Variability and anchoring points in weekly activity-travel patterns

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Abstract

Temporal rhythms in travel and activity patterns are analysed thanks to a seven-day travel diary collected on 707 individuals in the city of Ghent (Belgium) in 2008. The analysis confirms the large level of intrapersonal variability whether for daily trips, time use and activity sequences. However the analysis goes further by studying this variability along various time periods within the week. Moreover, the systematic day-to-day variability is shown to have an extremely low share in intrapersonal variability. A striking result is that socio-demographic characteristics are mostly unable to explain the high level of intrapersonal variability. Repetitive activity-travel behaviour is then detected, through combinations of attributes of activity at destination, travel mode, trip arrival time and destination location. The picture is at the same time one of diversity and of singularity in activity-travel patterns along the week. People tend to concentrate their weekly activity-travel patterns on a few anchoring points (i.e. “core stops”), despite a large dispersion. These results are somewhat encouraging for modelling behavioural adaptations to changes in the transport context.

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1 INTRODUCTION

Various travel demand management policy measures which are at stake today, such as flexible or staggering work hours, incentive to use enhanced bus or light-rail services, integration and chaining of various transport modes as alternatives to the car (e.g. bike and public transport), car pooling and car sharing or even congestion pricing, all need accurate prediction of their effectiveness in changing behaviour. Obviously these old and new policy measures will demonstrate their effectiveness only if they match with day-to-day behaviour of transport users at which these measures are aimed.

Conventional four-step models are the main tool to produce this kind of prediction, however they are generally based on household travel surveys which measure individual travel (and sometimes diary) on one day only (as in France, Switzerland and Belgium; see Raux et al, 2011a). There are abundant examples of errors when comparing ex-ante prediction with ex-post realisations, such as with the London Congestion Charging Scheme which endured an unpredicted level of traffic decrease in the charging zone after implementation. Unsuspected levels of either flexibility or rigidity in travel behaviour may be revealed in response to travel demand policy measures.

This is why the search for regularity, variability, flexibility or "anchoring points" in activity-travel behaviour is of crucial interest for modelling.

The literature upon individual day-to-day activity-travel behaviour has delivered, at least since the eighties, a definite picture of large variability in various dimensions of this behaviour.

Hanson and Huff (1982, 1988) analyse day-to-day variability of travel patterns on a 35 consecutive days data set and conclude that while a seven-day record of travel does not capture all the variability of behaviour, it does capture a good sampling of individual's typical daily travel patterns. Pas and Koppelman (1986), using a five-day record of travel, show that employed people have much lower levels of intrapersonal variability in trip frequency when compared with people who are not employed outside the home. Using a three-day travel data set, Pas and Sundar (1995) conclude that there is a considerable level of intrapersonal variability in daily trip frequency, trip chaining and travel time.

The Mobidrive six-week travel diary dataset (Axhausen et al, 2002) is also a source for several studies, e.g. in Schönfelder (2006). Schlich and Axhausen (2003) shows that travel day-to-day behaviour is more stable on work days. They argue that two weeks are required at minimum in order to measure variability. Schlich et al (2004) also provide measures of repetition on leisure travel.

Ettema and van der Lippe (2009) analyse a one-week time use survey held over couples in The Netherlands. They conclude that spatial factors play a limited role in task allocation, compared to personal and household characteristics (presence of young children, work status, age, gender). This last result is also in line with Raux et al (2011a).

Another critical issue in similarity measures is the scheduling of activities and trips. Wilson (1998) firstly introduced a Sequential Alignment Method (SAM) for activity pattern analysis. The method is originated from molecular biology, aiming to identifying segments of similarity between sequences of DNA or protein. The SAM has gained its popularity in comparing the

similarity between activity patterns recently (Joh et al. 2001, 2002; Schlich and Axhausen, 2004; Wilson, 2008; Shimamoto et al., 2009).

Multiday data sets are rare (even if originating in the 70's as referred to in the literature), and this paper takes the opportunity of availability of a new 7-day data set to explore again the issue of day-to-day activity-travel behaviour.

