especially with regards to housing, work and the ownership of mobility tools (i.e. driving licences, car, cycle and season tickets); and
- given the time horizons of the life-cycle choices, they must be based on expectations about the future utility of those choices over the duration of that time horizon.

The first consequence implies that all models of daily behaviour should account for that self-selection either directly through a model of that self-selection or a model of the available choice alternatives or indirectly through market segmentation or, less rigorously, through the inclusion of variables describing that self-selection[3]. For a model of daily mode choice the last strategy would, for example, lead to the inclusion of variables, such as licence holding, car ownership, season ticket ownership, vehicle kilometres travelled (VKT) in the last year, number of public transport and bicycle trips in the last month; in the case of destination choice, variables describing the size of the activity space or the detour implied by a destination relative to the route straight home or the preferred shopping location would be relevant.

The second consequence implies that models of long-term choices, which are based on observations of daily behaviour, could be misleading and, in general, should have low explanatory

[3] This has long been known, but little acted upon. See, for example, Swait (2001a, b) and the references there.

power. Behaviour observed on any one day and the imputed utility of the activities of that day will have some – unknown – correlation to the expected long-term utilities, on which the choices about the long-term commitments were based.

If, as we would expect, that correlation is low, then the resulting models will only find weak links between the daily behaviour part of the model structure and the long-term commitment part of the model structure. A good illustration is the recent model system for San Francisco (Bradley, Bowman and Lawton, 2000), in which the log-sum term of the daily behaviour part is swamped by socio-demographic variables in the long-term part of the system.

The implication that we should abandon attempts to try to explain observed long-term commitments by observed daily behaviour raises the issue of how to capture the utility of those long-term choices.

This paper wants to contribute to that search by reporting results of three different analyses undertaken by the authors: some descriptive results of the impacts of the long-term commitments on daily behaviour, a model of the composition of the mobility tools and finally a model of housing location choice. The remainder of the paper will follow that sequence of topics with a section for each and will conclude with a discussion of the results and a research agenda. The relevant literature and the data used will be discussed in the respective sections.

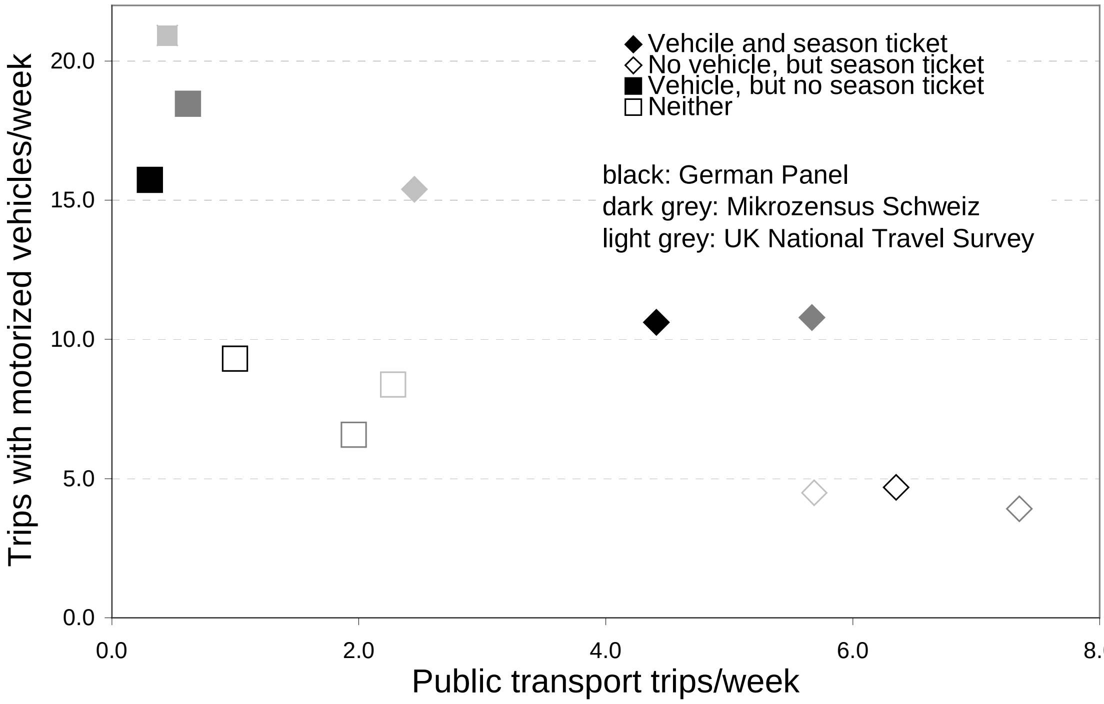
2 Examples for the impacts of long-term commitments

This section highlights two of the many impacts of long-term commitments on travel behaviour: between mode choice and mobility tool ownership and between the size of individuals' activity spaces and mobility tool ownership. These two examples address the questions raised above, but have received little attention in the literature.

The impact of car ownership on travel behaviour is well established in transport modelling (see, for example, Ortuzar and Willumsen [1995] or Cascetta [2000] or see the large number of car ownership models, for example De Jong, 1996; De Jong, 1998; Golob, Kim and Ren, 1996; Bradley, Golob and Polak, 1995; Hensher, 1992). Although the impact of season ticket ownership has been less well documented and its interaction with car ownership and travel behaviour has yet to be fully investigated, see recent papers by Axhausen and collaborators (Simma and Axhausen, 2001; Axhausen, Simma and Golob, 2001) or Hensher (1998).

Figure 1 shows these interactions in the UK, Germany and Switzerland (Simma and Axhausen [2001] describe the three national surveys used[4]). The strength is obvious, as is the supplementary effect between the two mobility tools. The formal modelling in the papers cited above confirms this impression. This raises an additional issue – if the travellers adjust not only their mode choice, but reduce their activity space to match the lower average speeds of public transport (see Schäfer [2000] for a current discussion of the *constant travel time budget* hypothesis or Beckmann, Golob and Zahavi [1983a, b]).

