

## Measurement issues in identifying variability in travel behaviour

Robert Schlich, IVT, ETH Zürich

Conference paper STRC 2001  
Session Behaviour

**STRC**

1<sup>st</sup> Swiss Transport Research Conference  
Monte Verità / Ascona, March 1.-3. 2001

# **Measurement issues in identifying variability in travel behaviour**

Dipl. Ing. Robert Schlich

Institut für Verkehrsplanung Transporttechnik, Strassen- und Eisenbahnbau (IVT)

ETH Hönggerberg

8093 Zürich

Phone: ++ 41-1-633 30 85

Fax: ++ 41-1-633 10 57

eMail: [schlich@ivt.baug.ethz.ch](mailto:schlich@ivt.baug.ethz.ch)

## **Abstract**

## **Keywords**

Measurement issues – variability – travel behaviour – Swiss Transport Research Conference – STRC 2001 – Monte Verità

## **1. Introduction**

An assumption frequently expressed in travel behaviour research is, that travel behaviour consists of routines mainly as travellers incline to repeat those activities they were content with. This assumption is based on utility maximisation theory, which assumes that humans try to perform activities as efficiently as possible. Out of a set of given possibilities they choose the activity whose implementation will realise the highest expected utility (Simon, 1955). This set of possible activities is however limited due to temporal or spatial constraints or obligations (Hägerstrand, 1970). It is reasonable to assume that humans perform a high proportion of actions regularly because those constraints and obligations do not change every day. For example, one can assume that commuting trips resemble each other concerning mode choice, route choice or departure times due to nearly constant conditions for these trips. Besides, it is unlikely that humans will judge their activities anew every time and predict a subjective utility to each possible activity. They will rather repeat an activity which offered them a satisfying experience without carefully judging any new alternatives.

The constraints or obligations may be similar from day to day – but still the chosen activities are not equal. Differences occur because people do not have the same needs every day - for example it is not necessary to go to a grocery store every day. Especially the motives connected with leisure traffic are not identical each day. A further cause of behaviour variability are unexpected events (e.g. different weather). Since general constraints (like working times or business hours) are declining it is probable that the share of trips that are identical is declining as well .

The question how repetitious travel actually is, has been the subject of scientific investigations for many years. An overview is given by Pendyala, Muthyalagari and Parashar (2000). However, intrapersonal variability (different behaviour of one person from day to day) played a minor role in travel behaviour research in competition with research with interpersonal variability (differences in the behaviour of different persons), thus there are few empirical results. This is surprising, because the question of intra-personal variability is of great interest to traffic planning. The attempt to reorganise the traffic system in a way that produces less environmental impact can only succeed, if the supply can be organised corresponding to the needs and desires of humans. The more variable and complex their behaviour is, the more flexible the supply has to be.

This paper wants to make a contribution to this issue by answering the question how the similarity and variability of travel behaviour can be measured adequately. The remainder of his paper is organised as follows. In the following section difficulties in the measurement of similarities of travel behaviour and some previous results are introduced. In the second section methods to calculate similarity and their advantages and disadvantages are discussed. These methods are applied to data of the Mobidrive survey (see section 2). The differences in the similarity measures are discussed in the third section. Special attention is given to the question, how the measured variability changes with different length of the reporting periods. Finally, further research gaps are identified.

## **2. Problems of similarity measurement**

The main cause of the lack of suitable data to analyse intrapersonal variability is the difficulty to obtain data about travel behaviour from respondents for a long period, which is compulsory for this type of analysis. The identification of long-term rhythms and division of the observed variability into intrapersonal and interpersonal variability can however only take place with longitudinal data (Pas, 1987; Zumkeller and Chlond, 1995).

The specific difficulties of long-duration survey questionnaires result from the high response burden of the persons interviewed. It must be ensured, that no self selection of respondents with special interests in the topic or similar socio-demographic backgrounds does take place, because this would bias the results. Additionally, it is feared that people will neglect to report especially short trips with increasing duration of the survey (Golob and Meurs, 1986). For these reasons, longitudinal data of travel behaviour has rarely been collected.

The following analyses are based on a dataset which is to a large extent unique. It is the result of a six week travel diary implemented in the context of the research project Mobidrive. Funded by the German Federal Ministry for Education and Research, in autumn 1999 in the cities Karlsruhe and Halle/Salle altogether 361 persons were interviewed. The project consortium consisted of the PTV AG (Karlsruhe), the Institut für Stadtbauwesen at RWTH Aachen and the Institute of Transport, Traffic, Highway and Railway Engineering (IVT) at ETH Zurich<sup>1</sup>. A documentation of sampling procedures, the survey instruments and data administration is provided by Axhausen, Zimmermann, Schönfelder, Rindsfuser and Haupt (2000), frequencies of the characteristics of all variables are documented by Schlich, König, Aschwanden, Kaufmanns and Axhausen (2000)<sup>2</sup>. Altogether, the interviewed persons reported 52273 trips on 14360 person days.