Beyond the expected day-to-day variability, another issue is also to find some empirical indications of stability or regularity in individual activity patterns along the week. A seminal idea is that of "core stops" developed by Hanson and Huff (1988): these are elaborated as combinations of activity, mode, arrival time and location, repeated a certain number of times within a period of several days, which may be interpreted as "anchors" for the remaining of the multiday individual's activity-travel.

The questions which guide the analysis are the following:

- What are the relative levels of interpersonal and intrapersonal variability, according to various attributes of activity-travel patterns?
- What are the days which are the most similar along the week from the point of view of activity-travel behaviour?
- Can anchoring points be found in activity-travel patterns, according to travel modes, activity performed, arrival times and places visited?
- Do individual characteristics influence the variability (or stability) observed and to what extent?

The analysis in this paper confirms the large level of intrapersonal variability whether for daily trips, tours, time use and activity sequence. However the analysis goes further by studying this variability along various time periods within the week. Moreover, the systematic day-to-day variability has an extremely low share in intrapersonal variability. Another perspective is then taken by searching for repetitive activity-travel behaviour, through attributes of activity at trip destination, travel mode, trip arrival time and destination location. The results on core stops are somewhat encouraging by showing some kind of concentration of activity patterns on a few anchoring points.

The organization of the paper is as follows. First the data, a one-week travel diary in Ghent (Belgium), are introduced. Then the overall methodology for measuring variability is presented. This method is applied in the next section successively to travel indicators (trips and home-based tours), time use over various activities, and daily activity sequence. In the following section a search for potential "core stops" in the week is performed. Finally, the results are discussed and some conclusions are drawn.

2 THE DATA

The data for the analysis is based on a seven-day travel diary collected in the city of Ghent in Belgium (Castaigne et al, 2008). The objective of this survey was to investigate individual's weekly activity patterns and their impact on day-to-day variation of travel behaviour.

The surveyed individuals are randomly drawn from the population in the city of Ghent based on the stratification of household size, gender and age of household head (12 to 75). The survey methodology is based on paper and web survey followed by phone support. Although this survey cannot collect the activity patterns of all members in the household, it still allows investigation of individual's daily activity patterns and the determinants related to individual's socio-demographic characteristics.

The collected information contains continuous trip chain information over a week (trip purposes of twelve categories, approximate address of destination, departure and arrival time of trip, travel cost, used modes and travel time) and its potential influence factors (socio-demographic characteristics and mobility practices). The survey was conducted from September to November 2008 and 717 individual 7-day mobility diaries were collected (starting from any day within a week).

The initial twelve activity categories are classified into six types for the analysis: 1 home (home), 2 work and school (work, school), 3 shopping (daily and long-term shopping), 4 personal business (personal business (bank, doctor etc.)), 5 social-recreation (eating, visit to family or friends, walking, riding, leisure, sport, culture etc.), 6 others (drop off/pick up someone and others).

3 METHODOLOGY FOR MEASURING VARIABILITY

Multidimensional statistical techniques could be applied (e.g. factor analysis), however the travel-activity pattern is so complex in its multiple dimensions that a cautious approach is adopted by analysing separately the various indicators. These are the number of trips per day, the time allocation to activities per day (i.e. daily time-budget), the activity sequence each day, all of them computed at the individual level.

Variability in day-to-day behaviour can be attributed either to interpersonal differences or to intrapersonal differences. Basic theoretical results regarding the splitting up of variance may be applied, along with the ideas of Pas (1987) who originally developed these measures for analysing day-to-day variability in individuals' travel behaviour.

The total variability of any daily travel/activity indicator (total sum of squares *TSS*) can be split up into interpersonal variability (between person sum of squares *BPSS*) and intrapersonal variability (within person sum of squares *WPSS*).

