IS TRAVEL BEHAVIOUR REPETITIVE FROM DAY TO DAY?

Peter Stopher and Yun Zhang
Institute of Transport and Logistics Studies, The University of Sydney

ABSTRACT

This paper describes research to explore the habitual and repetitive patterns of travel behaviour for improving travel demand modelling. The data used in this research are from two Australian panels from which GPS data were collected. The trips recorded by the GPS were initially classified into tours. A tour classification was then applied that grouped the tours into one of twelve tour types and the number of repetitions of each tour type within the time period of data collection were then determined. Having determined how often a particular tour type was repeated over a week or longer, the tours were then described in terms of certain tour characteristics as the initial means to search for identical patterns of travel from one day to the next. To determine if a particular tour type was repeated more or less identically on more than one occasion, the tour type repetitions were described by a coefficient of variation for each of tour travel time, tour distance, tour activity time, and total duration (time) of the tour. From this it was determined that there is relatively little repetition of tours from one day to the next, raising serious questions about the assumptions of repetitiveness that underlie almost all travel demand models.

INTRODUCTION

Since its inception, travel demand modelling has been based on the assumption that individual travel behaviour is highly repetitive in the short run. The basic assumption in data collection and modelling procedures has been grounded in the use of data from cross-sectional surveys of usually one day of travel for each respondent. For example, Bowman and Ben-Akiva (2001) presented an integrated activity-based model based on a twenty-four hour household travel diary survey. Vovsha, Bradley and Bowman (2005) presented an overview of the development of activity/tour-based models from 1995 to 2005, as well as developments before 1995, almost all of which were based on one-day self-report data. As noted many years ago by Stopher and Meyburg (1975), the underlying basis of travel demand modelling from cross-sectional, one-day data is that the travel to be modelled is repetitive and predictable. In fact, the notion of predictability is itself closely related to the notion of repetitiveness. Alternatively, one may state that the underlying and overarching principle of travel-demand modelling from cross-sectional surveys of one day of travel is that most travel is habitual in nature. This becomes clear when one considers the typical modelling data base. Typically, the data to be used to estimate models of travel demand is collected over a period of several months or even a year, and comprises a sample of households from which data are collected about a single day of travel, most often restricted to a single weekday (Monday to Friday).

As Pas and Sundar (1995) described, it is assumed that, if the travel behaviour reported is for a randomly chosen day (out of some longer time period), then an unbiased sample of behaviour (over that time period) is obtained. Furthermore, this type of one-day travel behaviour survey is commonly conducted in such a way that travel behaviour information is obtained for the different weekdays which leads to unbiased samples of travel behaviour on an average weekday. It is therefore an implicit assumption that choosing a random sample of households and thereby an almost random sample of people, and a random weekday, the resulting data will be representative of the travel undertaken by the population from which the sample is drawn. Because it is assumed, furthermore, that there are some systematic differences in travel on different days of the week, the sample is usually designed to represent each weekday approximately equally in the final sample.

Recently, however, a number of researchers have begun to examine issues relating to variability in the travel behaviour of individuals and households over time. Some research has focused on the development of an improved understanding of travel behaviour by examining some dynamic phenomena, such as adaptation and habit through the analysis of longitudinal data (such as Goodwin et al. 1990; Kitamura 1990 and Hensher et al. 1992). Other researchers have focused on variability in behaviours over a series of consecutive days. Most of the multi-day studies fall in this category. Pas and Koppelman (1987) and Pas (1988) examine intrapersonal variability in daily number of trips using a 7-day activity survey from 1973 in Reading, England. Huff and Hanson (1986, 1990) explore day-to-day variability through identifying relatively homogenous sociodemographic groupings based on observed multi-day data. Their studies suggest that survey periods of longer than a week may be needed to capture the habitual behaviour exhibited by individuals. Mahmassani (1997) focused on the variability of the home-to-work trips only, examining the effect of commuter characteristics and the commuter's travel environment on the likelihood of changing departure time and route choice from one day to the next for the morning. Finally, Schlich (2001) used a sequence alignment method to analyse intrapersonal variability in travel behaviour using a six-week travel survey conducted in Germany in the fall of 1999.

DATA USED IN THIS RESEARCH

As Stopher et al. (2008) note, one of the pragmatic reasons for collecting one day of data has been the perception that collecting more than this amount of data would impose too high a respondent burden on the sampled households. They also note that only a handful of surveys over the years have collected multi-day data, with a listing in their paper of only thirteen such surveys out of the hundreds or possibly even thousands of household travel surveys that have been conducted over the past 50 years around the world. While their listing is not exhaustive, it is likely that the total number of multi-day surveys that have been collected over the past half century is no more than 1 or 2 percent of the total of all surveys conducted.