The Mobidrive survey is at present unique in terms of the length of the reported period and completeness of available data items. There is one comparable example, which covers a period of five weeks - the Upsalla survey. This survey was conducted 1971 and is the basis of a series of publications by Hanson and collaborators concerning the stability of travel

---

<sup>1</sup> Further information available at <http://www.ptv.de/mobidrive/>

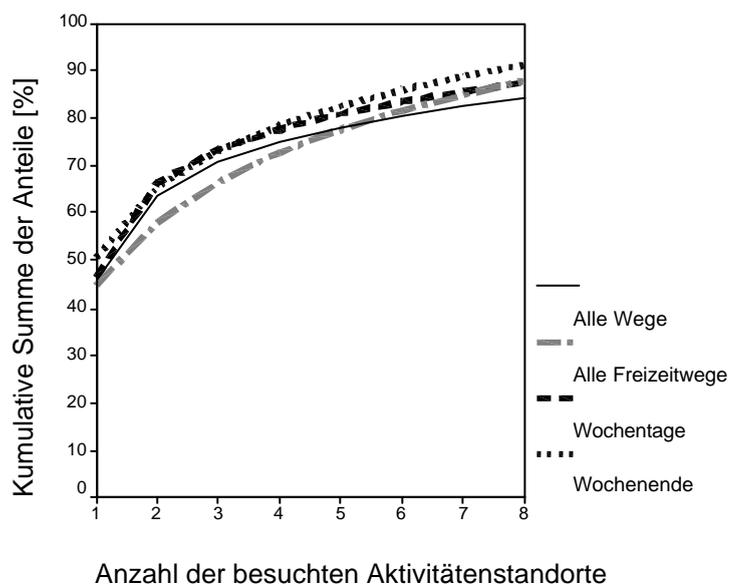
<sup>2</sup> Both papers are available at <http://www.ivt.baug.ethz.ch/forschungsseite.html>

behaviour (e.g. Hanson and Huff 1982, 1986 and 1988; Hanson and Burnett 1981 and 1982; Huff and Hanson 1986 and 1990). Besides, there are several travel behaviour surveys covering periods of one or two weeks. However, due to their comparatively short duration those surveys permit only limited calculations. Recent interest in GPS based tracking of vehicles has resulted in a number of initiatives which will generate long term records of car-based travel.

Another major problem of similarity measurement is the fact that there is no generally accepted procedure to identify similarity of behaviour over long periods. Usual behaviour indicators such as the number of trips per day, mean trip distance or mean trip duration neither consider the temporal dimension of activity chains, nor the complexity of behaviour and are thus unsuitable. There are several more complex measurement methods which differ substantially concerning their theoretical background and their level of complexity.

It is particular controversial which attributes shall be examined, how to classify and to weight them and with which algorithm the values of the attributes should be compared. Thus, the measures lead to different results for the same data (Hanson and Burnett, 1982). Hanson and Huff (1988) generally notice that the more detailed a measuring procedure is and the more attributes it covers, the smaller the observed similarities.

Figure 1 Number of visited places and their share of all trips



Source: Schönfelder and Axhausen (2001, p.6)

The way in which similarity is measured reflects the scientists view of what he thinks is important to measure and thus his view of the phenomenon he is trying to capture (Huff and Hanson, 1990). Consequently, empirical studies about similarity have different and partially inconsistent results. On the one hand, Kitamura and van der Horn (1987) show that daily participation in different activities (based on the categories working, leisure, shopping and other activities) is very stable. Based on the Mobidrive data Schönfelder and Axhausen (2001) also notice a low degree of spatial variability (see Figure 1). According to their results there are 2-4 places which normally cover about 70% of all places visited within 6 weeks.

In contrast to this, Pas and Koppelman (1986) find a high level of day-to-day variability based on the number of trips per day. Pendyala et al. (2000) confirm their results with a similar method on a new dataset. Similar results are found by Huff and Hanson (1986) based on a more complex measure, that considers different trip attributes. Their results show in spite of a high level of variability that some trips are performed very frequently in the same way.

It should be a target of transportation research to avoid these different results and to develop a generally accepted measure. As a contribution to this, in this paper different measurement methods are discussed and their results for the Mobidrive survey are compared.

### 3. Measurement methods

Based on the Upsalla survey, Susan Hanson (Hanson and Huff 1982, 1986 and 1988; Hanson and Burnett 1981 and 1982; Huff and Hanson 1986 and 1990) analysed in a number of papers intrapersonal variability. Among other things, she examined the frequency with which individuals exhibit activities with the same attributes during the entire investigation period (Huff and Hanson, 1986). In order to examine how much of a person's activity pattern can be considered repetitive to the extent to which two attributes of a trip occur together are counted in a contingency table for all possible combinations of attributes. As attributes of a trip the mode choice, trip purpose, trip destination, trip distance and the arrival time were selected. A concentration of all trips in only one cell of the contingency table „traffic mode by trip purpose“ would mean that all trips were executed with the same traffic mode and the same trip purpose, while a uniform distribution of the trips across all cells would mean that all possible trip combinations were implemented by this person with the same frequency.

The corresponding measure  $R_j$  (*overall repetition measure*), which calculates the sum of the deviations from the uniform distribution in relation to the concentration of all activities in only one cell is an index of repetition. The closer this index is to 1 the more concentrated are all trips in a small number of cells and the more repetitious the behaviour is.  $R_j$  is calculated with equation (1)

$$R_j = \frac{\sum_{i=1}^n |P_i - E_i|}{M_n} \quad (1)$$

with

$n$ : number of cells in contingency table

$P_i$ : share of activities in cell  $i$

$E_i$ :  $1/n$  or the share of all activities in cell  $i$ , in case of a uniform distribution  $i$