Indeed considering some indicator of daily activity-travel behaviour n_{ij} (e.g. number of trips made by the individual *i* on day *j*), we have

$$\sum_{i=1}^{I}\sum_{j=1}^{J}(n_{ij}-\bar{n}_i)=0$$

where

I is the number of persons in the sample

J is the number of days in the observation period

and $\bar{n}_i$ the mean daily travel/activity indicator for individual *i* over period *J*, $\bar{n}_i = \frac{1}{J}\sum_j n_{ij}$

It follows that $TSS = \sum_i \sum_j \left(n_{ij} - \bar{n}\right)^2 = \sum_i \sum_j \left(n_{ij} - \bar{n}_i\right)^2 + \sum_i \sum_j \left(\bar{n}_i - \bar{n}\right)^2 = WPSS + BPSS$

with $\bar{n}$ the mean daily travel/activity indicator over all individuals *I* and period *J*, $\bar{n} = \frac{1}{IJ}\sum_i \sum_j n_{ij}$

$WPSS = \sum_{i=1}^{I}\sum_{j=1}^{J}(n_{ij} - \bar{n}_i)^2$, the within-person sum of squares,

$BPSS = \sum_{i=1}^{I} J(\bar{n}_i - \bar{n})^2$, the between-person sum of squares,

When it comes to socio-economic analysis or modelling, the interpersonal variability *BPSS* is generally explained by between-person differences in socio-demographic or place-based attributes.

The intrapersonal variability *WPSS* can be further split up into a systematic day-of-week variability (between-day sum of squares *BDSS*) and a residual variability (within-day sum of squares *WDSS*).

$$WPSS = \sum_{i=1}^{I}\sum_{j=1}^{J}(n_{ij} - \bar{n}_i)^2 = \sum_i \sum_j \left[\left(n_{ij} + (\bar{n}_j - \bar{n}) - \bar{n}_i\right) - \left(\bar{n}_j - \bar{n}\right)\right]^2 = WDSS + BDSS$$

$\bar{n}_j$ is the mean daily travel/activity indicator over individuals on day *j*, $\bar{n}_j = \frac{1}{I}\sum_i n_{ij}$

$n_{ij} + (\bar{n}_j - \bar{n})$ is the travel/activity indicator for person *i* on day *j* adjusted for the systematic effect of day *j*

$WDSS = \sum_i \sum_j \left(n_{ij} + (\bar{n}_j - \bar{n}) - \bar{n}_i\right)^2$

$BDSS = \sum_j I(\bar{n}_j - \bar{n})^2$

4 VARIABILITY ON VARIOUS DIMENSIONS OF ACTIVITY-TRAVEL BEHAVIOUR IN THE WEEK

4.1 Variability in the number of trips and home-based tours per day

The 717 people surveyed all perform at least one outside activity (at least 1 return trip to home) and on average perform 10.3 return trips to home over the seven days with a standard deviation of 3.8. Other activities are practiced at various levels during the whole week, e.g. 57% for work,

26% for school, 87% for shopping and 95% for social recreation. However the variability in trip numbers is large when compared with that for home return trips.

Table 1 shows the inter- and intrapersonal variability in number of trips per day. One finds again the large level of intrapersonal variability in daily trip numbers denoted in the literature like in Pas (1987, with a seven-day data set) and Pas and Sundar (1995, with a three-day data set). However one can go further by analysing this variability along various time periods within the week.

First, the total variability of daily trip number (TSS, divided by the number of days on which this statistics is computed) is roughly the same whatever the five periods considered (from Monday-Friday to Saturday-Sunday). This indicates that the number and the type of days on which the variability is computed have no incidence on its level.

The between person variability (BPSS) is in general less than the within person variability (WPSS): the share of BPSS in total variability is minimum (35.8%) when considering the whole week (Monday to Sunday); it increases to make up 45% of total variability when considering Monday to Friday period (working days); and it is maximum (60.6%) when narrowing the period to the week-end (Saturday and Sunday). It is only over the week-end that the between person variability is above the within person variability.

