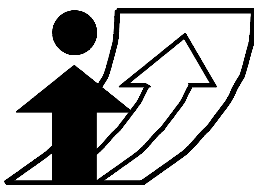# Between routines and variety seeking: The characteristics of locational choice in daily travel

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Between routines and variety seeking: The characteristics of locational choice in daily travel

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Abstract

The navigation of travellers in space, the daily distances travelled, the determinants affecting spatial reach and spatial choice processes choice have been for long important foci of travel behaviour research. Detailed information about the spatial aspects of travel is an essential base for traffic forecasting and the evaluation and design of transport infrastructure. Nevertheless, there is still need to better understand the characteristics of spatial mobility, especially if turning to questions of variability, regularity and dynamics of movements in space.

Important for the lack of research into the structures of reoccurring behavioural patterns and the stability of locational choice was both, the fact that suitable longitudinal data has not been really available so far and the insufficient accuracy of spatial information in travel data.

This data availability and research deficit has motivated researchers in the last few years to collect suitable data capturing the variability in individual travel as well as to develop methodology for detailed analysis. The exploration of the 1999 Mobi*drive* six-week travel diary data has deepened the understanding of daily travel routines and variability. At present, another innovative data set based on Global Positioning Systems information is prepared for investigation

Based on these two long-duration data sets with a high level of spatial accuracy, this paper reports on results on the variability of spatial choice and the structure of human activity spaces.

Keywords

Locational choice, activity space, International Conference on Travel Behaviour Research, IATBR

Preferred citation

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1.   The longitudinal perspective of travel

The complexity of daily life results in a diversity of individual activity repertoires and related travel patterns over time. The investigation of daily life travel for single travellers, i.e. the *intra-personal level* of travel (see Pas and Koppelman, 1986; Pas and Sundar, 1995 for definitions), has long been restricted by the absence of suitable survey data covering prolonged periods and methods to treat such data. For various reasons, the sensitivity of travel behaviour towards supply change (*pull strategies*) as well as demand orientated measures (*push strategies*) has so far been tested by collecting and analysing data bases on cross-sectional surveys, only. As a consequence, mobility patterns observed on single days have often been interpreted as optimal decisions of the traveller and as a state of behavioural equilibrium – which is assumed to exist for any point of time and any situation. Travel behaviour research has consistently questioned this working hypothesis (see e.g. Huff and Hanson, 1986; Jones and Clarke, 1988), as daily mobility contains a significant amount of variability and flexibility over time. The stability within travel as well as the deviations from the predominantly routinised structure of daily life can only be revealed by exploring individual panel data, i.e. observations of behaviour of single persons over a prolonged period.

Over the last years, the variability in daily life travel has been the focus in a range of studies based on the unique 1999 six-week travel diary data set Mobi*drive* (Axhausen, Zimmermann, Rindsfüser, Schönfelder and Haupt, 2002). The data set provides panel trip data for about 300 respondents over six weeks and therefor precious information on the variability and regularity in daily travel. The extensive investigation of temporal phenomena in persons' and households' activity demand and deduced mobility has deepened the transport research's knowledge in the individual organisation of daily life travel as well as structures and determinants of long-term travel behaviour.

The current paper is adding to the exploration of the longitudinal data by addressing for the first time the visualisation and measurement of human activity spaces (Schönfelder and Axhausen, 2002a; b; 2003). The identification of revealed individual activity spaces based on a longitudinal observation of trip making and activity performance will increase transport planning's ability to realistically define choice set for destination choice. Furthermore, it allows us to understand the behavioural mechanisms behind the dispersion and clustering of activities.

This papers gives an overview about the methodology to capture locational choice and individual activity spaces using the Mobi*drive* data set as well as a new data set based on automatically collected GPS information of vehicles.

2. Data sets and possible directions of investigation

As described above, individual travel data covering periods substantially longer than one week are rare as especially data collection by means of travel diaries is costly and includes the risk of loosing data precision by fatigue or no-response effects. In the following, two up-to-date longitudinal data sets are introduced which differ substantially from their data collection approach but which both showed successfully that collecting long-term individual travel information is nonetheless feasible. Due to the availability of exact location data for both data sets, they offer interesting opportunities for the analysis of spatial choice.

2.1 Mobidrive

The 1999-2001 Mobi*drive* project proved that the fear to lose information in multi-week travel diary surveys was unjustified (see Axhausen, Zimmermann, Schönfelder, Rindsfüser and Haupt, 2002). With the implementation of a continuous six-week travel diary as core of the project, a current data set of long-term individual travel behaviour is now available for analysis. The extensive investigation of the data during the last years has led to the development and the adoption of a range of analysis and modelling approaches for daily travel and the stability as well as variability within it (see Zimmermann, Axhausen, Beckmann, Düsterwald, Fraschini, Haupt, König, Kübel, Rindsfüser, Schlich, Schönfelder, Simma and Wehmeier, 2001 for an overview of results).

Based on the experiences made with a similar data collection experiment in the 1970s (Uppsala Household Travel Survey, see e.g. Marble, Hanson and Hanson, 1972), a continuous six-week travel diary survey was conducted in the German cities of Halle/Saale and Karlsruhe in autumn 1999. A total of 317 persons over 6 years in 139 households participated in the main phase of the survey, after testing the survey instruments in a pre-test with a smaller sample in spring 1999 (44 persons). The paper-based travel-diary instrument was supplemented by further survey elements covering the socio-demographic characteristics of the households and their members, the details of the households' car fleet and transit season tickets owned and personal values as wells as attitudes towards the different modes of transport.

One objective of the Mobi*drive* consortium was to provide exact locational data in order to facilitate the analysis of the variability in spatial behaviour over time (e.g. destination-, route- and mode-choice). The precise locational data was obtained by geocoding the trip destination addresses of all main study trips (approximately 40.000 trips). The addresses – including home and workplace locations – were transformed into Gauss-Krüger coordinates in a WGS

84 (World Geodetic System) geodetic reference system. The geocoding was positive for about 95% of the reported trips. Due to incomplete addresses and limited availability of digital address information outside the urban cores of the case study regions, the geocodes of the addresses have different degrees of resolution for the different spatial units. For the municipalities City of Karlsruhe and City of Halle, the street addresses could be geocoded on the basis of (small) building blocks (i.e. more than 90% of all geocoded trips), whereas outside the urban boundaries the addresses are available as geocodes of the centroids of the municipality, only.

2.2   Borlänge Rätt Fart GPS data

The Mobi*drive* experiences have increased researchers' interest in accessing long-term travel data bases which eventually capture even seasonalities in activity and trip demand. One obvious technical possibility is the collection of travel behaviour data by in-vehicle Global Positioning System (GPS) devices and GIS. This innovative data collection methodology is promising especially in the field of route choice analysis where exact choice data over longer periods is quasi non-existent. This methodology has been discussed and tested in transport research since mid of the 1990s (see Wolf, Guensler and Bachman, 2001 for an overview of feasibility studies).

The Institute of Transport Planning and Systems jointly with colleagues of the Department of Mathematics at the EPFL is currently exploring the potentials of a vehicle based GPS log data source from Sweden for the purpose of travel behaviour research (Schönfelder, Axhausen, Antille and Bierlaire, 2002; Schönfelder and Samaga, 2003). The fully automatically collected data contains movement information for single travellers for more than two years. The technical approach used here is the common combination of mobile GPS data loggers and a Geographical Information System (GIS) (see Draijer, Kalfs and Perdok, 2000 for an example). A range of vehicles were equipped with an on-board data collection system consisting of a GPS receiver, a data storage device with a GIS for mapping all movements and a mobile power supply.