Figure 1 Interactions between travel behaviour and ownership of mobility tools



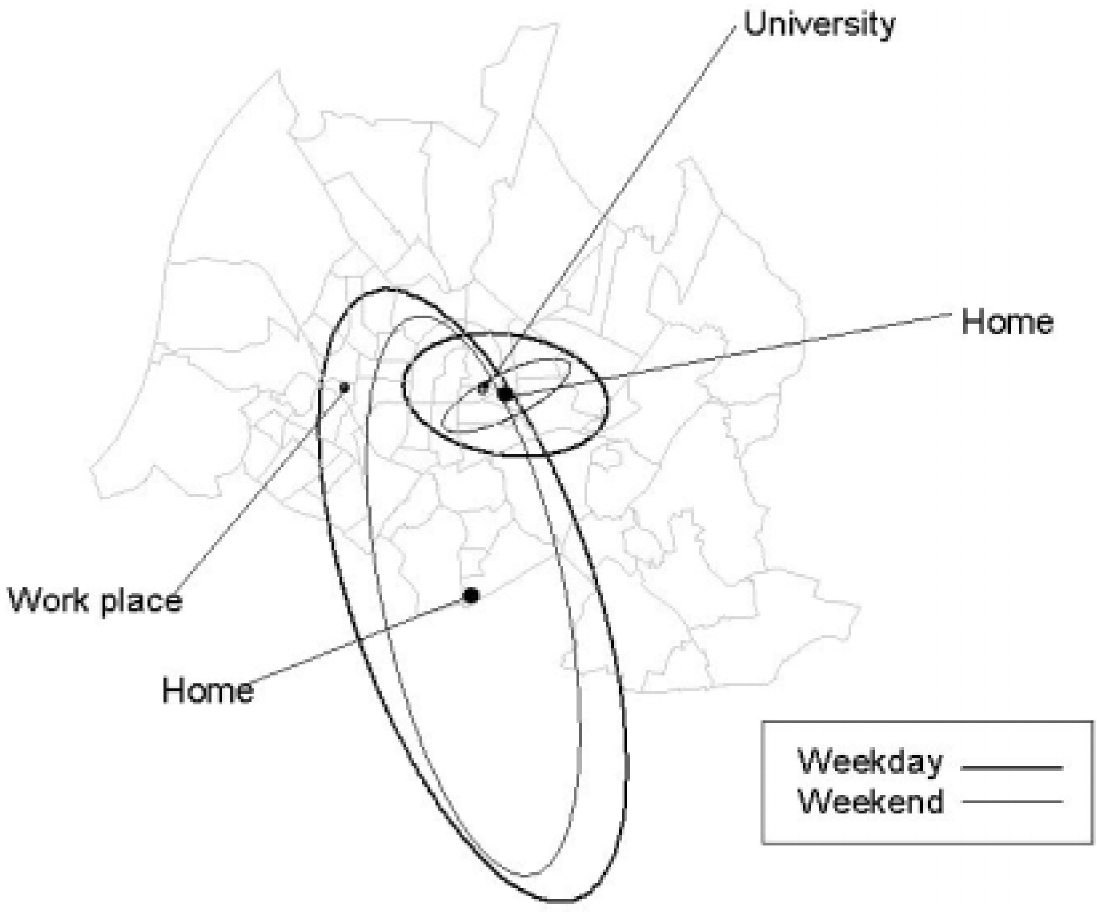
Source: Simma and Axhausen (2001)

Data sources, which allow the study of this question at the individual level, are rare, as substantial reporting periods are needed to estimate individual activity spaces with any confidence. The 1999 Mobidrive survey obtained a six-week travel diary for each respondent and is therefore suitable for this task (see Axhausen, Zimmermann, Schönfelder, Rindsfüser and

[4] German panel: Chlond, Lipps and Zumkeller (1996, 1998); UK NTS: Freeth (1999); Mikrozensus Schweiz: Bundesamt für Statistik, 1995.

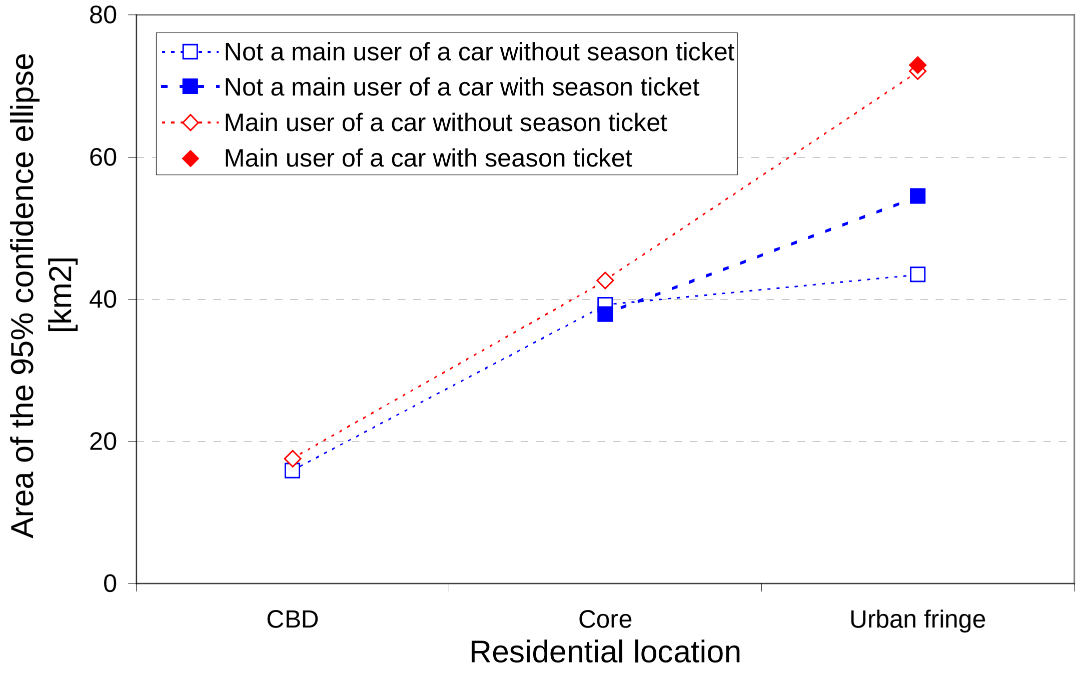
Haupt [2000] for the details of the survey and its quality). A first rough assessment of the size of the activity space of a person is the size of the area covered by the two-dimensional confidence ellipse, which can be calculated using the geocoded destinations of those six weeks (see Figure 2). Biologists analysing the home ranges of animals first proposed this measure (Jennrich and Turner, 1969; Southwood, 2000). Schönfelder and Axhausen (2001) have explored the distribution of the size of the activity space measured in this way and its interaction with mobility tool ownership and residential location. Figure 3 shows this interaction for the Mobidrive sample in Karlsruhe and Halle, two mid-sized German cities. Residential location dominates the effects of the mobility tools until reaching the quasi-suburban fringe of the cities themselves. Still, the expected effects are visible with car owners having larger activity spaces.