$M_n$ : maximum possible value for a table with  $n$  cells =  $2(n-1)/n$

A calculation of  $R_j$  for the Mobidrive data was done for all contingency tables of the variables mode choice (9 categories), trip purpose (10 categories), trip distance (5 categories), trip arrival time (4 categories) and trip destination (4 categories). The average  $R_j$  for all contingency tables can be found in another paper (Schlich, König and Axhausen, 2000). The results showed, that each person performs only a small share of all possible trip combinations. Additionally the results showed, that the observed amount of repetition depends on the chosen

attributes and the number of corresponding categories. Thus the  $R_j$  varied between 0.6 and 0.87, with a remarkable concentration on a small number of cells for all combinations with the attribute “mode choice“. Despite these results, one cannot conclude that activity patterns are highly repetitious from day to day. Some combinations of attributes cannot be performed in real life, because they do not make any sense (e.g. the combinations of long distance trips and the choice of non motorised travel modes) – nevertheless, they are taken into consideration for the calculation of the index. Their removal would lead to a higher level of observed variability. Additionally, the characterisation of the trips by only two attributes is as well unsatisfactory as is the categorisation of some attributes.

The index  $R_j$  is limited to measuring an overall repetition index for single trips - but according to Shapcot and Steadman (1978) or Pas (1988) the main observation unit should be the day instead of the trip. Hence, Huff and Hanson (1986) developed a second method to measure the similarity across all days for each person. This index takes the different attributes into account as well as the number of daily trips. The measure  $SH_{ij}$  (*similarity index Hanson*) notes the number of matches between pattern on two different days  $i$  and  $j$  based on the contingency tables and divides this by the number of stops in the longer activity chains.  $SH_{ij}$  is thus defined with equation (2)

$$SH_{ij} = \left[ 1 - \frac{1}{2} \sum_k |P_{ik} - P_{jk}| \right] \frac{n_i}{n_j} \quad n_j = n_i \quad (2)$$

- $P_{ik}$  : Share of trips in cell  $k$  of the contingency table at day  $i$   
 $i, j$  : index for the days to compare (with  $i, j = 1, 2, \dots, n$ , if  $i \neq j$ )  
 $n_i, n_j$  : number of trips at day  $i$  and  $j$

A value of 1 indicates identical travel patterns on two different days, while a value of 0 will occur when two days do not have any trips with the same attribute combination in common. The average similarity of all pair of days for each person based on the attributes trip purpose and travel mode can be seen below.

Unfortunately this method has also disadvantages. First, it cannot take all important attributes of a trip into account – the contingency tables consists of only two attributes. Thus, trips are considered as equal although they are quite different concerning different important attributes. Even more important, if days are compared at an aggregate level instead of the level of the sequence of activities. So neither the order of activities, nor the time at which they are performed are measured. A last disadvantage is the fact, that the trips of the day with the larger number of trips are ignored for the calculation.

Based on this criticism Pas (1980, 1983) developed another similarity index  $SP_{ij}$  (*similarity index Pas*), which assigns the trips of a day pairwise. He adopts the “primary-secondary attributes” concept of that Kendrick and Proctor (1964) introduced for analytical classification of plants and animals. Main issue of this concept is a pairwise comparison of “primary attributes“. Only in case of a match between the primary attribute of two compared trips comparisons are made for the secondary attributes of these trips – otherwise the comparison is not made. For comparing two daily travel activity pattern each trip in the pattern is described by one primary variable and a set of secondary variables. The primary characteristic is a binary variable which describes whether a trip was performed or not. The trips are compared in their order off occurrence. If the trip was performed, characteristics as travel mode, trip purpose etc. are compared as secondary attributes. The terms “primary” and “secondary” are used only to indicate that the attributes are serially dependent and do not indicate that some attributes are more important than others. The weight that is assigned to the primary and secondary attributes can be different depending on the special focus of a study. Equation (3) describes the calculation for this similarity index, that consists of the number of daily trips of the day with the smaller number of trips (weighted with the factor  $\mathbf{a}$ ) and a function for a match between two attributes (weighted with the factor  $\mathbf{b}$ ).

Depending on the importance of the number of trips compared to the other attributes for the study, the weights  $\mathbf{a}$  and  $\mathbf{b}$  can be chosen differently. Additionally another weight  $\mathbf{w}$  can be added to differentiate the importance of each secondary attribute. This flexible approach allows to adopt the measure for interests.

$$SP_{ij} = \mathbf{a}n_{\min} + \mathbf{b} \left[ \sum_{t=1}^{n_{\min}} \sum_{k=1}^{n_{sa}} \mathbf{w}_k m_{ijks} \right] / (\mathbf{a}n_{\max} + \mathbf{a}n_{\min}) \quad (3)$$

- $S_{ij}$  : similarity index for two daily activity pattern i and j  
 $t$  : trip within a daily activity pattern (1,2,...n)  
 $\mathbf{a}$  : relative weight of primary attribute (trip n performed?)  
 $\mathbf{b}$  : relative weight of secondary attribute (0 - 1) and ( $\mathbf{b} + \mathbf{a} = 1$ )  
 $n_i$  : number of trips in daily activity pattern i  
 $n_j$  : number of trips in daily activity pattern j  
 $n_{\max}$  : maximum number of daily activity pattern i and j  
 $n_{\min}$  : minimum number of daily activity pattern i and j  
 $m_{ijks}$  : function for matching of 2 attributes; 1 in case of a match, otherwise 0  
 $n_{sa}$  : number of secondary attributes  
 $\mathbf{w}_k$  : weight of secondary attribute k in relation to other secondary attributes with  

$$\sum_{k=1}^{n_{sa}} \mathbf{w}_k = 1$$

The chosen weight for the different weight coefficients must be considered while interpreting the result of the index.  $SP_{ij}$  varies between 1 and 0, with 0 indicating that there are no matches between the two daily activity pattern at all. The maximum value of 1 signifies the highest value measurable between two days, but has to be interpreted based on the chosen weight for  $\mathbf{a}$  and  $\mathbf{b}$ . If  $\mathbf{a}$  was chosen as 0,  $SP_{ij}$  does not recognise the difference between the number of daily trips. If the attributes of the realised trips on the day with fewer trips are equal to the trips on the other day  $SP_{ij}$  judges both patterns as equal, ignoring the difference in the number of trips.