The GPS data set *Rätt Fart* was made available for travel behaviour analysis by transport psychologists from the universities of Dalarna and Uppsala (Sweden) in 2002. The traffic safety project *Rätt Fart* (Right Speed)[1], based in the Middle-Swedish town of Borlänge, is one of the sub-projects of the Swedish National Road Administration initiative approach *Intelligent*

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[1] See http://www.rattfart.com

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Speed Adaptation (ISA) (see Vägverket, 2000). Rätt Fart in Borlänge itself had its focus on provision of information for the drivers using GPS devices. The study was conducted from 1999 to 2001 with about 260 private and commercial cars which were equipped with GPS and speed adaptation systems over the period of up to 2 years. The essential characteristics speed, acceleration, actual time, location etc. were stored internally for analysis in logs every second respectively every tenth second depending to the road link.

The movement file contains 245.000 private car trips. The area for detailed monitoring was limited, though, to the town of Borlänge plus some surrounding region – an area with a radius of about 20 km around the town centre of Borlänge.

As the data set was not collected for travel behaviour analysis purposes, the vehicle movement data needed to be cleaned and enriched to obtain usual survey data comprehensiveness and quality. For a small sub-sample of the Borlänge GPS data set an initial post-data processing procedure has been applied (Schönfelder and Samaga, 2003) consisting of

- _Identifying unique origins and destinations of travel_: Trip starts and ends are predefined in the Rätt Fart approach by switching on respectively turning off the car (which includes the ISA device). This automatically starts or interrupts the transmission of data. However, final positions of movements to the destinations vary significantly due to transmission inaccuracies or simply by using different parking spaces for same destinations over the period of monitoring. Algorithms to categorise unique starting respectively ending points were developed.

- _Detecting additional trip ends_: Fortunately, durations during which the vehicle does not move – or in other words, during which zero speed is observed are very rare. Initial investigations of sub-samples showed that both, transmission problems such as "lost" signals and periods of zero-speed concern only about 0.1% of all data logs.

- _Identification of trip purposes:_ Together with the identification of the trip-end positions, the assignment of trip purposes for the observed trips is the major postprocessing task. The trip purpose is central for travel behaviour analysis as it indicates the reason for travelling and therefore is an important determinant for analyses based on individual utilities (e.g. route choice modelling).

In spite of the still initial character of the data post-processing approach, the imputed data base shows potential for an intense spatial and temporal investigation of daily life travel. As Mobi_drive_, the data set reveals the variability and stability in trip making and activity performance over time.

## 3. Describing and measuring spatial mobility: The *activity space*

Human spatial behaviour and the mechanisms of locational choice is an important issue in transport research and geography. Over the last 50 years, researchers and planners have become increasingly interested in "how individuals make spatial behavioral decisions and how those separate descisions may be summarized by models and generalizations to explain collective actions" (Fellman, Getis and Getis, 1999, 70).

Individual panel data allows to add the longitudinal level of behavioural analysis to those investigations. Two of such longitudinal phenomena are stability and variety seeking. They are addressed at this point as an introduction to the question of describing and measuring destination choice over time and to demonstrate the possibilities of panel data analysis.

Although people have many places they visit for different activities (Figure 1), this does not mean that each place is visited with the same frequency. On the contrary, there is a small number of locations which is predominant for particular activities within the observation period. From a methodological but also from a planning point of view it seems interesting to know how many locations are necessary to know to describe a substantial part of one's travel behaviour. Especially for future longitudinal surveys which cannot guarantee the extensive support of the respondents as in Mobi*drive*, this aspect seems crucial.

Figure 2 indicates that locational choice is reasonably routinised. For leisure activities for example, the cumulative share of the four most important locations is about 40-50% of all visits with the cumulative activity duration and expenditures of about 60-80% for this particular activity purpose. The number of locations frequented is even lower for the more compulsory activities like work, shopping or education which shows the regularity in daily travel.

Figure 1   Distribution of unique locations observed by trip purpose (Mobi*drive*, 6 weeks)
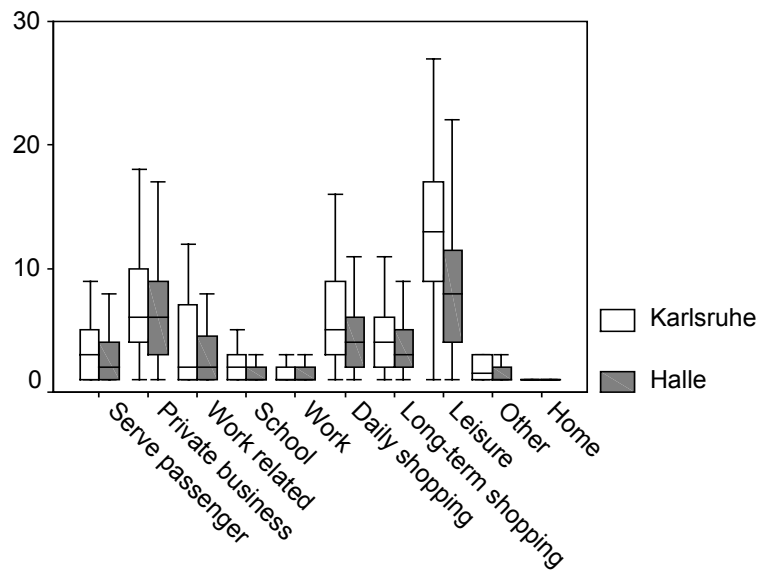
Extremes and outliers are not shown

Figure 2   Stability and variety seeking in locational choice by purpose: Trip frequencies, activity durations and expenditures covered by the four most visited (unique) locations
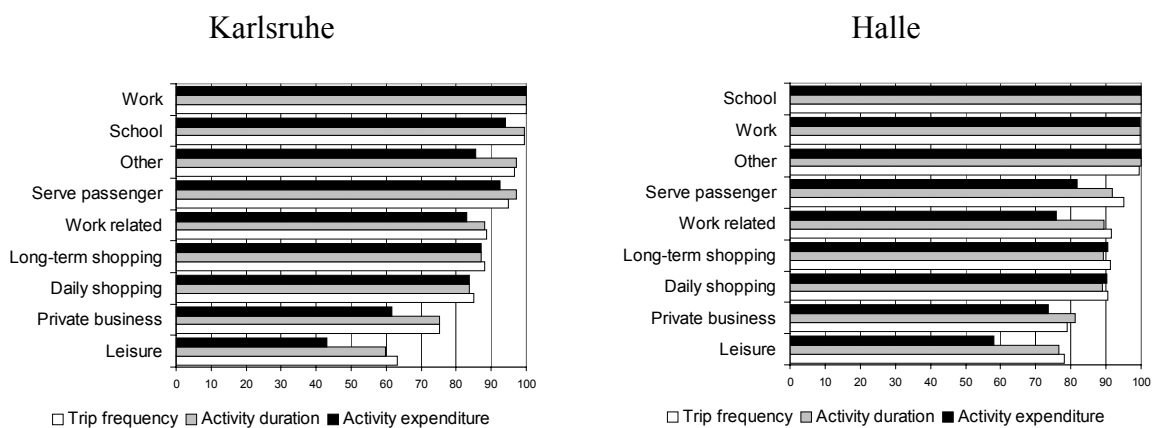

The extensive analysis of the temporal aspects of travel within the Mobi*drive* framework has indicated that there is strong regularity in travel behaviour over the prolonged observation periods but with a substantial background variability as well. Using the geocoded trip data, the

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question arose if this is also true for the locations visited. Or in other words, do people have a restricted number of places they know and visit?