Figure 2 Examples of activity spaces as confidence ellipses (Mobidrive; Karlsruhe)



Lower left: Full time married employed; Top right: Single student

Figure 3 Size of activity space by mobility tool ownership and residential location



Data source: Schönfelder and Axhausen (2001) and further calculations based on the Mobidrive survey

The size of the interactions demonstrated here justify the further investigations of the broader questions raised above. They are not negligible, even if existing modelling practise tends to ignore them. One particularly important motivation is the concern about social exclusion and its interaction with spatial behaviour (see, for example, Atkinson and Kintrea, 2001). The themes are equally relevant to the discussion of new urban forms (see Brown and Cropper, 2001 or Axhausen, 2000).

3 Composing the set of mobility tools

As argued above, households compose the set of mobility tools to match their preferences, their needs and their location choices (i.e. home, work and leisure). The current composition of that set is easy to observe, but it is difficult to judge for the analyst, if this current set still reflects existing preferences given the durations of the commitments involved. Normally, surveys do not enquire about these possible differences, nor do they collect indicators of that possible disequilibrium. This question can be avoided in two ways: one can work with stated-response (SR) data or with households that have recently moved. In the first case, one would assume that the respondent is able to abstract from her current situation, at least to a large extent, and that her responses will reflect her true preferences. In the second case, one could assume, that the move is an opportunity to rebalance the locations and the set of mobility tools, so that the household is at or close to its optimal point.

In the Mobiplan project, both types of data were collected. The data collection is described in the next two subsections.

3.1 Mobiplan: a survey of recently moved households

The Mobiplan project had the goal to develop an internet-based transport advisory tool for potential movers (see Kreitz, Axhausen, Friedrich and Beckmann, 2001). To support this goal, a series of surveys was conducted to understand the behaviour of moving households better (Zimmermann and Fell, 2001).

The project had originally intended to trace the travel behaviour of households before and after a move. This objective had to be reformulated after it became clear that a suitable panel could not be recruited within the time frame and budget of the project[5]. The project refocused its attention on recently moved households, which were recruited into a two-wave panel spanning approximately the first six months after the move. The cities of Karlsruhe and Halle and the surrounding Kreise[6] provided addresses of households, which had moved into their areas, from their population registers[7]. These registers are well kept, as many taxes are allocated to the municipalities based on the number of registered inhabitants.

The addresses were provided every two weeks. In an initial screening, households were removed if they had relocated from outside the two study areas (Karlsruhe and Halle and their

[5] The sample of movers obtained by the study reported in Van Lierop (1986) gives an idea of the potential costs involved.

[6] The German federal states, Länder, are organised into municipalities, which cover their area exhaustively. All but the largest of them (i.e. the major cities) are grouped into Kreise, which take on various administrative tasks, some delegated from the municipalities and some delegated from the Land.

[7] All moving households have to register with their local population register within a small number of weeks. Non-compliance can be fined. The register serves various functions, such as the electoral roll, as the draft register, as the basis for tax lists etc.

environs, defined as the service area of the local Verkehrsverbund[8] in Karlsruhe and the surrounding Kreise in the case of Halle), if they contained household heads born before 1930 and if they had moved within their neighbourhood. The first exclusion was due to the wish to avoid households that had to build up their mental maps (Lynch, 1960; Downs and Stea, 1977) of the areas from scratch, as the project wanted to see how the travel behaviour adjusted to the new location within the existing environment of the household. This aim motivated also the third exclusion. As the project wanted to concentrate on economically active households, the second criterion had to be imposed.

The first contact with the household was an announcement letter on official stationary, which asked for co-operation, but it also informed the households about the possibility to phone in their refusal to participate. About 4-5 days after receipt of this letter, the households were called for a screening interview. This was necessary to achieve the desired quotas and to arrange the initial personal interview. The following quotas were set: minimum 30% of households with children; maximum 30% of single households; maximum of 6% student single households; 2:1 proportion of residents of the core city and its surroundings. The complex rules for the quotas, the need for a valid telephone number just after the move and the large survey programme made recruitment difficult (see Zimmermann and Fell, 2001). In the end, only 9% of the original addresses participated, but these are a very respectable 36% of those available for screening (see Table 1 for the experiences of the first Karlsruhe wave, which was mirrored in Halle).

The full survey programme included the following elements (for the instruments, see PTV AG, Fell, Schönfelder and Axhausen, 2000):

Wave 1 (Start of December 1999 to end of May 2000)

- Personal interview with the household about the motivation for the move, the search process, detailed socio-demographics, an activity frequency survey for the period six months before (for details about this specific instrument, see Schlich and Schönfelder, 2001)
- One-week travel diary

Wave 2 (Start of March 2000 until start of August 2000) (only for a subset of those households recruited in the first wave).

- Changes in the socio-demographics and an activity frequency survey for the current period

[8] Verkehrsverbünde organise the local and regional public transport provision in most German agglomerations. Their legal status and internal organisation differs from region to region, which make generalisations difficult. For details about the Karlsruher Verkehrsverbund see www.kvv.de.

- One-week travel diary
- Attitude and value questionnaires

Table 1 Mobiplan: Response behaviour and recruitment in Karlsruhe (first wave)

Step	City of Karlsruhe			Environs of Karlsruhe		
	Number	% of sample	% of available	Number	% of sample	% of available
Sample	2642			1319		
No/wrong phone number or address	1656	62.7		880	66.7	
Not reached (after 4-7 attempts)	327	12.4		124	9.4	
Available	659	24.9		315	23.2	
Refused	328	12.4	49.8	177	13.4	56.2
Quota already full	60	2.3	9.1	11	0.8	3.5
Recruited	271	10.3	41.1	127	9.6	40.3
Dropped out	36	1.4	5.5	13	1.0	4.1
Completed	235	8.9	35.7	114	8.6	36.2

Source: Zimmermann and Fell (2001), p. 113

Based on the data collected in wave 1, two versions of a data set were constructed which focus on the issues of mobility tool ownership: the first version matches the variables collected in a related stated-response experiment (see below), while the second version adds further socio-demographic variables from the household survey conducted as part of Mobiplan.

The sample collected matched the known characteristics of movers in the study areas. The travel behaviour is comparable to what is known about the population from other representative one-day diaries in the study areas.

3.2 The mobility tool ownership stated-response exercise

The Mobiplan advisory tool (Kreitz, Axhausen, Friedrich and Beckmann, 2001) is implemented as a web-based service. To allow customisation it includes a basic survey of the socio-demographics of a person and of her/his mobility preferences. In the overall context of the project, it was an obvious choice to use this platform for further internet-based surveys. One of these was a stated-response (SR) survey of the preferences for the composition of the household's mobility tools (see also Louviere, Hensher and Swait, 2000; Axhausen, 1995; or Axhausen and Sammer, 2001).