The following results are based on calculations with the weights  $\mathbf{a}=0,5$  and  $\mathbf{b}=0,5$  (with the attributes trip purpose, traffic mode, trip destination and departure time with  $\omega=0,25$  for each of them). So the number of trips is chosen as the most important attribute of the daily pattern. Thus, it is not surprising that the average similarity measured in Mobidrive with  $SP_{ij}$  is bigger than measured according to the method of Huff and Hanson ( $SH_{ij}$ ) (see below).

Both measures for daily activity patterns are based on a comparison of trips and do not consider the duration or the time at which they are performed. This is not sufficient if traffic is understood as a derived demand and as a consequence of the whole context of a day.

Temporal aspects are of special interest for activity based analysis of travel behaviour and thus should also be present in similarity measurement.

Because of this, an attempt was made to calculate similarity based on the time budget instead of trips (Jones and Clarke, 1988). They developed an index  $SC_{ij}$  (*similarity index Clarke/Jones*), which divides the day in temporal intervals and compares the chosen activities of two days within the same interval. If the same activity is performed within the same interval the basic index increases by 1, if it is performed at one day one interval earlier or later than on the other day,  $SC_{ij}$  increases by 0,5. The result is divided by the maximum possible value if all 96 intervals on a day were equal (based of a division of the day in 15 minute intervals). A resulting value of 0 indicates again that two daily patterns have nothing in common while a value of 1 represents identical activity patterns. The index can be calculated with the following equation (5). Again the trip purpose is divided into nine categories.

$$SC_{ij} = \frac{\sum_{n=1}^{\max} f(x)}{\max} \quad \begin{aligned} f(x) &= 1 \text{ if } Int_{ni} = Int_{nj} \\ f(x) &= 0,5 \text{ if } Int_{ni} \neq Int_{nj} \text{ and } (Int_{ni} = Int_{nj-1} \text{ or } Int_{ni-1} = Int_{nj}) \\ f(x) &= 0,5 \text{ if } Int_{ni} \neq Int_{nj} \text{ and } Int_{ni} = Int_{nj-1} \text{ and } Int_{ni-1} = Int_{nj} \end{aligned} \quad (4)$$

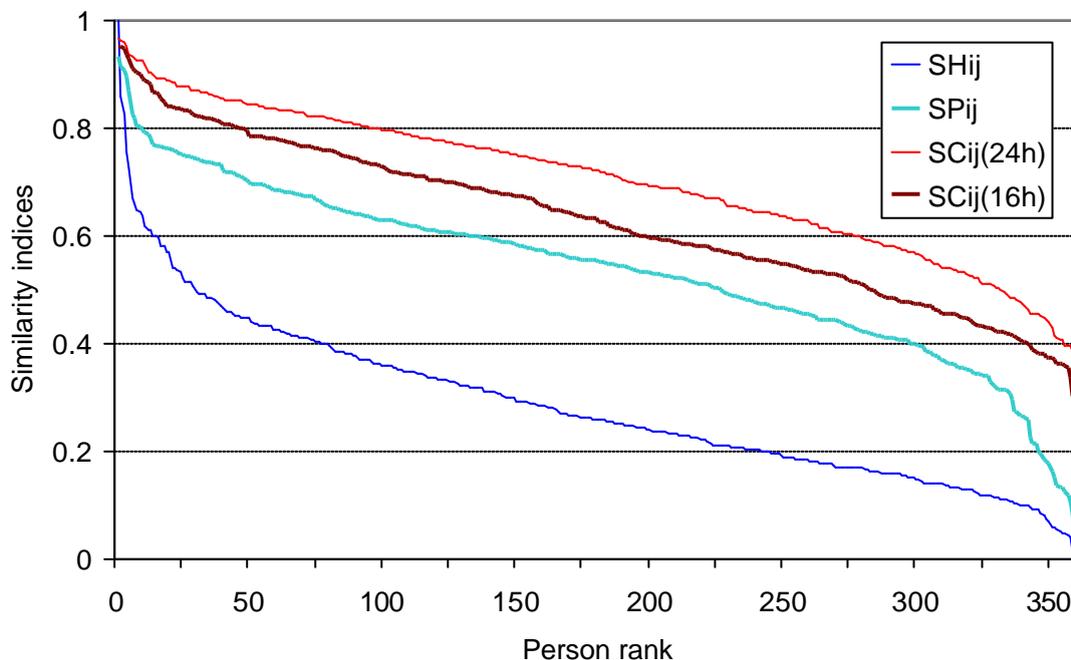
A disadvantage of this measure is that most attributes like traffic mode which are important for traffic planing are ignored – the index is based exclusively on the performed activities. Unfortunately, this variable is not conducted in most surveys. Instead the activity is assigned to the intervals based on the quoted trip purpose. This assignment is sometimes insufficient Especially if activities at home are not reported separately, activities like “sleeping” or “meeting friends at home” are measured as equal. Another bias is caused by the weight of each interval. If the intervals in the night are weighted equal to all others the measured similarity will increase because of the similar amount of sleep each night. Therefore it is reasonable to change the weight of the night intervals depending on the topic of interest. The following results are presented in two ways: First it is calculated for all hours with equal weight for all 96 intervals as  $SC_{ij}(96)$ . Then it is compared with a calculation which excludes the intervals between 10 a.m. and 6 p.m. ( $SC_{ij}(64)$ ).