The following figure shows the average number of additional locations per day that had not yet been visited previously during the Borlänge Rätt Fart monitoring period. Obviously there is an almost unlimited number of places people know, because even after several weeks there are still places people "discover" as new destinations – at least from the perspective of the analyst[2].

Figure 3   "New" locations visited over of the monitoring period
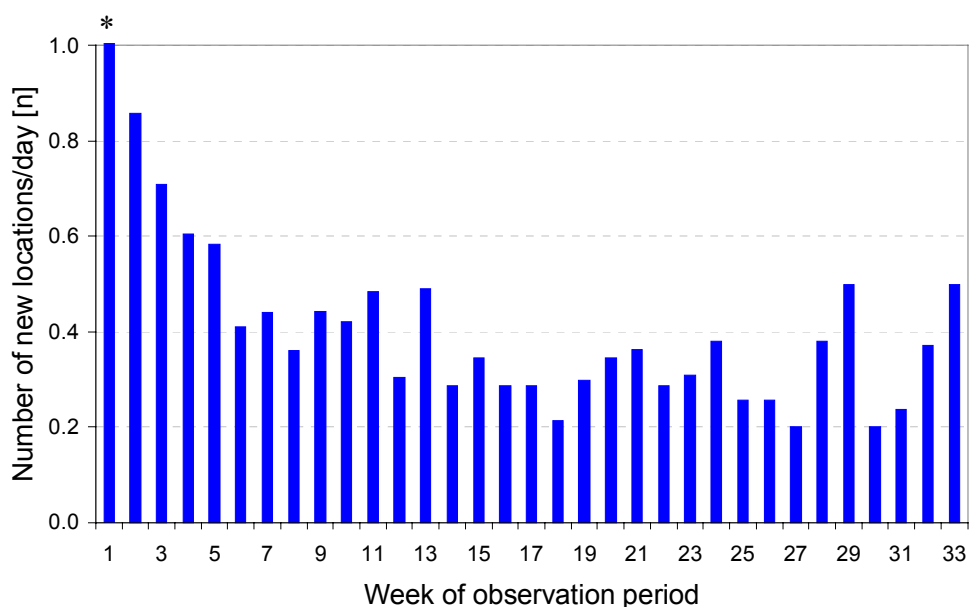
"New" defined as locations which have not yet been visited respectively observed before

* Week 1: 1,41; 39 person Borlänge GPS data subsample

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[2] It should be said, though, that of course the term "new" or "novel" location is a misnomer, as people have some activity locations which they only visit with very low frequency, such as the dentist. These locations are not genuinely new, i.e. previously unknown.

The individual perspective: Activity spaces

The aggregate perspective of locational choice as described above overlooks that individual patterns differ substantially between the travellers as well as for the individuals over time. A micro-geographical concept which captures these daily mobility structures is the *activity space*. The activity space concept – which was developed in parallel with a range of related approaches to describe individual perception, knowledge and actual usage of space in the 1960s and 1970s (see Golledge and Stimson, 1997 for a discussion) – aims to represent the space which contains the places frequented by an individual over a period of time. Activity spaces are geometric indicators of the *observed or realised* daily travel patterns (see also Axhausen, 2002). This is stressed here as related concepts such as the action space (e.g. Horton and Reynolds, 1971), the awareness space (e.g. Brown and Moore, 1970), the perceptual space (e.g. Dürr, 1979), mental maps (e.g. Lynch, 1960) or space-time prisms (e.g. Lenntorp, 1976) describe the individual *potentials* of travel – based on spatial knowledge, mobility resources, the objective supply of opportunities etc.

Activity spaces are defined as a two-dimensional form which is constituted by the spatial distribution of those locations a traveller has personal contact with. The geometry, size and inherent structure of activity spaces are supposed to be determined by three determinants (Golledge and Stimson, 1997) (Figure 4):

- Home: The position of the traveller's home location, the duration of residence, the supply of activity locations in the vicinity of home and the resulting neighbourhood travel
- Regular activities: Mobility to and from frequently visited activity locations such as work or school
- Travel between and around the pegs: Movements between the centres of daily life travel

Figure 4   Simplified activity space representation
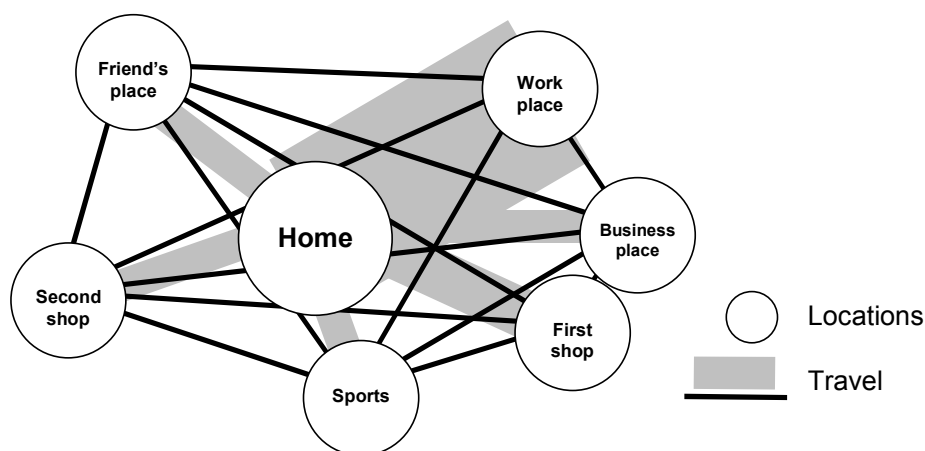
Adopted from Maier, Paesler, Ruppert and Schaffer (1977) 57

Empirical work on revealed activity spaces is rare. The physical mapping or enumeration of the places visited by individuals - such as shown for Mobi*drive* and Borlänge examples in Figures 5 and 6 – are only possible if there is longitudinal, geocoded travel data available or at least lists of visited places plus the frequency of visit. Where such work has been done, it was mostly done with a distinct focus on travel potentials or opportunities. This was often inspired by the conceptual approaches of space-time geography which puts spatial movement into a context of individual and societal and constraints (Hägerstrand, 1974). Only few studies concentrated on the detailed measurement of individual activity spaces (e.g. Dijst, 1999)[3].

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[3] It should be noted that there is a range of studies of spatial behaviour and activity spaces on the aggregate level of sociodemographic groups or zones. Those studies use cross-sectional travel or time-use data.