Table 1: Inter and intrapersonal variability in number of trips per day

Period	TSS	BPSS	WPSS	BPSS /TSS (%)	BDSS	WDSS	BDSS /WPSS (%)
Mon-Fri	4.16	1.88	2.29	45.1%	0.03	2.26	1.2%
Mon-Sat	4.23	1.72	2.52	40.6%	0.02	2.49	0.9%
Mon-Fri, Sun	4.15	1.58	2.57	38.0%	0.15	2.43	5.7%
Mon-Sun	4.22	1.51	2.71	35.8%	0.13	2.58	4.7%
Sat, Sun	4.18	2.53	1.65	60.6%	0.21	1.44	12.5%

Remark: BPSS, WPSS, BDSS, WDSS and TSS is divided by 10^3 and by the number of days considered

When it comes to further breakdown of within person variability (WPSS) into between-day (systematic day-to-day) and within-day variability, the results show that the systematic day-to-day variability (BDSS) has an extremely low share of WPSS (about 5% on Monday-Sunday period). This is again in line with Pas (1987) but one can analyse the variations of this share along the various periods.

First, if one considers the first four lines of the table, which include the working days (Mon-Fri) and Saturday or Sunday, the level of within-day variability (WDSS) remains approximately the same (from about 2.3 to 2.5). However, the share of BDSS changes significantly when Sunday is included (from about 1% to 5%), and peaks up to 12.5% when the period is narrowed to Saturday-Sunday (BDSS increases while WDSS decreases sharply). Somewhat expected,

regarding variability in trip numbers, Sunday appears definitely as a different day from other days of the week, including not only the traditional working days but also Saturday.

Overall this indicates that the within person variability has to be explained by factors other than systematic day-to-day variability.

4.2 Variability in the individuals' daily time use

The daily travel/activity indicator under study here is the duration of activity *a* on day *j* for individual *i* (in minutes) d_{ija}. Only out-of-home activities are distinguished while in-home activities are not available in detail.

Hence $\bar{d}_{ia}$ refers to the mean duration of activity *a* for individual *i* over period *J*,

$$\bar{d}_{ia} = \frac{1}{J}\sum_{j} d_{ija}$$

$\bar{d}_{ja}$ is the mean duration of activity *a* over individuals on day *j*, $\bar{d}_{ja} = \frac{1}{I}\sum_{i} d_{ija}$

and $\bar{d}_{a}$ is the mean duration of activity *a* over all individuals *I* and period *J*, $\bar{d}_{a} = \frac{1}{I}\sum_{i} \bar{d}_{ia}$

$$BPSS = \sum_{i=1}^{I}\sum_{a=1}^{K} J(\bar{d}_{ia} - \bar{d}_{a})^2$$

$$WPSS = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{a=1}^{K} (d_{ija} - \bar{d}_{ia})^2$$

$$BDSS = \sum_{j}\sum_{a} I(\bar{d}_{ja} - \bar{d}_{a})^2$$

Table 2 shows the various figures of variability for time allocation to activities per day. TSS is remarkably stable across the various periods of observation, except for a decrease in variability on Saturday-Sunday period. Within this variability the share of between-person variability (BPSS) is in the majority only when considering working days (Monday-Friday, 58%) or the week-end (Saturday-Sunday, 59%). On the opposite the share of BPSS is minimal (and less than half) when considering the whole week (Monday-Sunday): the intrapersonal variability in time allocation over the whole week takes the lead.

Regarding the breakdown of intrapersonal variability (WPSS), the share of systematic day-to-day variability is again in the minority (BDSS, less than 20%), however with significant differences when considering various periods in the week. This share is almost null (0.6%) on the working days period (Monday-Friday) and about 1% on the week-end period.

This indicates that within whether the working days or week-end period intrapersonal variability is not driven by alternation of days but by other kinds of variability.