## 4. Empirical Results

### Comparison of different measures

Following the previous discussions one would expect that the similarity depends strongly on the chosen measurement method and weights. The findings are therefore relative results which should be compared to each other. Thus, the first task is to compare the different measures based on one dataset. For each person of the dataset each day was compared to all others and the average similarity was calculated for all of the indices introduced. Since it is very likely that the weekend days are very different from all other days due to less constraints these days will be treated separately. The working days (except Fridays) were regarded as whole, because it has been shown in the past that the type of working day does not have any significant influence on daily variability (Pas, 1988).

Figure 2 Distribution of the similarity indices for all persons by rank on working days (Monday to Thursday)



The empirical results with the Mobidrive data are consistent with the presumption that the measures differ strongly from each other (see Figure 2). The figure shows for each person the average similarity of each day with all other days. The persons were sorted on the x-axis in descending order of their average similarity value. In general, the similarity measured with a trip based index ( $SH_{ij}$  or  $SP_{ij}$ ) is lower than the similarity based on time budget ( $SC_{ij}$ ). Because of the high average value for  $SC_{ij}$  it was presumed that the high similarity was caused by the intervals at night, which were counted equal to the others intervals. However after removing the night hours the value of  $SC_{ij}(64)$  is still much higher than those measured according to Pas ( $SP_{ij}$ ) and Hanson ( $SH_{ij}$ ).

Since the differences between the measures are nearly constant it seems reasonable to assume, that the different results are just due to differences in the level of similarity. However it is not possible to see in Figure 2 if each person has a similar rank in the order of persons for the different measures or if their rank differs. This was tested by assigning a rank to each of the 361 persons in the dataset (corresponding to the average value) for all measures and to calculate the correlation between them. If the persons have similar ranks regardless of the chosen measure this would be indicated by high correlations. Vice versa a low correlation would be a sign that the differences between the measures are not just a constant difference in the measurement. In this case different measures would describe persons differently concerning their variability.

The calculations (see Table 1) show a very strong correlation within both trip based and timebudget based indices with a correlation coefficient of 0.85 between  $SH_{ij}$  and  $SP_{ij}$  and 0.97 between  $SC_{ij}(96)$  and  $SC_{ij}(64)$  respectively. Attention should be paid to the fact, that a high correlation does not mean that the measures reflect the same facts. Instead it indicates that the average similarity between the day of one person in relation to the average similarity of the other person are related for different measures.

On the other hand, the correlations in the ranking between time budget based and trip based measures are weaker with a correlation coefficient of 0.33 ( $SC_{ij(64)}$  and  $SH_{ij}$ ) and 0.50 ( $SC_{ij(64)}$  and  $SP_{ij}$ ). Thus, it is reasonable to assume that the different results are indeed caused by differences in the level within similar types of measures, but point on totally different interpretations of variability between them.

Table 1 Correlation coefficients of rankings for different similarity measures

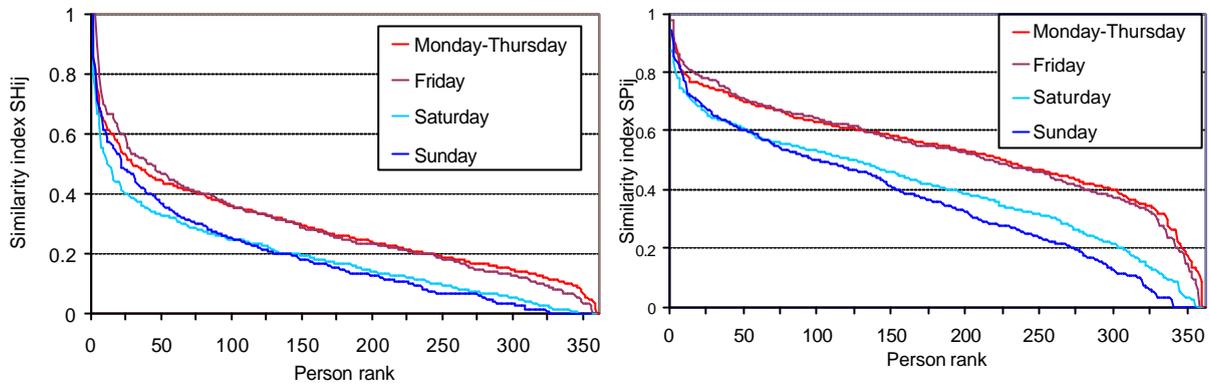
	RANG_Han	RANG_Pas	RANG_C96	RANG_C64
RANG_Han	1.00	0.85	0.33	0.33
RANG_Pas		1.00	0.50	0.49
RANG_C96			1.00	0.97
RANG_C64				1.00

So far the analysis was limited to working days (without Fridays), because weekend activities distinguish themselves clearly from activities performed during the week. Correspondingly the measured variability is lower if the observed time period is a whole week. However it is also of interest to know how stable a persons' behaviour is for the same type of constraints. Therefore, the analyses were also made for Fridays, Saturdays and Sundays with all other days of the same type. The results should be interpreted carefully, because for each type of day there are only 6 different days and thus only 30 comparisons of two days of the same type.