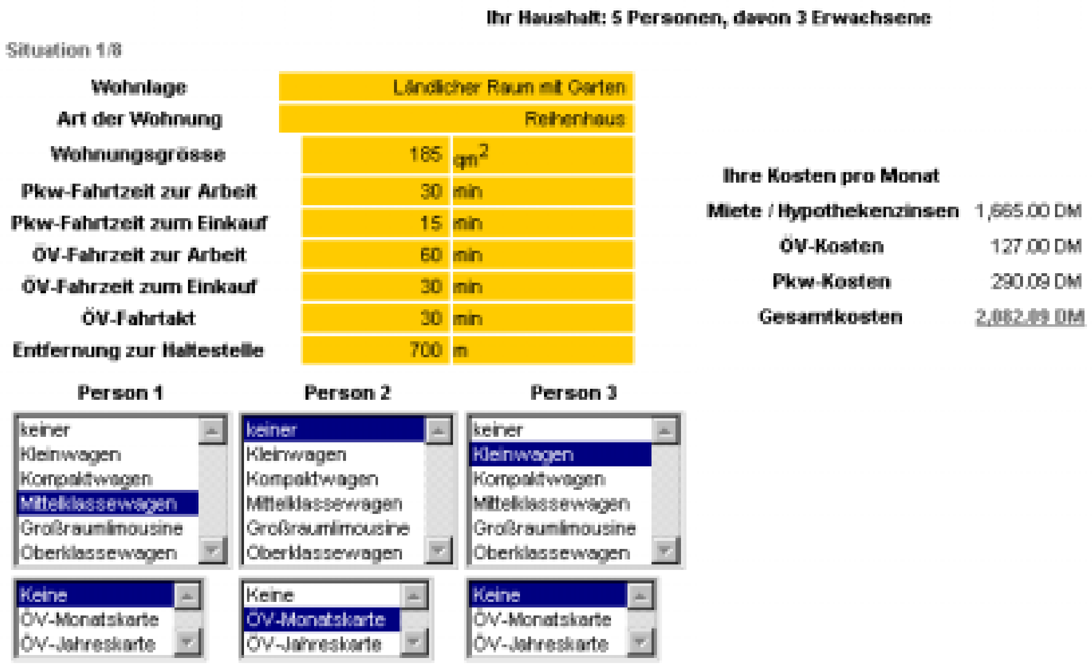
The logic of the long-term time horizons of these choices (see above) implies that the residents can only focus on a small number of core variables, as they are themselves unable to assess the costs and travel times of all their future travel. Still, they know their workplace, they can identify the nearest local shopping area and they have an idea of their leisure preferences and the associated locations (sport grounds, clubs etc.). They also know about their need for work-related travel and their preferences with regards to the travel for their main holidays. While work-related travel is becoming less important in its share of trips and kilometres travelled, it is still the major time commitment of a person and the quality of the connection between home and work is therefore important. The same applies, but with less force, to the connections with daily and weekly shopping. Leisure, with the exception of some firm commitments (clubs, church etc.), is too disperse for a household to assess in detail in advance. Here a household has decided on the level of speed and travel time it wishes to obtain given its home location.

The variables for the SR experiment were selected in line with this argument (see Table 2). This set, arrived at independently, is similar in spirit to that used by Eliasson in his dissertation on housing location and travel choices (see Eliasson and Mattson, 2000) and Boarnet and Crane (2001a, b) in their work on the impact of urban form on travel behaviour.

The types of housing and the specific space/person match the local conditions. Eight of the twelve possible combinations were used in the experiments. The size of the accommodation was customised for each respondent based on the number of members in her/his household plus a share for the joint areas of a house or flat.

The experiment was not formulated as a traditional stated-choice exercise, but as a more open stated-response query. While the housing situation and the travel times to work and local shopping were given, the respondent had to compose the set of mobility tools. As one can see in Figure 4, the respondent had to choose for each household member, with a firm commitment to daily travel (i.e. work and study), the type of car (none, subcompact, compact, family, luxury, people mover) and the type of season ticket (none, monthly, annual). The total cost of each set was estimated using rough assumptions about the average cost of each vehicle type and the average amount of travel given the location (König, 2001). The respondent could then refine the selection until it matched her/his preferences. This iterative element is unusual and only possible in a computer-supported exercise.

Figure 4 Screen shot of mobility tool ownership SR experiment



Source: König and Axhausen (2001) Figure 2; the screen has been adjusted to fit the printed page. The introductory text, which explains the task to the respondents, has been removed, but see the above text for its content.

The survey was conducted during the winter and spring 2000/2001 at the Institut für Soziologie of the Universität Karlsruhe. Sixty respondents participated as part of a larger evaluation of the Mobiplan advisory tool, while a further 106 undertook only this SR experiment and two further stated-choice surveys. An interviewer was always present for questions. Each of the respondents answered eight out of 72 situations of an orthogonal factorial design (König, 2001).

The sample was recruited to match certain age and household-size criteria. In particular, the bulk of the respondents should be economically active and in a situation where the choice situation described is relevant to them (see Table 3 and Table 4). In addition, there was to be an equal share of men and women.

Table 2 Variables included in the stated response exercise and their attribute values

Variable												
Location of the residence	CBD with balcony			Urban with balcony			Suburban with garden			Rural with garden		
Type of accommodation	De-tached	Terrace	Flat	De-tached	Terrace	Flat	*De-tached*	*Terrace*	*Flat*	*De-tached*	*Terrace*	*Flat*
Size												
Joint [m^2]	-	-	30	-	30	30	50	40	30	60	50	-
Per person [m^2/Person]			20		20	20	20	20	20	25	25	
Mortgage per month [DM/m^2]	-	-	m^2*15,-	-	m^2*14,-	m^2*13,-	m^2*13,-	m^2*12,-	m^2*11,-	m^2*10,-	m^2*9,-	-
Rent [DM/qm^2]	-	-	15,-	-	14,-	13,-	13,-	12,-	11,-	10,-	9,-	-
Car travel time to work [Min]	10, 20, 30			10, 20, 30			20, 30, 40			30, 45, 60		
Car travel time to shopping [Min]	5, 10			5, 10			10, 20			15, 30		
PT travel time to work [Min]	10, 20, 30			10, 20, 30			20, 30, 40			30, 45, 60		
PT travel time to shopping [Min]	5, 10			5, 10			15, 30			30, 45		
Headway at local stop [Min]	5, 10			10, 15			15, 30			30, 60		
Distance to local stop [m]	100, 200, 300			100, 200, 300			100, 300, 500			300, 500, 700		

Table 3 Distribution of household sizes

Number of household members	One	Two	Three	Four
Share [%]	14.5	66.2	14.5	4.8

Table 4 Age distribution of the sample

	Sex			
Age [Years]	Females [%]	Males [%]	All [%]	Number
Up to 25	22.5	19.1	21.1	35
26 to 35	35.1	43.9	39.8	66
36 to 45	18.1	19.1	18.6	31
46 to 55	9.0	4.9	5.5	9
56 to 65	4.3	3.7	4.8	8
Unknown	11.0	9.3	10.2	17
Total	100.0	100.0	100.0	166

The respondents traded the two types of tools as can be seen in Table 5. The budget shares allocated are reasonable and the average shares are of the order of magnitude known from official expenditure surveys (i.e. 12%).