Table 2: Inter and intrapersonal variability in time allocation to activities per day

Period	TSS	BPSS	WPSS	BPSS /TSS(%)	BDSS	WDSS	BDSS /WPSS(%)
Mon-Fri	0.11	0.06	0.04	58.0%	0.00	0.04	0.6%
Mon-Sat	0.11	0.05	0.06	44.0%	0.01	0.05	12.0%
Mon-Fri, Sun	0.11	0.05	0.06	43.3%	0.01	0.05	14.6%
Mon-Sun	0.11	0.04	0.07	35.8%	0.01	0.06	17.0%
Sat, Sun	0.07	0.04	0.03	59.2%	0.00	0.03	1.4%

Remark: BPSS, WPSS, BDSS, WDSS and TSS is divided by 10^9 and by the number of days considered

4.3 Variability for individuals' daily activity sequence

The SAM distance (or Levenshtein distance) between two sequences of activities can be calculated by applying a dynamic programming algorithm, computing the least number of operations (deletion, insertion and replacement) – with weighting coefficients – necessary to equalize two sequences. This method has been extended to multidimensional SAM taking into account the dependencies between different attributes of activity patterns (activity type, location and duration, beginning and ending time, travel mode; see Joh et al, 2002). However this makes the calculation of similarity more complex as mentioned by Schlich and Axhausen (2004). The choice of attributes and their scaling, categorizing and weighting still lack theoretical justification. Thus a one-dimensional alignment method is applied to compare activity type sequences.

In the general formulations n_{ij} is replaced by s_{ij} the SAM distance for individual *i*, between day *j* and the other days of the week, defined as $s_{ij} = \sum_{k=1}^{J} d(q_{ij}, q_{ik})$ with q_{ij} being the activity sequence on day *j* performed by individual *i*.

Thus $\bar{s}_i$ is the mean SAM distance for individual *i* of all days *j* of period *J* to all other days in the same period *J*, $\bar{s}_i = \frac{1}{J}\sum_j s_{ij} = \frac{1}{J}\sum_{j=1}^{J}\sum_{k=1}^{J} d(q_{ij}, q_{ik})$

$\bar{s}_j$ is the mean SAM distance over all the individuals of day *j* to all other days in period *J*, defined as $\bar{s}_j = \frac{1}{I}\sum_i s_{ij} = \frac{1}{I}\sum_i\sum_{k=1}^{J} d(q_{ij}, q_{ik})$

$\bar{s}$ is the mean SAM distance over all the individuals and all days of period *J*, $\bar{s} = \frac{1}{I}\sum_i \bar{s}_i$

Other statistics are straightforward:

$BPSS = \sum_i J(\bar{s}_i - \bar{s})^2$

$$WPSS = \sum_i \sum_j I(s_{ij} - \bar{s}_i)^2$$

$$BDSS = \sum_j I(\bar{s}_j - \bar{s})^2$$

Table 3 shows the inter- and intrapersonal variability of SAM distances for various periods in the week. The total variability (TSS) is minimal in the week-end period (Saturday-Sunday), at a significantly lower level than on other days, and maximal when considering the whole week (Monday-Sunday). This indicates a specificity of Saturday and Sunday in activity sequences, when compared with the remainder of the week, and also a significant degree of homogeneity of these two days in the nature of activities when compared with the working days.

The main difference with previous indicators is the high level of between-person variability, always over intrapersonal variability (with a share of more than 70%). This share is maximal on the working days period (Monday to Friday). Thus the heterogeneity of individuals would explain a large part of variability in the sequencing of activities.

Hence the intrapersonal variability (WPSS) is small and within it, the systematic day-to-day variability (BDSS) is even smaller (roughly between 1% and 9%).