The analysis illustrates for all measures that behaviour on the weekend days is by far more variable than on the working days (see Figure 3 and Figure 4). The result is not surprising due to the smaller number of individual obligations at the weekend – still it is remarkable that the level of difference differs between trip based and timebudget based measures. In general, the difference in variability on a weekend day compared to a working day is bigger if measured by a trip based index.

Figure 3 Similarity index at different types of day [ $SH_{ij}$ ,  $SP_{ij}$ ]

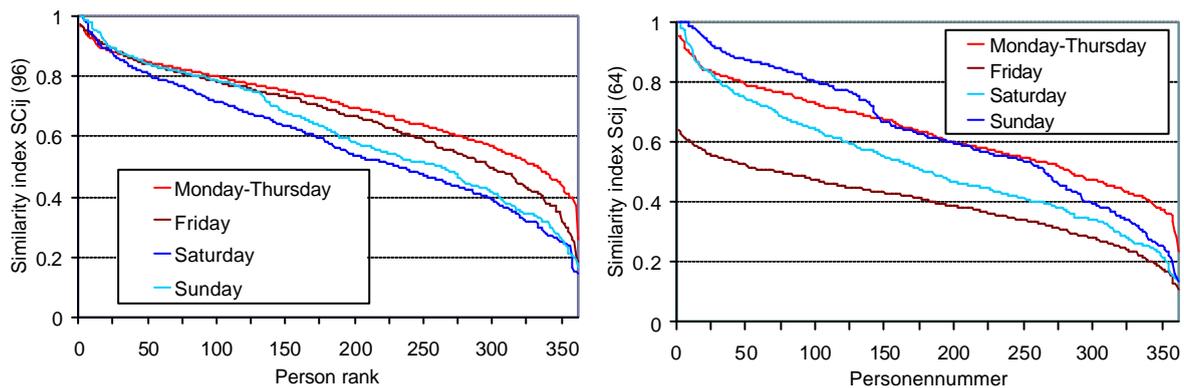
Measured according to Huff & Hanson (1986)      Measured according to Pas (1983)



It is interesting that the trip based measures show Fridays at a comparable level of similarity to the other working days while the behaviour is much more variable if measured with a timebudget based index. In terms of stability of behaviour at the weekend there is no clear trend, if Saturdays and Sundays are compared.

Figure 4 Similarity index at different types of day [ $SC_{ij}(96)$ ,  $SC_{ij}(60)$ ]

Measured according to Jones& Clarke (1988)      Measured according to Jones& Clarke (1988)



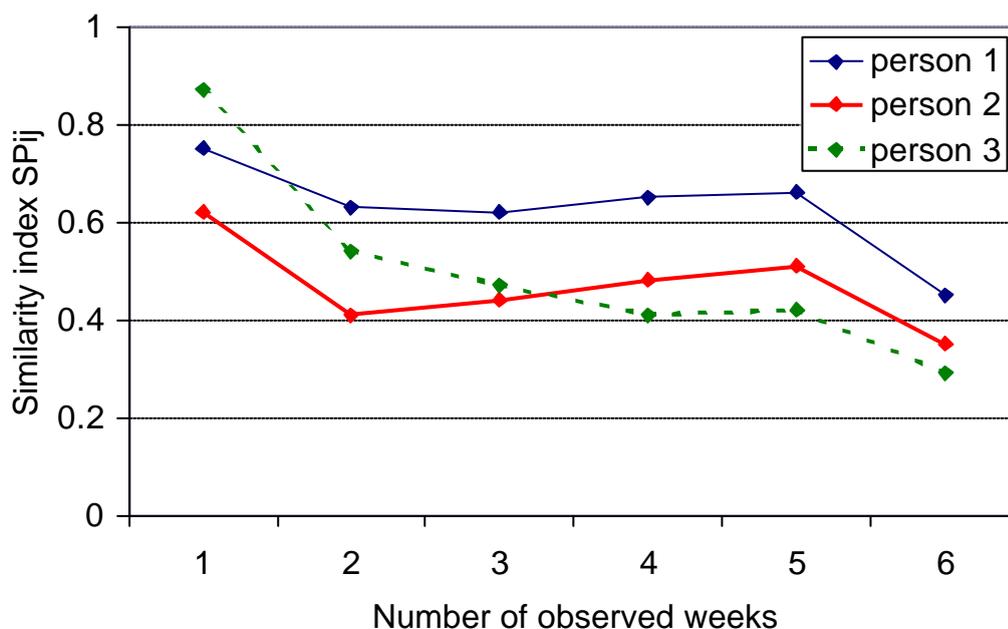
## Duration of observed period

One basic condition in analysing intrapersonal variability is to observe behaviour over a long period. This is the only way to cover as much as possible out of the spectrum of all activities a person performs and to avoid biases in forecasts as far as possible (Pas, 1987). How long does the observed period have to be? This question is addressed by comparing the measured variability of activities of three randomly chosen persons for different time periods. The time periods start always with the first reported day and cover one to six weeks. The characteristics of the chosen persons can be seen in table 2.