Table 5 Number of chosen combinations by share of income spent on vehicles and season tickets

Share of income spent on season tickets	Share of income spent on vehicles					Sum
	Up to 9.99%	10-19.99%	20-29.99%	30-39.99%	≥ 40%	
Up to 2.99%	472	223	46	17	1	759
3.00 – 5.99%	119	78	19	6	1	223
6.00 – 8.99%	21	28	8	8		65
9.00 – 11.99%	5	1	1			7
≥ 12.00%	1					1
Sum	618	330	74	31	2	1055

3.3 Modelling framework

A bivariate ordered probit model was developed to model the composition of mobility tools within households. Like the trivariate ordered probit model, which was developed by Scott and Kanaroglou (2002), the bivariate ordered probit model is an extension of McKelvey and Zavoina's (1975) seminal work on the ordered probit model. For the present application, the bivariate ordered probit model has two primary strengths. First, it considers both the *discrete* and *ordinal* nature of the decisions confronting households – namely, the number of cars to own and the number of season tickets to own. Second, the model captures interactions between these decisions – in other words, tradeoffs between the mobility tools. A more detailed discussion of the bivariate ordered probit model will be the subject of another paper.

Models were estimated for both the revealed preference (RP) data set and the SR data set that were constructed as part of the Mobiplan project. A program was written in GAUSS™ (Aptech Com, 2001) for this task. To allow for comparisons, the same independent variables were included in both models. The first group of variables corresponds to *household characteristics* and includes both the number of members with daily commitments (i.e. work or study) and the monthly household income remaining after accounting for housing costs. The number of members with daily commitments is included in the models by a series of dummy variables. One commitment serves as the reference category. These variables not only capture the importance of daily commitments on mobility tool ownership, but also account for differences in household size. It is hypothesized that a positive relationship exists between the number of household members with daily commitments and the number of cars and the number of season tickets owned. In general terms, household income is spent on three categories of goods: housing, mobility tools and all other goods. The final household characteristic included in the models accounts for this. It is hypothesized that a positive relationship exists between monthly household income remaining after accounting for housing costs and the number of cars owned, and that a negative relationship exists between the independent variable and the number of season tickets owned. This latter relationship suggests that as remaining income increases, households would rather spend it on cars than on season tickets.

The second group of variables corresponds to characteristics associated with the *residential location* of the households. A series of dummy variables describing the location of households within the urban system is included in the models. These dummy variables correspond to the urban core, suburbs and urban fringe. The central business district (CBD) serves as the reference category. A positive relationship is postulated between the number of cars owned and distance from the CBD, as measured by the three locational variables. The opposite relationship is postulated for the number of season tickets owned. Distance to the nearest public transit stop is also included in the models with respect to the number of season tickets owned. As distance increases, it is postulated that the number of tickets decreases.

Finally, as demonstrated in Figure 1, a negative relationship is postulated between the number of cars owned and the number of season tickets owned. Simma and Axhausen (2001) find such a relationship between car availability and season ticket ownership for individuals included in three national surveys—namely, those for Switzerland, Germany and Great Britain.

3.4 Results of the analysis

Table 6 presents the results for both models. With one exception, all parameter estimates are significant at the 0.05 significance level. Furthermore, the signs for all variables are as hypothesized. An earlier specification ruled out non-linear effects for two variables – namely, household income remaining after housing costs and distance to the nearest public transit stop. Further analysis using the SR data set also showed that the travel time difference between car and public transit to work was significant for both the number of cars and the number of season tickets. In addition, the travel time difference to shop was also significant for the number of season tickets. These three variables were not included in the specifications shown in Table 6 because the RP data set had too many missing values to allow for their estimation.

With very few exceptions, the results for both models are remarkably similar. Generally, as the number of household members with daily commitments increases, the number of cars and the number of season tickets also increases. However, the large negative correlation coefficients in both models suggest that as such commitments increase, one mobility tool will be emphasised over the other. In other words, one tool is substituted for the other. Other variables in both models suggest that cars will be emphasised at the expense of season tickets. This is especially so if the household is located anywhere other than the core of the city. For example, if the household resides in the urban fringe, the negative effect of this variable on the number of season tickets coupled with its positive effect on the number of cars and the negative correlation coefficient means that cars will be emphasised in household decisions concerning mobility tools. Additionally, the results also indicate that as remaining household income increases and as the distance to the nearest public transit stop increases, there is a movement away from season ticket ownership.

Table 6 Mobility tools: Parameter estimates for best models

Variable	SR Data Set		RP Data Set	
Number of Cars				
Constant Term	-0.635	**	-0.538	**
Household Characteristics				
Two members with daily commitments	0.748	**	0.912	**
Three members with daily commitments	1.854	**	0.960	**
Four members with daily commitments	2.101	**	2.143	**
Income remaining after housing costs [DM per month/5000]	0.618	**	0.603	**
Residential Location Characteristics				
Core			0.416	**
Suburb	0.679	**	0.577	**
Fringe	1.245	**	0.876	**
Threshold Values				
One and two cars	1.908	**	2.074	**
Two and three cars	3.487	**		
Number of Season Tickets				
Constant Term	1.155	**	-0.390	**
Household Characteristics				
Two members with daily commitments	0.693	**	0.468	**
Three members with daily commitments	1.064	**	1.275	**
Four members with daily commitments	1.975	**	1.110	**
Income remaining after housing costs [DM per month/5000]	-0.800	**		
Residential Location Characteristics				
Suburb	-0.542	**		
Fringe	-0.874	**	-0.515	**
Distance to nearest public transit stop [km]	-0.450	*	-0.420	**
Threshold Values				
One and two season tickets	1.366	**	1.090	**
Two and three season tickets	3.000	**	2.116	**
Correlation Coefficient	-0.593	**	-0.466	**
$\rho^2(0)$	0.359		0.363	
$\rho^2(C)$	0.218		0.148	
N	1035		374	

$\alpha = 0.10$: *; $\alpha = 0.05$: **

4 Choice of home location

The housing location choices of the Mobiplan respondents should give a good insight into the preferences of these households, as explained above. In addition, the data can shed some light on the question of the importance of the vicinity to the previous address, although the sampling strategy will lead to an underestimate of that influence, as it excludes respondents moving within their neighbourhood.