Table 3: Inter and intrapersonal variability in individuals' daily activity sequence

Period	TSS	BPSS	WPSS	BPSS /TSS(%)	BDSS	WDSS	BDSS /WPSS(%)
Mon-Fri	0.05	0.04	0.01	78.7%	0.00	0.01	1.3%
Mon-Sat	0.07	0.05	0.02	72.5%	0.00	0.02	8.4%
Mon-Fri, Sun	0.07	0.05	0.02	73.6%	0.00	0.02	3.7%
Mon-Sun	0.10	0.07	0.03	71.3%	0.00	0.03	4.5%
Sat, Sun	0.00	0.00	-	100.0%	-	0.00	NA

Remark: BPSS, WPSS, BDSS, WDSS and TSS is divided by 10^9 and by the number of days considered

5 SEARCHING FOR CORE STOPS IN THE WEEK

The search for core stops starts with the measure of repetition of travel behaviour based on trip characteristics. Each trip can be classified based on one- or multi-dimensional trip attributes. These four attributes are activity type, transport mode, arrival time at destination and activity location. Activity is classified as seven categories: 1. work; 2. school; 3. shopping; 4. personal business; 5. social recreation; 6. others; 7. home. Mode is classified as: 1. walk; 2. bicycle; 3. car; 4. public transportation. Arrival time is classified as: 1. 0:00- 8:30; 2. 8:31- 10:30; 3. 10:31-12:30; 4. 12:31-16:00; 5. 16:01-18:30; 6. 18:31-23:59. Location of activity is based on the 45 zones actually visited by the overall sample.

On average, individuals perform almost five activities among the seven potential, they use three of the four potential modes, arrival times of their trips fall within five intervals of the six possible and they visit only six locations (with a maximum of 14) among the 45 visited overall

by the sample. This first overview indicates at the same time diversity and singularity in activity-travel across the week. People seems to perform the whole range of activities (except work for non-workers and school for adults non-students), they use various transport modes and at any time. However, they visit only a very few places among the infinity of potentials.

Definition of "core stops" has somewhat to do in the arbitrary. Hanson and Huff (1988) define them as stops which occur at least half the "representative days" they have elaborated on a 35-day recording period. Here only a 7-day recording period is available. In this application core stops are defined for each individual as the trips, classified by four-attribute characteristics (activity, mode, arrival time, location), *occurring at least three different days in the week*. Since, as analysed above, Saturday and Sunday are very different compared to the five remaining working days, a frequency of three times in a week is somewhat large.

Table 4 shows the distribution of core stops based on four-attribute characteristics of trips (activity, mode, location, arrival time), overall (last line of the table) and broken down over activity type. With the definition above, for almost everybody there is no core stops for activities like shopping, personal business, social recreation and "others" (see column "% of zero" in the first section of the table, which goes from the 80% to the 100%). For school, less than half of people concerned have core stops (100-55.4 = 44.6%), while they are in the majority for work (100-35.8 = 64.2%) and return to home (100-21.8 = 78.2%). This definitely separates mandatory activities (i.e., work, school) and home as anchors while other activities are far more flexible in location, time and mode used.

When it comes to the distribution in percentage, for half of the sample (see column "Q2" in the "percentage of trips" section of the table) at least 30% of all trips are core stops. This percentage of core stops rises to more than 40% for home trips (they occur with the same combination of mode x arrival time) and to more than 60% of work trips (they occur with the same combination of mode x arrival time x location).

However the "arrival time" attribute is probably blurring the concentration of trips in core stops. Thus core stops based on three attributes (excluding the "arrival time" attribute, leaving only activity, mode and location) are analysed in Table 5. With this restriction to three attributes, nearly everybody has home return trips as core stops (3% in the column "% of zero" in the first section of the table): this is somewhat expected in this specific case since as place and activity ("home") are fixed, the only attribute remaining is mode. The percentage of zero trips in core stops for individuals engaging in mandatory activities is decreasing: three-quarter of workers have work trips in core stops (100-23.9 = 76.1%) and more than half of schoolgirls(boys) and students have school trips in core stops (100-46.2 = 54.8%). Flexibility of shopping, personal business, social recreation and "other" activities is confirmed since the percentages of individuals having no trips as core stops for these activities are still high (from 71% to 97%).

The distribution in percentage shows a significant increase of core stops shares. Over all activities the minimum percentage of trips being core stops for half of the individuals goes from 30% with four attributes to 56% now with the three attributes activity x mode x location (more than 43% for three-quarter of the sample). Breaking down by activity, and thus having only two attributes (mode x location), at least 86% of home return trips are core stops for half of individuals (and at least 75% of trips for three-quarter of the sample). These figures are respectively 83% and 43% for work trips for the sample of workers. 57% of school trips are core stops for half of the sample of schoolgirls(boys) and students.