Table 2 Socio-demographic characteristics of three randomly chosen persons

Person number	Socio demographic characteristics
1	Female, age: 73 years, retired, no children, married, Karlsruhe
2	Male, age 34 years, employed, 3 children, married, Halle
3	Male, age 45 years, employed, 1 child, married, Halle

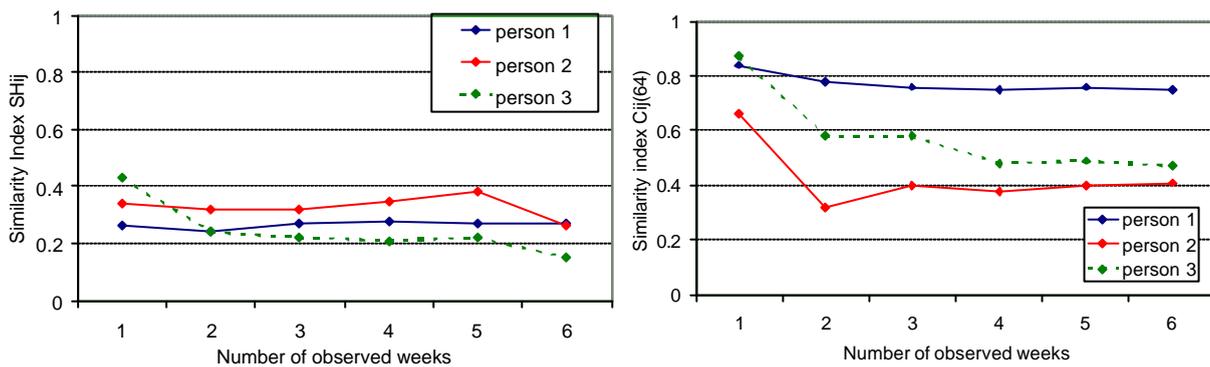
Figure 5 Average similarity of daily activity pattern for different observation periods measured according to Pas (1980)



The measurement according to Pas shows for these persons different results for different time periods (see Figure 5). As expected, the stability in activities is highest for person 1, who is retired. For all persons the total amount of variability is increasing with the increasing duration of the observation. The longer the observed period is, the higher the number of different performed activities and thus the smaller the variability index. This process is not uniformly continuous for all six weeks. On the contrary, the average similarity is sometimes increasing, although it is decreasing in the long run. This could be due to repeated activity patterns after a period of extremely unusual behaviour.  $SP_{ij}$  is not stabilising even after the full period of six weeks. Another interesting trend is the strong decline of the index comparing a two week observation with a one week observation.

Figure 6 Average similarity of daily activity pattern for different observation periods

Measured according to Huff & Hanson (1986)      Measured according to Jones & Clarke (1988)



If the measurement of variability is based on  $SH_{ij}$  and  $SC_{ij}(64)$  (see Figure 6) a strong difference in the level of variability is found – not surprising with respect to the different results on the aggregate level. Both measurement methods confirm the tendency of decreasing stability with increasing observation period. In contrast to  $SP_{ii}$  they report a stability after two weeks. Even if a longer period is observed, the resulting index is nearly the same.

With this fact in mind it seems reasonable to recommend that empirical surveys about travel behaviour research should cover a period of at least two weeks. In case of special survey topics like travel habits on weekends or short vacancies this period is of course too short.

## **5. Discussion and methodological outlook**

This paper introduces different methods to measure similarity of travel behaviour and compares empirical results of these methods based on the data of a six week travel diary from the project Mobidrive. The results show the expected wide range of measured variability. To avoid different interpretations, it is necessary to carefully choose a method that matches the focus of the study. In general, the results show that the day to day behaviour seems to be more variable if measured with trip based methods instead of a time budget based methods. Furthermore, they confirm that the measured variability declines if the used method gets more complex. This result is consistent with theoretical considerations (Hanson and Huff, 1988) and recent surveys (Beckmann, 2000). If travel is understood as a derived demand it is necessary to analyse variability in a complex way. Thus, this paper confirms the results of Pas and Koppelman (1986) and Pendyala et al. (2000) who reported a very high intrapersonal variability. The variability index measured according to Huff and Hanson (1986) for working days is less than 0.5 for about 85% of all persons and less than 0.2 for about 50% of all persons (see Figure 2). In contrast to the different level of variability, the different methods all report a similar trend concerning variability at different types of day: travel behaviour is clearly more stable on working days. Similar results are also available for the question of how long the period of observation should be at minimum – all measures show that this should not be less than two weeks.

Still the observed methods have disadvantages – for example, they do not take the order of the activities into account. Further methodological research is needed to incorporate the full information that is given in a travel diary. One promising approach is the sequence alignment method (Wilson, 1998) that measures similarity based on the Levenstein distance (Sankoff and Kruskal, 1983) instead of an euclidean measurement.

The results make clear that it is necessary to develop demand profiles of person groups based on similar temporal or spatial demands. Their needs should be addressed with different actions in order to promote travel opportunities that have less environmental impacts. In this context the question arises to what extent an activity that is performed regularly is at the same time habitual. If most behaviour is habitual this should be taken into account in promoting new travel opportunities, because it would make a change in behaviour even more difficult (Aarts and Dijksterhuis, 2000).