The literature about housing and residential location choice is vast and no attempt will be made to review it here. Useful reviews are provided by Srour, Kockelman and Dunn (2001); Hunt, McMillan and Abraham (1995); Clark and Dielemann (1996); and Mobiplan Konsortium (1999).

Kreitz and Jürgens (2001) provide a descriptive analysis of the chosen locations and of the reasons for the move. This paper will therefore concentrate on a first analysis of the data using a simple random utility approach (Ben-Akiva and Lerman, 1985; Ben-Akiva and Bierlaire, 1999), but see Lyon and Wood (1977) for a description of the search process, which raises doubts about that application.

4.1 Construction of the choice sets

In situations where the analyst wants to model choices among large or very large numbers of often similar alternatives, it can be shown, that unbiased parameter estimates can be obtained by constructing the set of alternatives for estimation as the chosen alternative plus a small random sample of all other alternatives (see Ben-Akiva and Lerman, 1985; McFadden, 1978). To increase the set of alternatives for these random draws information about advertised houses and flats was collected for the study period. The two main sources of property and rental advertisements are the local monopoly newspaper and a local small-ads only paper (*Badische Neueste Nachrichten* and *Sperrmüll*). All relevant objects, which were advertised on the 21./22. and 24. February 2001, were coded for use in the analysis. This added 1157 objects to the 349 objects, into which the Mobiplan respondents had moved.

Each object was geocoded. For objects, for which no exact address was known, the centre of gravity of the municipality or neighbourhood was used. Based on this information, network models were used to calculate road distances, road and public transport travel times and number of changes to the old residence, the work place, the *Mittelzentrum* (local urban centre of intermediate rank) and the *Oberzentrum* (regional centre). In addition, the travel times and number of changes to the respective work places, schools and universities of the household members were also calculated.

For the analysis reported here, 15 alternatives were drawn for each observed household as a pure random sample only classified by the type of tenure (purchase, rental and shared accommodation). They were marked as being located in the federal states Baden-Württemberg and Rheinland-Pfalz, as the data set only includes locations in Baden-Württemberg as destinations for the moves (see above).

4.2 Estimation approach and results

The variables available can be grouped into the following categories:

- **Change from previous location**: change or not in the type of location (urban core, urban fringe, outside city limits of Karlsruhe), type of change in type of location, distance to previous location;
- **Relative location of the residence**: distances and travel times to the *Mittelzentrum*, the *Oberzentrum*, the work places and the places of study;
- **Characteristics of the residence**: type of accommodation (house, flat), size (m^2), monthly costs (imputed from the advertised purchase price for objects for sale); and
- **Characteristics of the household**: number of members, age distribution, household income (after tax), mobility tools and their use (vehicle kilometres driven, current public transport trips/week).

The first group of variables is often mentioned in discussions of housing choice, but is normally not included in the model estimation, as they are often not available at all or so dated, as to be without importance. In this case, with a sample of just moved households, it was desirable to include them.

The relative location variables are substitutes for the theoretically more desirable log-sum accessibility variables (see Srour, Kockelman and Dunn, 2002; Simma, Axhausen and Vrtic, 2001; or Kockelman, 1997). These log-sum variables derived from destination- or destination and mode-choice models aggregate the spatial attractions around a location in a form consistent with utility maximisation (Ben-Akiva and Lerman, 1985). Neither type of model was available nor could they be estimated ad-hoc for this study. The impedance variables used provide some approximation, as they distinguish between the nearest Mittelzentrum and Oberzentrum, which in turn are major concentrations of shopping, leisure, study and work.

The impedance variables with respect to the places of work and study reflect the current constraints of the household, but not future possibilities, as they would be captured with a log-sum accessibility term. The underlying assumption is that the household members will not simultaneously change home and work location. All members of the household were considered and included to reflect the concerns of all persons with a fixed commitment to travel (see also Timmermans, Borgers, van Dijk and Oppewal, 1992 for the case of dual earner households).

One group of variables will not be used in the models reported here – namely, those describing the municipality of the residence: subregion, socio-economic qualities (average purchasing power, unemployment rate, age structure, distribution of professions, average accommodation costs, share of pupils continuing with higher education, etc.) and spatial qualities (share of open space, accessibility of leisure, shopping and work opportunities, etc.). A recent hedonic price study of housing costs in Cardiff (Orford, 2000) has made clear that area effects can be substantial and have to be accounted for to avoid biased estimates. While Orford (1999) used a linear multilevel regression framework, and while mixed logit models (Hensher and Greene, 2001) allow the transfer of this approach into the discrete choice framework, this paper will not include such estimates. They will be the subjects of a later paper.

The models were estimated using Limdep 7.0 (Greene, 1998). The initial model included the relevant variables in linear form. As can be seen in Table 7, that model formulation results in unexpected signs for a number of variables and has low explanatory power. Further work showed that it is advantageous to reformulate some variables and to introduce quadratic terms to capture non-linear responses by the households.