Figure 5   Distribution of activity locations: Two persons (Mobi*drive*)
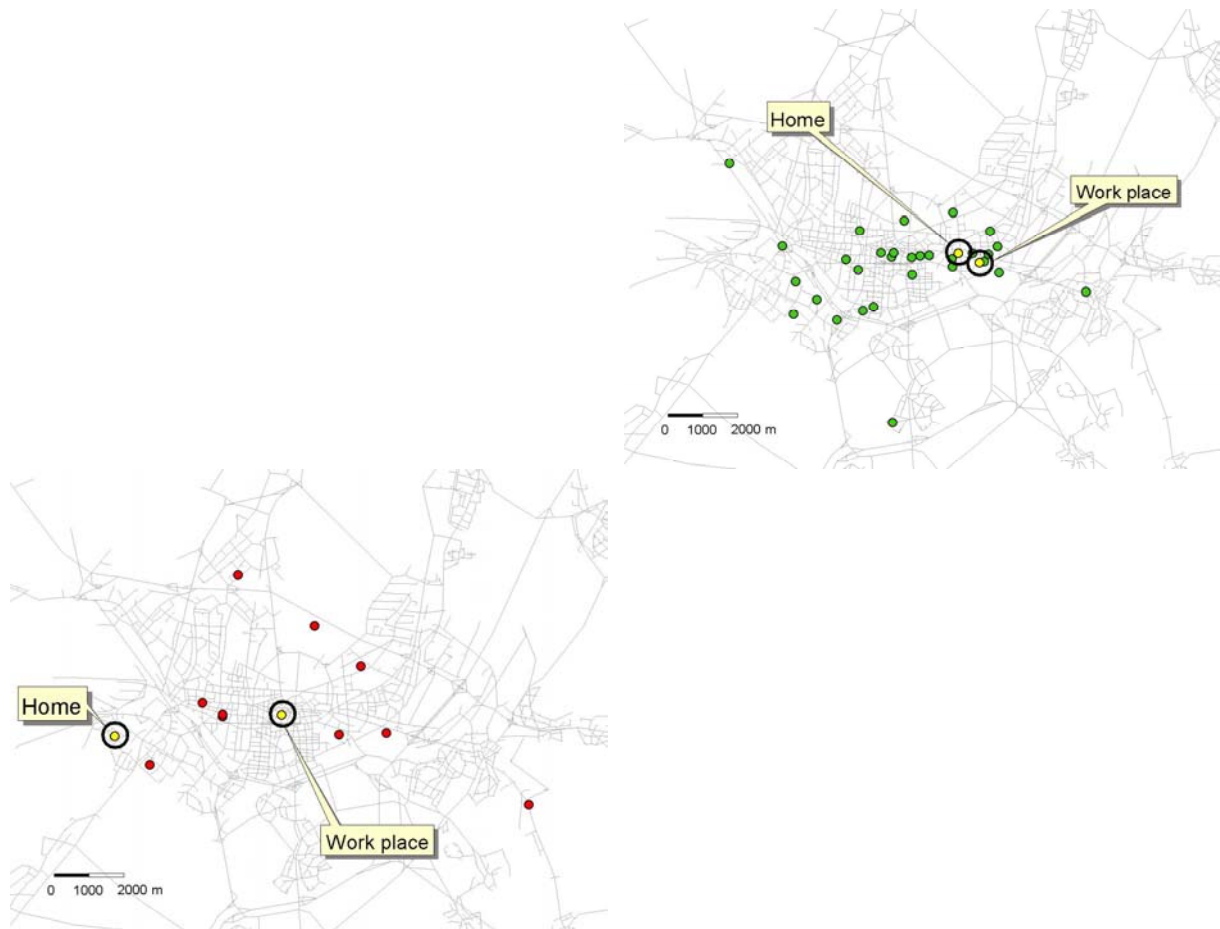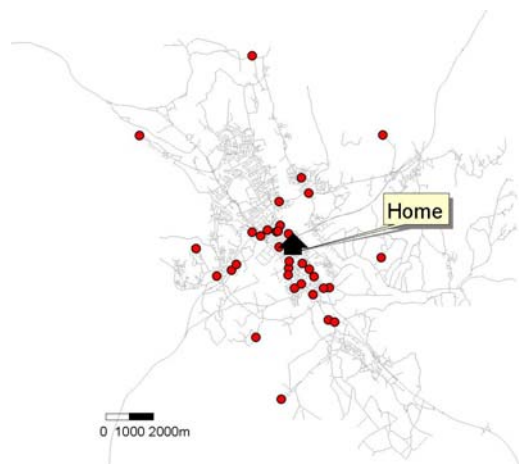

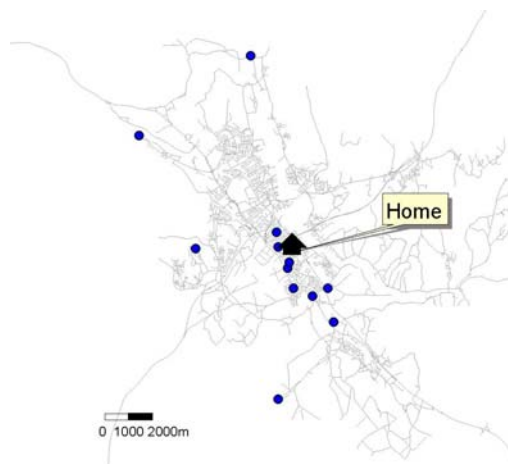Left: Man, 50, full-time, 1 child, 120 trips / 6 weeks
Right: Woman, 24, full-time working, single, 216 trips / 6 weeks

Figure 6   Distribution of activity locations by day-of-week: Borlänge example

Monday to Friday locations   Saturday locations

Retiree, male, 71years; observation period: app. 4 months

Development of concepts

The lack of earlier empirical research required the development of suitable measures to operationalise the activity space concept based on individual panel data. Describing and comparing revealed spatial activity patterns of individuals over time is therefore a challenge on a conceptual level and also for data processing.

The methodological development to capture human activity spaces has so far lead to three measures which are models of human behaviour and simplifications of environmental perception and actual decision processes (see Schönfelder and Axhausen, 2002a; b; 2003). The concepts are:

- A two-dimensional confidence ellipse (interval) around a suitably chosen centre point.

- The activity space measured by *kernel densities* where again information about the locations visited is used.

- The third approach is based on the idea of *shortest paths network*, i.e. the length of the minimum distance of the routes between the locations visited over time.

Figure 7 gives an overview of the measures.

Figure 7   Measuring activity spaces: Overview of concepts developed

a) Confidence ellipses

Dots show location and intensity of observed activity locations of one respondent
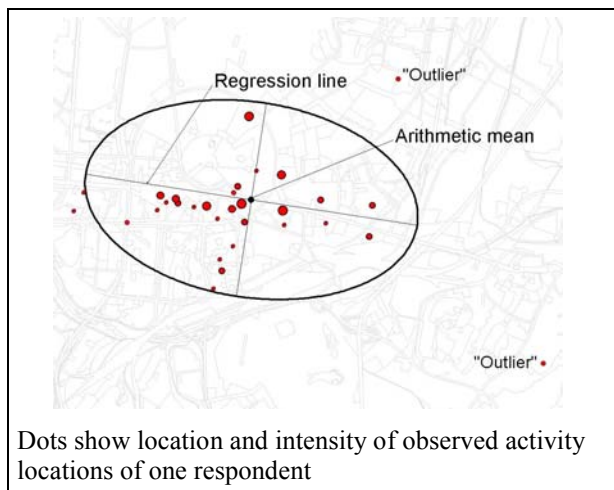
- Basic approach: Confidence ellipses, i.e. smallest possible area in which a defined share of all visited locations is situated

- Measure: Size (plus direction of main axis)

- Special feature/quality: Shows dispersion of visited locations

b) Kernel densities

- Basic approach: Density surface; based on the proximity of activity locations

- Measures: a) Area covered exceeding a certain threshold value, b) "Volume" (sum of all kernel densities calculated)

- Special feature/quality: Represents local clusters / sub-centres within individual activity space

c) Shortest paths network (SPN)