## 6. Reference

- Aarts, H. and A. Dijksterhuis (2000) The automatic activation of goal-directed behaviour: the case of travel habit, *Journal of Environmental Psychology*, **20** (1) 75-82.
- Axhausen K.W., A. Zimmermann, S. Schönfelder, G. Rindsfuser and T. Haupt (2000) Observing the rhythms of daily life: A six-week travel diary, *Arbeitsbericht Verkehrs- und Raumplanung*, **25**, Institut für Verkehrsplanung und Transporttechnik, Strassen- und Eisenbahnbau, ETH Zürich.
- Beckmann, J. (2000) *Analyse der Aktivitäten - Verkehrsverhalten unter Berücksichtigung der speziellen Fragestellung der Stabilität/Variabilität (Rhythmik)*, Diplomarbeit am Lehrstuhl für Stadtbauwesen der Rheinisch Westfälischen Technischen Hochschule Aachen, Aachen.
- Golob, T.F. and H. Meurs (1986) Biases in response over time in a seven-day travel diary, *Transportation*, **13** (2) 163-181.
- Hägerstrand, T. (1970) What about people in regional science?, *Papers of the Regional Science Association*, **24** (1) 7-21.
- Hanson, S. and K.O. Burnett (1982) The analysis of travel as an example of complex human behaviour in spatially-constraint situation: definition and measurement issues, *Transportation Research A*, **16** (2) 87-102.
- Hanson, S. and K.O. Burnett (1981) Understanding complex travel behaviour: Measurement issues, in P.R. Stopher, A.H. Meyburg and W. Brög (Eds.) *New Horizons in Travel-Behaviour Research*, 207-230, Lexington, Massachusetts/Toronto.
- Hanson, S. and P. Hanson (1981) The travel-activity patterns of urban residents: Dimensions and relationships to sociodemographic characteristics, *Economic Geography*, **57** (5) 332-347.
- Hanson, S. and J.O. Huff (1982) Assessing day-to-day variability in complex travel patterns, *Transportation Research Record*, **891**, 18-24.
- Hanson, S. and J.O. Huff (1986) Classification issues in the analysis of complex travel behaviour, *Transportation*, **13** (4) 271-293.
- Hanson, S. and J.O. Huff (1988) Systematic variability in repetitious travel, *Transportation*, **15** (2) 111-135.
- Huff, J.O. and S. Hanson (1986) Repetition and variability in urban travel, *Geographical Analysis*, **18** (2) 97-114.
- Huff, J.O. and S. Hanson (1990) Measurement of habitual behaviour: Examining systematic variability in repetitive travel, in P.M. Jones (Ed.) *Developments in Dynamic and Activity-Based Approaches to Travel Analysis*, 229-249, Gower, Aldershot.
- Jones, P. and M. Clarke (1988) The significance and measurement of variability in travel behaviour, *Transportation*, **15** (1) 65-87.
- Kendrick, W.B. and J.R. Proctor (1964) Computer taxonomy in the fungi imperfecti, *Canadian Journal of Botany*, **42** (1) 65-88.

- Kitamura, R. and T. van der Hoorn (1987) Regularity and irreversibility of weekly travel behaviour, *Transportation*, **14** (2) 227-251.
- Pas, E.I. (1983) A flexible and integrated methodology for analytical classification of daily travel-activity behaviour, *Transportation science*, **17** (4) 405-429.
- Pas, E.I. (1980) *Towards the understanding of urban travel behaviour through the classification of daily urban travel/activity patterns*, Dissertation at Northwestern University, Evanston.
- Pas, E.I. (1987) Intrapersonal variability and model goodness-of-fit, *Transportation Research A*, **21** (6) 431-348.
- Pas, E.I. (1988) Weekly travel-activity behaviour. *Transportation*, **15** (1) 89-109.
- Pas, E.I. and F.S. Koppelman (1986) An examination of the determinants of day-to-day variability in individuals' urban travel behaviour, *Transportation*, **13** (2) 183-200.
- Pas, E.I. and S. Sundar (1995) Intrapersonal variability in daily urban travel behaviour: Some additional evidence, *Transportation*, **22** (2) 135-150.
- Pendyala, R.M., A. Parashar and G.R. Muthyalagari (2000) Measuring day-to day variability in travel characteristics using GPS data, paper presented at the 80th Annual Meeting of the Transportation Research Board, January 7-11, 2001 Washington.
- Sankoff, D. and J.B. Kruskal (1983) *Time warps, string edits, and macromolecules: The theory and practice of sequence comparison*, Addison-Wesley, Reading.
- Schlich, R., A. König and K.W. Axhausen (2000) Stabilität und Variabilität im Verkehrsverhalten, *Strassenverkehrstechnik*, **44** (9) 431-441.
- Schlich, R., A. König, A. Aschwanden, A. Kaufmann and K.W. Axhausen (2000) Mobidrive: Data format guide, *Arbeitsberichte Verkehrs- und Raumplanung*, **35**, Institut für Verkehrsplanung, Transporttechnik, Strassen- und Eisenbahnbau, ETH Zürich, Zürich.
- Schönfelder, S. and K.W. Axhausen (2001) Mobidrive - Längsschnitterhebungen zum individuellen Verkehrsverhalten: Perspektiven für raum-zeitliche Analysen; paper presented at CORP 2001, 14.-16.02.2001, Wien.
- Shapcott, M. and P. Steadman (1978) Rhythms of urban activity, in T. Carlstein, D. Park and N. Thrift (Eds.) *Human Activity and Time Geography*, 49-74, Arnold, London.
- Simon, H. (1955) A behaviour model of rational choice, *Quarterly Journal of Economics*, **69** (2) 99-118.
- Wilson, W.C. (1998) Activity pattern analysis by means of sequence-alignment methods, *Environment and Planning A*, **30** (6) 1017-1038.
- Zumkeller, D. and B. Chlond (1995) Nutzen and Realisierungsprobleme einer bundesweiten Paneluntersuchung zum Verkehrsverhalten, *Internationales Verkehrswesen*, **47** (1-2) 20-25.