Table 7 Housing location choice: Parameter estimates

Choice set (Mobiplan respondents and locally advertised objects)	Baden-Württemberg (BW) and Rheinland-Pfalz			Only BW
	Accommodation share of income [%]		Accommodation share of income minus mean observed share [%]	
Accommodation costs				
For owners (linear)	0.404	4.288 **	3.081 **	2.882 **
For owners (squared)		-1.946 **	-1.946 **	-1.790 **
For renters (linear)	-1.572 **	3.213 *	-1.072	-0.989
For renters (squared)		-7.934 **	-7.934 **	-7.878 **
For shared accommodation (linear)	7.478 **	15.953	-5.740	-5.684
For shared accommodation (squared)		-31.901	-31.901	-31.594
Space/head of household (m2)	-0.001			
Space/head minus observed mean (linear)		0.032 **	0.032 **	0.032 **
Space/head minus observed mean (squared)		-0.001 **	-0.001 **	-0.001 **
Accommodation is a house	-1.000 **	-0.673 **	-0.673 **	-0.670 **
Road distance to old accommodation [km]	-0.051 **	-0.066 **	-0.066 **	-0.067 **
Road distance to Oberzentrum [km]	0.009			
ln(road distance to Oberzentrum) [km]		0.196 **	0.196 **	0.155 **
Road distance to Mittelzentrum [km]	-0.008			
Public transport trip duration to Mittelzentrum		-0.0001 **	-0.0001 **	-0.0001 **
Mean road and public transport trip duration to work places	-0.006 *	-0.013 **	-0.013 **	-0.013 **
Mean public transport trip duration to school/university	-0.013	-0.024 **	-0.024 **	-0.022 *
Same type of location	0.502 **	0.415 **	0.415 **	0.414 **
Move from urban core to urban fringe	0.938 **	0.682 **	0.682 **	0.688 **
L(0)	-970	-970	-970	-973
L(β)	-872	-762	-762	-758
adj R^2	0.10	0.21	0.21	0.22
N	350	350	350	351

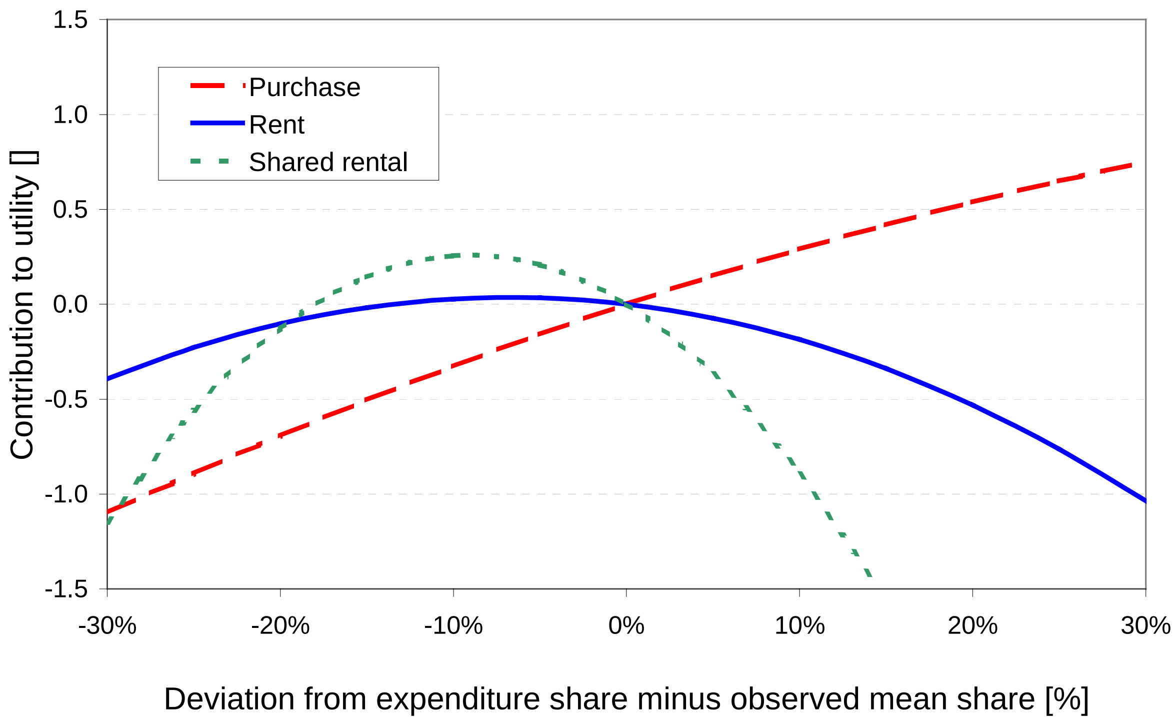
$\alpha = 0.10$: *; $\alpha = 0.05$: **

Observed mean shares of accommodation costs of net income: Owners 31%, renters: 27% and persons in shared accommodation: 34%

Observed Mean space/head: 45 m^2

Given the large spectrum of accommodation costs and incomes, it was advantageous to standardise the costs relative to income. The parameter estimates for the cost variables in the first model show positive signs for owners and persons residing in shared accommodations. Introducing a squared term does not remove that problem, but shows that a different interpretation is required. These results indicate the preferred budget shares for this type of housing. This is even more easily visible when deducting the observed mean shares from the Mobiplan respondents (third model). Figure 5 shows that the households would like to reduce their share of the accommodation costs for rental and shared accommodations. For owners, the figure indicates a willingness to increase massively the share spent. This counterintuitive result must be due to the imperfect estimate of incomes, but more importantly of the accommodation costs. The estimates of mortgage costs do not include any capital, which the household had available for a down payment or differences in the initial standard of outfitting, which can vary substantially in Germany (from an empty shell to a house with a fully furnished kitchen).

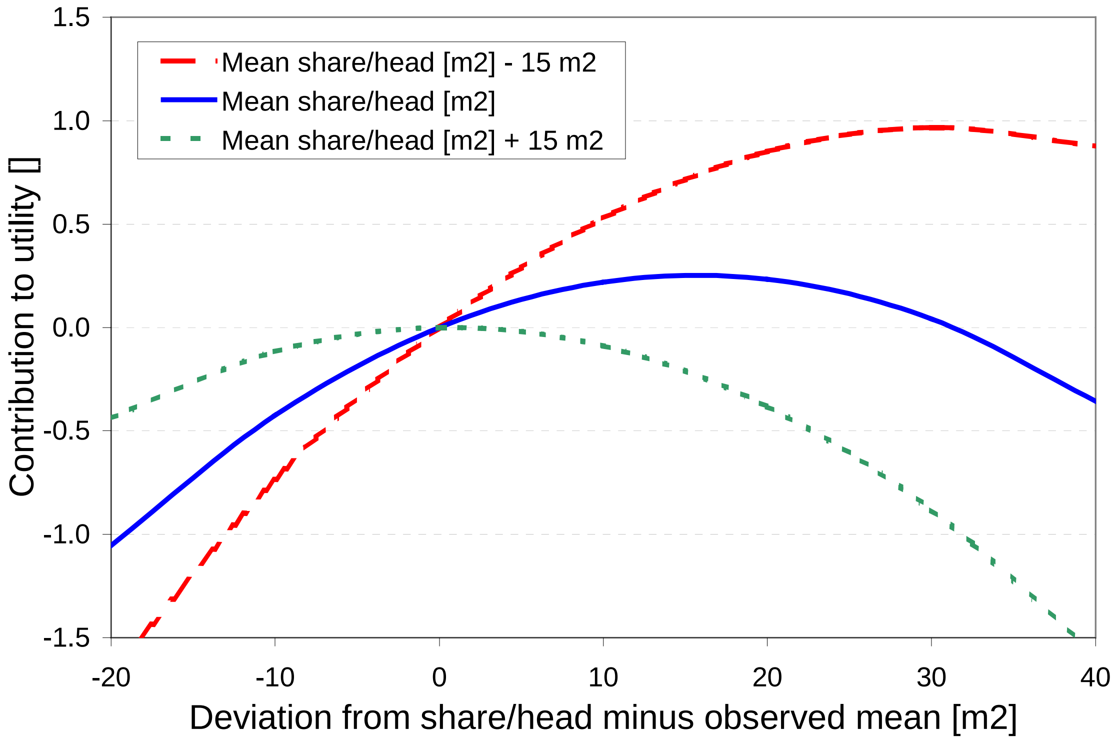
Figure 5 Utility contribution of changes in share of accommodation costs minus observed mean share [%]