Boldness of network links corresponds to frequency of network link usage
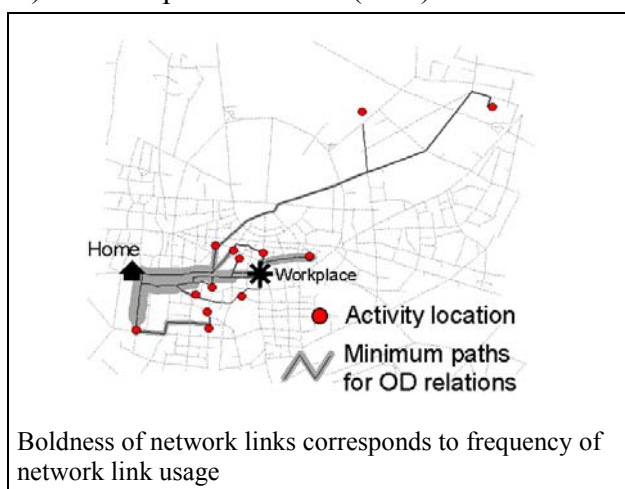
- Basic approach: Set of shortest paths between all origin-destination relations observed

- Measure: a) Length of tree (unweighted/weighted by frequency of single link usage), b) Size of buffered area around the tree indicating potential knowledge spaces

- Special feature/quality: Indicator for the perception of urban space and networks

Confidence ellipses

Confidence ellipses – also called prediction interval ellipses – are an explorative method to investigate the relationship between two variables (bivariate analysis). They are often used for hypotheses testing and to detect outliers. Confidence ellipses are analogous to the confidence interval of univariate distributions defined as the smallest possible (sub-)area in which the true value of the population should be found with a certain probability (e.g. 95%). Similar methodological techniques have long been used in habitat research (see Jennrich and Turner, 1969; Southwood and Henderson, 2000) as well as in the activity space oriented work of the 1970s UMOT project (*Unified Mechanism of Travel*) and subsequent studies (Zahavi, 1979; Beckmann, Golob and Zahavi 1983a; 1983b).

The size of the area is the actual measure for the activity space size and may be used to compare the dispersion between travellers or of one respondent on different days of the week (see Figure 8). The orientation of the ellipse is determined by the sign of the linear correlation coefficient between the coordinates x and y of the activity locations; the longer axis of the ellipse (if shown) is the regression line.

In order to approach a more realistic representation of human behaviour, modifications of the actual concept are possible. For example, the home location could be taken as a substitute for the mathematical centre (i.e. the arithmetic mean point) in the calculation of the covariance matrix. This stresses the importance of home for daily life travel and would use a real-world location instead of the artificial mean point of the chosen locations. Secondly, two ellipses covering the activity locations related to home (such as home-based grocery shopping) and those of a further peg (work etc.) could be merged into one to visualise and measure the potential locational effects of the separation of the home location and further important centres (see e.g. Holzapfel, 1980).

Figure 8   Activity spaces over time[*]
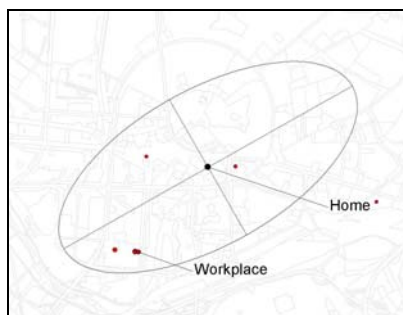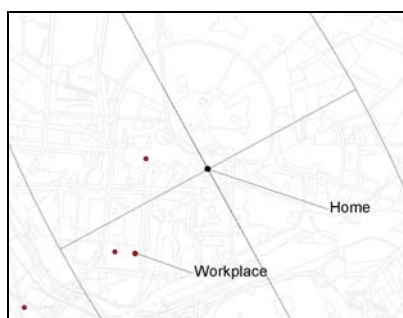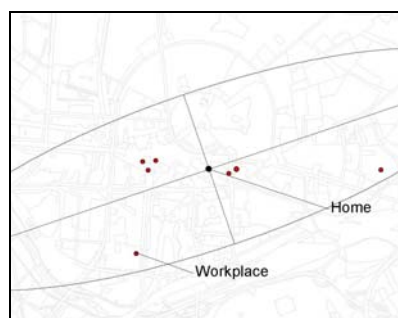
Mondays

Tuesdays
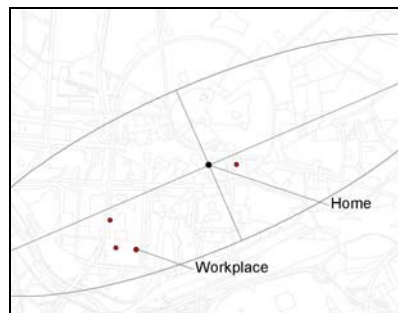
Wednesdays

Thursdays

Fridays

Saturdays

[*] 95% confidence ellipses; centre: household's home location) of one single
Mobi*drive* respondent (female, 33, nurse, 2-person household); same clipping of
underlying urban area

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Kernel densities

The basic process behind the estimation of kernel densities is a transformation of a point pattern (such as the set of activity locations visited) into a continuous representation of density in a wider area (see Silverman, 1986 or Fotheringham, Brunsdon and Charlton, 2000). Generally spoken, the estimation is an interpolation or smoothing technique which generalises events or points to the area they are found in. The interpolation then leads to a calculation of a value for any point, cell or sub-region of the entire area which characterises the density. Geographical Information Systems (GIS) apply standard calculation methods such as the *fixed kernel* and often represent the kernel densities in grid structures (Mitchell, 1999). The actual measure is defined by the number of shaded cells which exceed a given density threshold repsectively the area calculated multiplying the cells with the chosen cell size. Alternatively, the sum of all grid cell density values (i.e. the *volume*) may be chosen as an indicator for activity space size.

Figure 9 shows a visualisation of kernel densities for one Borlänge test driver. The observation period covers appr. 4 months form April to August 2001. It shows nicely the variation in size and structure of the locational choice patterns over the week with a large activity space during the weekdays, similar densities for weekdays and Saturdays in the city centre area and around the home location as well as the reduced local travel intensity on Sundays.

Figure 9   Visualisation example: Activity space compared by days of the week[*]

[*] Retiree, male, 71years; observation period: app. 4 months; grid cell size: 500*500 meters, activity locations weighted by frequency of visit, bandwidth: 1000 m

Shortest paths networks (SPN)

SPN are the part of the road network which was actually used by the respondents during the period of reporting (monitoring). This particular portion and the roads' adjacent built environment can be assumed to be known by the traveller dependent on the frequency of usage. SPN are constructed by analysing the assumed (as in Mobi*drive*) or monitored shortest paths between all reported origin-destination pairs.

What can be seen from the two examples in Figure 10 is that again the home location is the *major hub* for daily life travel acting as a central node in the network. This is what could be

expected as the share of complex trip chains with diffuse travel relations is much smaller than the amount of simple home-based trips, such as home-work-home, home-shop-home or home-leisure-home. More than 70% of all Mobi*drive* home based activity chains (i.e. *tours* or *journeys*) involve only one out-of-home activity.