Table 4: Core stops distribution per activity type, based on four-attribute (activity, mode, location, arrival time) characteristics of trips

	Number of trips which are core stops, per person per week									Percentage of trips which are core stops, per person (%)							
Activity at destination	N*	Mean	S.D.	% of zero	Min	Q1	Q2	Q3	Max	N*	Mean	S.D.	Min	Q1	Q2	Q3	Max
Home	717	4.4	3.4	21.8%	0	3	4	7	19	717	41.2	27.1	0	25.0	43.8	61.5	100.0
Work	406	2.7	2.4	35.8%	0	0	3	4	14	406	50.2	40.9	0	0.0	60.0	83.3	100.0
School	186	2.0	2.4	55.4%	0	0	0	4	9	186	37.5	43.7	0	0.0	0.0	83.3	100.0
Shopping	627	0.4	1.3	91.2%	0	0	0	0	10	627	4.7	16.0	0	0.0	0.0	0.0	85.7
Personal business	368	0.0	0.2	99.5%	0	0	0	0	3	368	0.4	5.8	0	0.0	0.0	0.0	100.0
Social recreation	684	0.6	1.9	88.2%	0	0	0	0	20	684	6.0	17.5	0	0.0	0.0	0.0	100.0
Others	528	1.0	2.5	81.6%	0	0	0	0	16	528	10.6	24.2	0	0.0	0.0	0.0	100.0
Total (N=717)	717	8.1	5.9		0	3	7	12	34	717	29.8	19.4	0	15.2	30.0	42.9	85.7

N*: Number of individuals with number of trips >0

Remark: Core stops are defined for each individual as the trips, classified by four-attribute characteristics (activity, mode, arrival time, location), occurring at least three different days of a week

Table 5: Core stops distribution per activity type, based on three-attribute (activity, mode, location) characteristics of trips

	Number of trips which are core stops per person per week									Percentage of trips which are core stops per person (%)							
Activity at destination	N*	Mean	S.D.	% of zero	Min	Q1	Q2	Q3	Max	N*	Mean	S.D.	Min	Q1	Q2	Q3	Max
Home	717	8.6	4.0	3%	0	6	8	11	23	717	81.5	21.0	0.0	75.0	85.7	100.0	100.0
Work	406	3.7	2.6	23.9%	0	3	4	5	17	406	67.2	40.3	0.0	42.9	83.3	100.0	100.0
School	186	2.6	2.6	46.2%	0	0	3	5	11	186	47.4	45.8	0.0	0.0	57.1	100.0	100.0
Shopping	627	1.0	2.2	79.7%	0	0	0	0	16	627	13.8	28.7	0.0	0.0	0.0	0.0	100.0
Personal business	368	0.1	0.6	96.5%	0	0	0	0	4	368	2.5	13.9	0.0	0.0	0.0	0.0	100.0
Social recreation	684	1.3	2.8	75.0%	0	0	0	1.5	21	684	15.3	28.4	0.0	0.0	0.0	10.0	100.0
Others	528	1.8	3.5	71.2%	0	0	0	3	22	528	20.8	34.7	0.0	0.0	0.0	48.3	100.0
Total (N=717)	717	14.9	7.7		0	10	13	19	40	717	54.0	18.2	0.0	42.9	55.6	66.7	100.0

N*: Number of individuals with number of trips >0

Remark: Core stops are defined for each individual as the trips, classified by three-attribute characteristics (activity, mode, location), occurring at least three different days of a week

6 DISCUSSION AND CONCLUSION

The large level of intrapersonal variability in daily trip numbers already demonstrated in the literature is confirmed. However this analysis goes further by studying this variability along various time periods within the week.