See Table 7 (third model)

Equally, the model could be improved by expressing space per head relative to the observed mean of 45 m^2 in the Mobiplan sample, which is generous, but not extreme. Using the mean and values plus or minus 15 m^2 as a basis for the estimation did not change the conclusion that the households would like to increase their space consumption further to about 60 m^2/head (see Figure 6).

Figure 6 Utility contribution of changes in space/head of household minus observed mean space/head [m^2]



See Table 7 (third model)

The consistent bias against living in a house would be surprising in a British or US context, but in Germany apartments in low-rise buildings[9] are popular and widely available in the housing market.

The change variables make a substantial contribution to the explanatory power of the models. The distance to the old location is highly significant and has a large parameter value. The linear form performed better than the alternatives tested (natural log, linear plus squared term). Households do not like to move too far away from their established centre of activities (see Butler, Chapin, Hemmens, Kaiser, Stegman and Weiss, 1969 for similar American patterns).

9 Unless a subsidised body or a big management firm (life insurance, pension fund) owns the building, the owners of a building's flats will form a co-operative to manage the joint aspects of the buildings (roofs, hallways, lifts, gardens) including a joint fund for capital expenses.

In principle, they prefer to stay with the same type of urban environment (core, fringe, outside city limits), unless it is a move to the urban fringe within the city limits, which is the preferred location for the Mobiplan sample[10]. This persistency has been argued in the literature, but these are the first formal parameter estimates known to the authors.

The combination of variables included here is unusual and make comparisons with the literature difficult. The natural log of the road distance to the Oberzentrum has a significant positive parameter, while one would expect a negative one in the tradition of urban economics. Still, the Karlsruhe region has a strong network of Mittelzentren for shopping and less so leisure activities plus a substantial number of suburban shopping centres. The vicinity to those is measured separately (linear; public transport travel time[11]). The distance to work and study is described in detail by the mean travel times by road (work only) and public transport to those locations for the household members concerned (linear). These last parameters are all significant and negative. In this context, it remains for distance variable to the Oberzentrum, the CBD of the traditional model, to capture roughly the density gradient in the area. The positive sign is justifiable against this interpretation. This interpretation is supported by the dummy variable mentioned above, which indicates the preference for a move to the urban fringe.

Specific variables describing access to the public transport systems, such as density of public transport stops, or its service level, such as number of services, were omitted to avoid collinearities with the variables mentioned above.

The final model excludes all alternatives outside Baden-Württemberg (i.e. those located in Rheinland-Pfalz). The parameter estimates are basically unchanged. There is no need for a reinterpretation of the results so far.

Further experiments with the Baden-Württemberg only data set showed that indicators for the specific subregion of the location did not add further explanatory power. Given the experiences of Orford (1999), this conclusion has to be preliminary until mixed logit estimates confirm them. Equally, further model estimates will be necessary to see if the municipal environment has a significant impact.

No attempt has been made to include the available information about the mobility tools of the household into the formulation of the variables. Various interaction terms would have been obvious candidates: ratio of road distances to number of cars owned or ratio of public trans-

[10] This could be due to the way the sample was generated. Estimates with proper population weights will have to be performed during the further studies of this data set.

port duration to number of season tickets. Equally, it would be possible to estimate the respective costs given mobility tool ownership. Given our arguments above and the results above about the trade-offs of the households between these tools, it seemed unreasonable to transfer the choices the household made for their chosen location to the not-chosen alternatives, especially as further work on a joint model of location and mobility tool ownership is planned.

5 Conclusions and outlook

This paper has argued the case, that self-selection effects are pervasive in spatial and transport-related decision making. This argument is not new, but the recent interest in appropriate models of change and of daily behaviour under constraints brings it to forefront of interest again. Using descriptive examples and two choice models (set of mobility tools of a household and housing location choice) the paper demonstrates these effects empirically.

While the statistically proper solution is the development of self-selection models, which make the decisions about the constraints endogenous to the system (see Bhat, Sivakumar and Axhausen, 2002 for an example), this strategy is difficult in this context due to the long time-horizons/long histories of the relevant decisions. In this paper the constraints were described with variables reflecting those previous decisions. In the model of the mobility tool choice: housing location (type of location, distance to nearest public transport stop; housing costs; distances to work and shopping); in the model of residential choice: distance to previous residential location, type of previous location, distances to work and education). All were significant and had the expected signs.

The data are not exhausted with these first models. As mentioned above, a number of improvements will be pursued in further work: improved data for the mobility tool data set (distances to work and education), mixed logit estimates in the residential location choice to account for area effects and finally joint models of residential location and mobility tool ownership.

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[11] The duration includes the number of necessary changes weighted with a factor of 10 minutes each.

6 Acknowledgements

The analysis within this paper is based on the data of the Mobiplan project. The authors wish to thank all project participants at the Institut für Stadtbauwesen (RWTH Aachen), PTV AG (Karlsruhe), Institut für Soziologie (Universität Karlsruhe) and IVT (ETH Zürich) for their help and the project for its willingness to make the data available. The PTV AG, Karlsruhe, implemented the stated-response survey on mobility tool ownership. The authors want to acknowledge the special contribution of Dr. Markus Friedrich and his colleagues in the development of the survey and the Mobiplan advisory tool.

Mr. M. Fix (PTV AG, Karlsruhe) added the various distances and travel times using appropriate network models and public transport service databases. This is gratefully acknowledged.

The Mobiplan and Mobidrive projects were funded by the German Ministry of Research and Technology through its programme "Understanding Mobility Better."

The results and their interpretation are the sole responsibility of the authors.

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