Figure 10   Two examples of *minimum networks* (Mobi*drive*): Road links used over six weeks of reporting
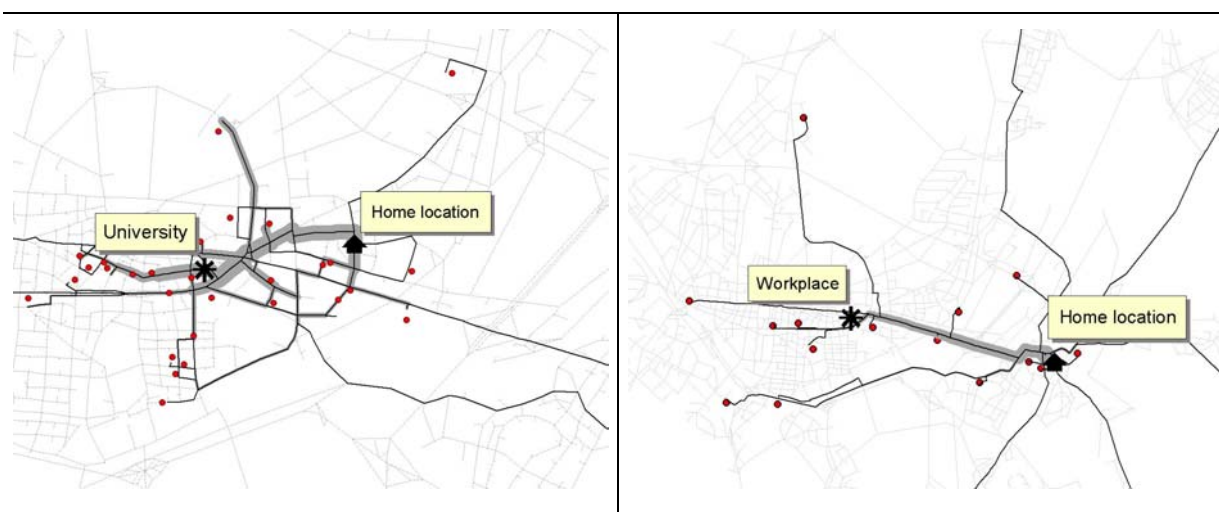
[*] Boldness of network links corresponds to frequency of usage

4.   The nature of human activity spaces – selected results

The examples already indicated that there is variability in size and structure of the activity spaces between the days of the week for a single traveller and between respondents of certain sociodemographic groups. In the following, some selected results are presented which underpin these notions and demonstrate the qualities developed indicators.

## 4.1   Variation in size and correlation between the measures

The differences in activity space size defined by the proposed measures are obvious between the Mobi*drive* respondents (Figure 11) and the same could be shown for the Borlänge GPS

data as well. A great amount of the differences can be simply explained by the amount of travel observed during the survey period. Table 1 shows that each of the measures correlates with the amount of travel, i.e. the number of trips made over the period of reporting. This is especially true for the volume measure (kernel densities) where there is an almost one-to-one correlation. At first sight, this findings seems to be unattractive. One could ask if an indicator for the size of individual activity spaces is useful which tells us that the structures of spatial mobility are tied purely to the amount of travel. At the same time, though, the outcome of the investigation strongly confirms our expectations. It indicates that the usage as well as the up-to-date knowledge or urban space is a function of the amount of contact a traveller has. This again has strong implications for the interpretation of the analysis results – e.g. considering questions of sustainable transport or justice (see brief discussion at the end of this paper).
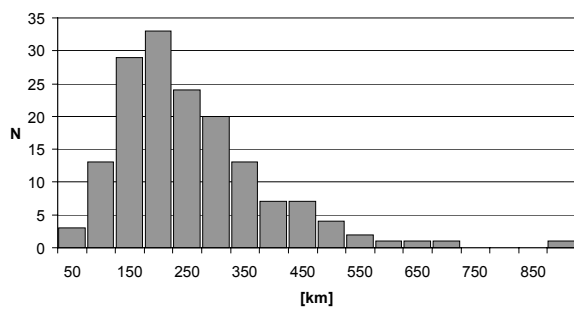
Figure 11   Variation in activity space size, Mobi*drive**

Confidence ellipse size

"Visited area", grid cells with positive Kernel densities value [500*500m]
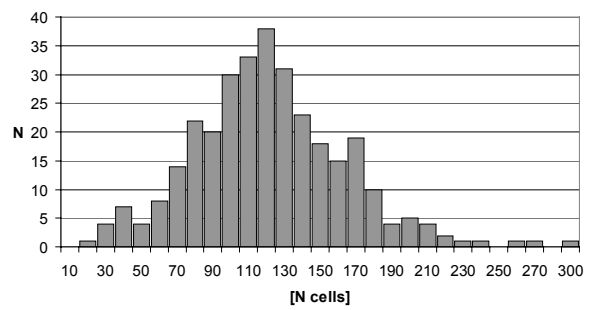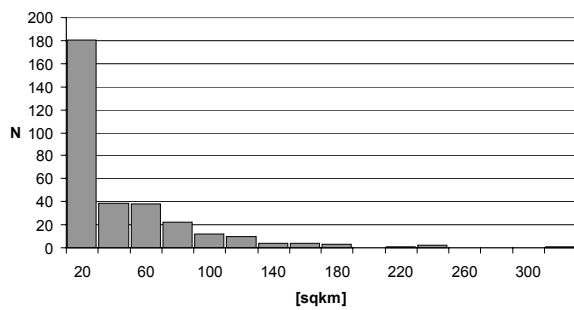
Lengths of shortest path networks

* Based on locations within city boundaries only

Table 1   Pearson correlation coefficients between the amount of travel and the size measures (Mobi*drive*: Karlsruhe only)

	Number of trips	Number of unique locations	95% confidence ellipses (weighed), local trips only	Area with positive kernel activity density estimate (unweighted)	Volume with positive kernel activity density estimate	Length of SPN (unweighted)	Length of SPN (weighted by number of journeys)
Number of trips		0.68		0.53	0.98	0.45	0.55
Number of unique locations			0.22	0.74	0.63	0.70	0.76
95% confidence ellipses (weigthed), local trips only				0.39		0.65	0.59
Area with positive kernel activity density estimate (unweighted)					0.49	0.78	0.81
Volume with positive kernel activity density estimate						0.39	0.50
Length of SPN (unweighted)							0.93
N	159	159	159	159	159	159	159

All correlations shown are significant at the 0.05 level (2-tailed).

4.2   Initial analysis of socio-economic determinants

An initial analysis of the socio-economic determinants of the activity space size has been reported in Schönfelder and Axhausen, 2002a;b; 2003. Summarising these results, there is still an ambiguous picture of personal attributes influencing the size of the activity spaces. Nevertheless, two main results could be identified:

- In line with similar analysis of spatial mobility using cross-sectional data, the household location and the car usage / car availability as well as their joint effects are main factors for the size of the activity space – especially for confidence ellipses (Figure 12). Although none of the case study areas exceed 300.000 inhabitants, a *suburbia effect* is visible. Travellers of households with locations at the edge of the cities show considerably more dispersed activity spaces than more central households – for both, weekdays and the weekend days. It is interesting, though, that the effect is not necessarily a linear one as for weekdays the sizes of ellipses for the lower categories (up to app. 6km distance from CBD) are close together. These findings are only a starting point, though, as the sub-group of the peripheral households is small for the data sets analysed. For Mobi*drive*, there are only 6 such households in Karlsruhe, and 4 for the city of Halle.