First of all overall variability in daily trip numbers is roughly constant whatever the periods considered within the week (number and type of days). Then within this overall variability, intrapersonal variability is generally greater than interpersonal variability, except in the week-end period. And finally the systematic day-to-day variability has an extremely low share in intrapersonal variability. Overall this indicates that intrapersonal variability has to be explained by factors other than systematic day-to-day variability.

When it comes to daily time allocation to activities a slightly different picture appears. Overall variability in time allocation is roughly constant whatever the periods considered within the week except on week-end (where it decreases). Unlike the case of trips, intrapersonal variability is lower than interpersonal variability either on working days or on week-end. However intrapersonal variability is still greater when considering the whole 7-day week. Moreover, as for trips, intrapersonal variability is not driven by alternation of days (systematic day-to-day variability) but by other sources of variability.

The differences in activity sequence between days are minimal in the week-end period, at a significantly lower level than on other days, and maximal when considering the whole 7-day week. This indicates a significant degree of homogeneity of the two week-end days in the nature of activities when compared with the working days. There is also a great difference with previous activity-travel indicators, since interpersonal variability in activity sequences is always over intrapersonal variability.

Another perspective is then taken by searching for repetitive activity-travel behaviour, summed up through attributes of activity type at trip destination, travel mode, trip arrival time and destination location. The picture is at the same time one of diversity and of singularity in activity-travel across the week. People perform the whole range of activities (except for work or school depending on the individual status), they use the various transport modes, and at any time. However, they visit only a few places among the infinity of potentials. This is a story of limited location choice set.

The picture is also one of concentration of activity-travel patterns on few combinations, despite a large dispersion. Core stops are defined for each individual as the trips, classified by four-attribute characteristics (activity, mode, arrival time, location), occurring at least three different days in the week. Core stops concern essentially mandatory activities (i.e., work, school) and home as anchors while other activities (like shopping, personal business, social recreation) are far more flexible in location, time and mode used. For half of the sample at least 30% of all trips are core stops. This percentage rises to more than 40% for home trips and to more than 60% for work trips.

Most of the percentage dispersion comes from the “arrival time” attribute. If this attribute is excluded, leaving only activity, mode and location, of course the percentage of trips which are

core stops increases. Flexibility of shopping, personal business, social recreation and "other" activities is confirmed, opposite to mandatory activities. Over all activities the minimum percentage of trips being core stops for half of the individuals rises to 56% with the three attributes, and to 83% for work trips for the sample of workers, to 57% of school trips for half of the sample of schoolgirls(boys) and students.

As shown in Raux et al (2011b) the influence of socio-demographic characteristics on intrapersonal variability is weak, whether for daily trips, tours, time use and activity sequence. Men have in general lower intrapersonal variability than women which would mean either more flexibility or more irregular constraints (e.g. linked to maintenance, childcare, shopping) for women. Access to car for students (through holding a driving license) is also linked to greater intrapersonal variability. Regarding the individual's percentage of core stops the influence of socio-demographic characteristics is as well weak. Men (non-workers) have a higher percentage of core stops, while holding a driving license is associated with a lower percentage of core stops. As the percentage of trips which are core stops may be considered as an indicator of stability, there is an obvious convergence with intrapersonal variability. However, if socio-demographic characteristics explain weakly intrapersonal variability, what is left as explanatory factors?

Overall this analysis of variability of activity-travel behaviour over a 7-day period shows that individual behaviour is neither completely habitual (or routine) nor completely random, in agreement to what was initially a working hypothesis of Hanson and Huff (1986). However, a limitation of this analysis is the reference to the day as the basis for computing the activity-travel indicators, while the rhythm of repetition could be every other day or on three days, or so on.

The global picture is both that intrapersonal variability is large, and the role of systematic day-to-day variability is marginal. Moreover, a striking result is that socio-demographic characteristics are mostly unable to explain the level of intrapersonal variability.

However results on core stops are somewhat encouraging by showing some kind of concentration of activity patterns on a few anchoring points. This is a stimulating perspective for modelling behavioural adaptations to changes in the transport context.

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