Figure 12   Household location and car usage as determinants for activity space size*, Mobi*drive*

Karlsruhe only
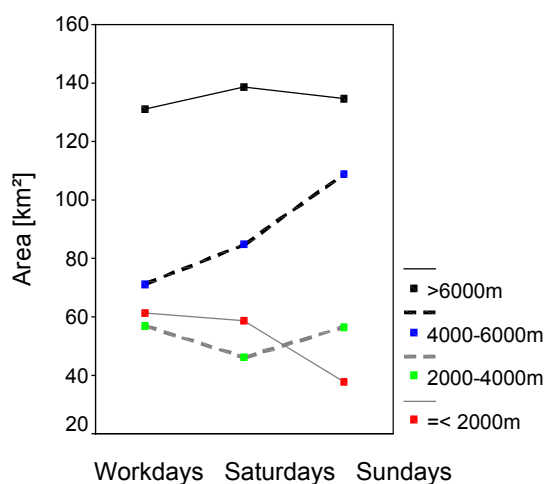
Mean values; distances from city centre
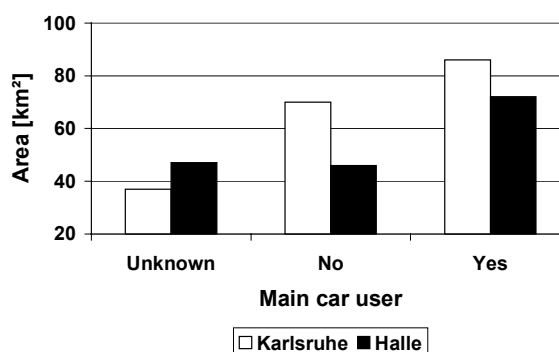
* Activity space size defined by area of 95% confidence ellipse

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- A second initial finding is the fact, that those determinants which have generally an impact on the amount of mobility – temporal variations within the week and specific travellers' attributes such as occupation as well as fixed commitments – also influence the size of the activity space. Employed Mobi*drive* respondents have larger activity spaces during the working days of the week compared to e.g. retirees or pupils, and there is equalisation between the sociodemographic groups for the weekend days. This is especially obvious for self-employed respondents who show 30-40% greater daily mean travel distances, durations and trip frequencies on working days than average. On weekends, though, this extra shrinks to almost zero.

Figure 13   Mean values of kernel density measure by day of week and selected socio-demograhic groups (Mobi*drive*: Halle)
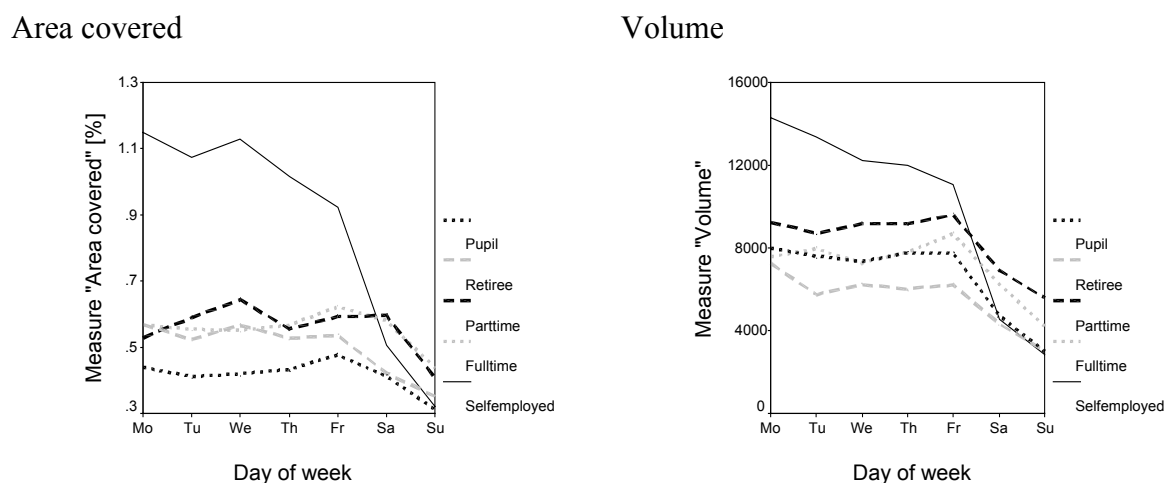
4.3   Clustering of activities

One further interesting issue is the question whether and how intense travellers cluster their activities in subcentres of their daily activity space. As mentioned above and as seen from the visualisation examples, there is clear evidence that the character of activity spaces is determined by the requirements and fixed commitments of the travellers and that activity demand is satisfied at few locations in space. In order to minimise travel times and distances, people tend to group their activity demand in the vicinity of home and the other pegs of daily life, such as work.

Figure 14 shows that almost all Mobi*drive* respondents behave this way. Given a rather rough definition of a cluster of activities (e.g. defined by a certain number and distance between the

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observed locations and a minimum share of travel demand covered by the cluster), in total more than 80% of the sample have at least one of such distinct centres of daily life[4].

Figure 14   Internal structure of activity spaces: Clusters
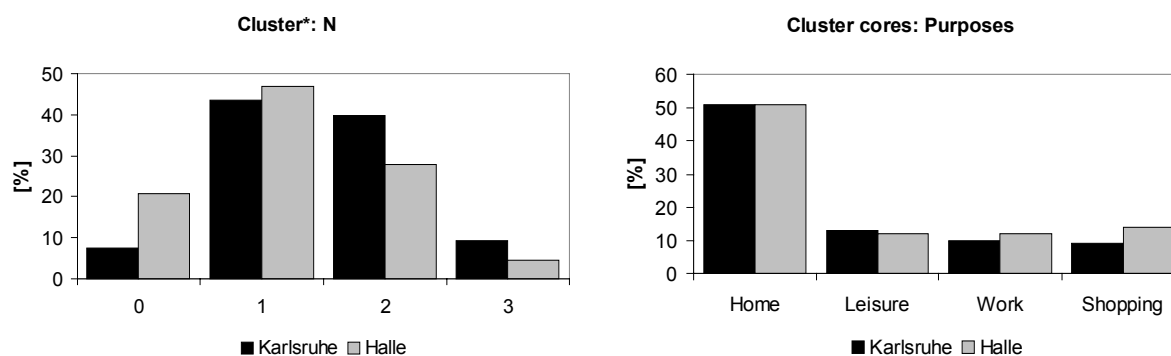
Clusters defined by: Catchment radius 1000m, minimum 10% of all trips in cluster, minimum three unique locations associated with cluster

Using the same definition, it becomes clear that activity clusters evolve to a large extent around the home location. This again underpins the importance of home for one's activity patterns. More than half of all cluster centres, i.e. the core defined by the most important location in terms of visiting frequency, are home whereas other activity purposes are only of little importance. For the Mobi*drive* sample at least, there is no indication that for example the workplace and the surrounding area play a significant role for the efficient combination of work and the rest of the activity spectrum of activities in eventually distance minimising clusters (see also below).

If home is such an central anchor of daily life, it seems interesting to explore which and how intense other activities are performed in a walking distance from that point. Table 2 shows for Karlsruhe that within a radius of 1000m from home (crow fly distance) – 70% of all observed walking trips fall within this distance class – a big share of the inner-urban daily travel can be found. Even considering the great variability between the respondents (see large standard deviations) and the differences between the infrastructural quality of their home vicinities, it can be stated that recreational as well as private business and shopping activities are tied to home.

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[4] The clusters were generated using a nearest centroid sorting cluster method (Anderberg, 1973) which is implemented in the SAS software package.

As shown earlier (Rindsfüser, Schönfelder and Perian, 2001, 98ff.), there are differences between the certain socio-economic groups for the level of close-to-home activity performance. Whereas putatively less mobile persons such as pupils and the unemployed make intensive use of the home's surrounding area for example for leisure activities, the highly mobile persons such as the self-employed and student tend to have a significantly more disperse activity location choice for leisure. Table 2 also shows that the vicinity of the workplace obviously absorbs only few daily trips which is especially true for leisure and daily shopping.

Table 2   Activity demand in the household location's neighbourhood, Karlsruhe

Maxim of distance from location: 1000m

	Home							Workplace*						
	Respondents who reported the respective activity	Share (all activities of that type) [%]	Std.	Share duration [%]	Std.	Share expenditure [%]	Std.	Respondents who reported the respective activity	Share (all activities of that type) [%]	Std.	Share duration [%]	Std.	Share expenditure [%]	Std.
Private busin., admin.	60	**70**	43	67	46	16	37	24	**4**	20	4	20	0	0
Group/club meeting	89	**45**	46	44	46	31	45	32	**3**	18	3	18	3	18
Daily shopping	149	**47**	32	40	34	43	37	59	**13**	22	13	23	12	23
Other	39	**44**	47	42	47	5	22	13	**12**	31	13	32	15	38
School	53	**42**	48	42	48	14	35	10	**10**	32	10	32	0	0
Private business, other	156	**32**	29	29	32	26	38	60	**13**	23	11	22	13	29
Walk or stroll	107	**29**	41	27	42	3	17	40	**6**	19	3	14	5	23
Meeting friends	146	**26**	32	22	30	4	19	57	**3**	9	2	7	0	0
Active sports	93	**25**	35	25	36	13	32	31	**8**	25	8	25	0	0
Serve passenger	110	**24**	35	21	36	6	22	42	**11**	26	9	24	3	17
Going out at night	137	**18**	28	17	28	15	31	54	**13**	25	11	22	10	22
Excursion (culture)	68	**15**	34	14	34	8	27	30	**13**	32	13	31	12	32
Long-term shopping	150	**13**	22	9	19	9	21	58	**14**	26	12	25	14	29
Work related	68	**13**	30	13	31	4	16	36	**24**	36	21	37	12	32
Garden/cottage work	36	**12**	28	9	25	3	17	16		0	0	0	0	0
Meeting family	17	**12**	33	12	33	0	0	9	**11**	33	11	33	0	0
Window shopping	52	**12**	31	7	25	8	27	17	**18**	39	18	39	13	34
Work	82	**11**	30	11	30	4	20	61						
Further education	27	**8**	27	8	27	0	0	9	**7**	22	5	15	0	0
Excursion nature	68	**4**	21	4	21	0	0	25	**1**	7	0	0	0	0

* Only for the group of respondents of which the second most important location is the workplace

Wheras it is interesting to note that the travellers' homes still act as an important anchor point of daily life, Table 2 also showed that there is significant variability between the Mobi*drive* respondents. One of the reasons for that is certainly the difference between the quality of supply of shopping and other opportunities around the particular home locations. Exact information about the supply of opportunities and the infrastructural quality of the travellers' home areas is still difficult to obtain in travel survey settings. Fortunately, for Mobi*drive* it was possible to obtain selected geocoded point-of-interest data for Karlsruhe using ordinary Yellow-page business addresses and a geocode engine for digitalisation. The data sets covers about 3000 leisure, shopping and administrative facilities in the Karlsruhe region. Using this data set and the general information about the home locations' population density as indicators for the level of supply, it could be found that there exists a significant relationship between supply and demand for daily shopping (Table 3). The number of shopping trips to the home area (within a radius of 1000m) as well as the shopping trips made by "slow modes" (walk and bicycle) increases with better shopping supply and higher density. Even considering the initial character of this analysis which should be deepened in more sophisticated destination choice models, the trend seems clear and confirms land-use policy's approach to strengthen residential areas as centres of daily activity demand.

Table 3   Pearson correlation coefficients between selected home based supply of shopping and shopping trip demand (Karlsruhe only)

	Number of shopping opportunities within radius of 1000m from home	Share of shopping trips performed within a radius of 1000m from home	Share of shopping trips performed within a radius of 1000m from home by slow modes
Population density of home location surroundings (building block level)	0.64	0.26	0.26
Number of shopping opportunities within radius of 1000m from home		0.26	0.27
Share of shopping trips performed within a radius of 1000m from home			0.83
N	149	149	149

All correlations shown are significant at the 0.05 level (2-tailed). Shopping opportunities involve bakeries, butchers, chemists, local grocery stores and supermarkets.

5. Conclusions

The approaches presented to describe and to measure the structure and the size of individual activity spaces are models of human behaviour and therefore simplifications of environmental perception and actual decision processes. Turning to these simplifying features of the proposed measures at first, there are some critical issues to discuss, such as

- the over-representation of actually used urban space especially with the confidence ellipse measure ("Is the area covered by the geometries actually used or perceived by the travellers?")

- the assumption of the continuousness of space usage and knowledge pretended by the geometric shapes of the measures ("Do we really perceive, know and use urban areas in a continuous way? Should we rather represent spatial behaviour by indicators of contact with single features of the environment, such as activity locations, landmarks, network sections or important junctions?")

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- the strong impact of the frequency of travel on the measurement results, especially for the kernel densities ("If there is such a high correlation between the size of the activity space and the individual amount of travel, what is the extra gained by an investigation of activity spaces and their determinants?")

Taking these points into account, the development of the measures is a substantial contribution to the analysis of long-term travel behaviour. As for other analysis tasks based on longitudinal data sets, there are only few indicators for the stability and variability of travel behaviour available. The conceptualisation of the measures reflects the travel research's intention to combine the existing theories on spatial behaviour and knowledge acquisition with empirical analysis. Based on longitudinal data which yields respondents' information on a day-to-day basis, this is possible for the first time.

Future methodological work will focus more strongly on the following questions and issues:

- Is a *continuous* representation of individual activity space acceptable? How can the measures of individual activity space better integrate and represent the clustered character of daily activity patterns?
- Internal structure: What 'happens' in and between the subcentres (mode choice, share of duration etc.)?
- Interactions between the accessibility of locations as well as the spatial supply of opportunities
- Activity space and destination choice modelling: Which are the ties?

The results provide a relevant background for the discussion on transport policy and planning. From our point of view, three aspects are of a particular importance:

First, the analysis makes clear that the existing theoretical concepts of the human activity space need to be partly rethought. There is some evidence that the supposed bipolar structure of daily life which is believed to be constituted between home and work respectively home and school is vanishing. Whereas home is an undoubted peg or anchor of most activity spaces, the workplace seems often more isolated in terms of activity clustering as so far assumed. In addition to that, one could question if the other (minor) activities are spatially organised between work and home as authors have argued in the past (Holzapfel, 1980). Investigating the distribution of activities in the urban areas, there is indication for a less organised locational choice apart from one's home area.

Secondly, the enumeration of daily activity locations and the analysis of the distribution of such places reveals both, the supply structure of activity opportunities in space and the destination choice behaviour of travellers given their perceived supply. This invites transport planning and research to once more evaluate present and imaginable future urban structures from

the perspective of sustainable transport policy. This includes for example measures to increase the amount of the opportunities (i.e. potential destinations) to satisfy the activity demand in the household's neighbourhood which eventually reduces travel expenses, further congestion and emissions. There is evidence that local accessibility oriented land-use planning matters (Banister, 2000; Simma, 2000). We do not neglect, though, that the there are complexity and non-linearities within the interaction between locational supply and the actual choice of destinations.

Finally, the activity space issue has to be put on the agenda when discussing the relationship between poverty, the deprivation of urban areas and transport. Kenyon, Lyons and Rafferty (2002) argue that important determinants of the activity space such as poor or unavailable transport (e.g. car ownership) as well as reduced accessibility to facilities, goods and services are dimensions and factors of social exclusion. The size and structure of the activity space therefore may act as a – highly political – indicator of social justice and the efficiency of a infrastructure supply policy matching societal needs.

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