In contrast to this, recent data collection efforts by the authors have included a number of multi-day surveys using GPS devices as the mechanism to record the data, thereby mitigating much of the concern about both respondent burden, and self-reporting error and fatigue that would be likely to impact the quality of conventional travel survey data. In addition to providing multi-day data, these data have also been collected from panels, so that there exist data that allow one to compare the travel patterns of one individual not only over several days, but also from year to year. These data open up the possibility to examine the underlying assumptions about habit and repetitiveness of travel.

For this particular research, the data that were used were obtained from a panel of households that was drawn at random from households in the Western suburbs of Adelaide, South Australia. In 2005, a sample of approximately 200 households was empanelled and asked to carry GPS devices with them wherever they went outside the home for a period of seven days. The GPS devices measured all travel undertaken by respondents, irrespective of mode and surveys were undertaken in the Spring, but avoiding school holidays. All household members in each sampled household over the age of 14 years were asked to take part in this survey. In 2006, these same households were approached again to carry GPS devices for seven days. As is normal in any panel survey, some households had moved away, some households had dissolved, and some households did not wish to participate again. A few households were not contactable during the survey period, also. To maintain panel numbers, additional households were sampled in 2006, drawn at random again from the same geographic area, and asked to take part in this survey. In addition, a second study had been initiated in 2005 and had continued into 2006, in which a panel of 50 households drawn at random from the same geographic area, had been asked to carry GPS devices for 28 days. As many of these households as were willing to continue were also added to the sample and asked to carry GPS devices for 15 days in the 2006 wave of the main South Australia panel. To allow for attrition between the second and third wave, because the goal of the survey was to examine changes in travel behaviour from one wave to the next, an oversample was drawn in 2006, so that the panel should still be at the level of 200 households in the final wave in 2007. While details of this panel have been reported elsewhere (Stopher et al., 2009), those details are reproduced here for the convenience of the reader.

Tables 1 and 2 show the disposition of the sample for the three waves of the panel. A pilot survey was conducted ahead of the main survey, to test the methodology, but the second wave of the pilot coincided with the first wave of the main survey and so the households in that second wave of the pilot survey (which was not changed at this point from the method of the main panel waves) were combined with the Wave 1 sample to create the full Wave 1 sample. It can be seen that 202 households completed wave 1, 308 households completed wave 2, of which 138 were from Wave 1, and 36 were from the other study and were effectively completing their third wave of the survey. In Wave 3, a total of 197 households completed the survey, of which 178 completed the 7-day task and 19 completed the 15-day task. These sample sizes are quite substantial, because of the measurement of multiple days of data, the implications of which are documented in Stopher et al. (2008). Two hundred households with an average of 2.1 adults per household, measured for 7 days provides a maximum of 3,560 person days of data.

Table 1: Sample Disposition for the Initial GPS Recruitment Panel for Wave 1

Disposition	Pilot Wave 2	Main Wave 1	Main Wave 1 Plus Pilot Wave 2
Sample	54	1000	1054
Attempted to contact	54	699	979
Known Refusing Households	0	323 (46%)	417 (43%)
Total ineligible	0	209 (30%)	272 (28%)
Households Recruited	54 (100%)	167 (34%)†	221(31%)†
Households failing to comply	3 (6%)*	16 (10%)*	19 (9%)*
Households completing wave	51 (94%)*	151 (90%)*	202 (91%)*

† Percent of Eligible Households
* Percent of Recruited Households

Table 2: Sample Disposition for Waves 2 and 3 of the GPS Panel

Disposition	Main Wave 1	15-day Households	New Recruits	Final Total Wave 2	Main Wave 2	15-day Households	Final Total Wave 3
Sample			550				
Approached	200	44	338		246	33	279
Ineligible	25 (13%)	3 (7%)	21 (6%)		9 (3.7%)	1 (3%)	10 (3.6%)
Refused	26 (13%)	4 (9%)	165 (49%)		38 (15.4%)	4 (12.1%)	42 (15.1%)
Continuing/Recruited	149 (75%)	37 (84%)	152 (45%)	338	199 (80.9%)	28 (84.8%)	227 (81.4%)
Did not comply	11 (7%)*	1(3%)*	18 (12%)*	30 (9%)	21 (11%)†	9 (32%)†	30 (13%)†
Completed	138 (93%)*	36 (97%)*	134 (88%)*	308 (91%)	178 (89%)†	19 (68%)†	197 (87%)†

*Percent of Recruited Households
†Percent of Continuing Households

A summary of the demographics of the three waves of the panel as compared to 2001 and 2006 census statistics for the region is shown in Table 3. From this table, it can be seen that the panels under-represent one-person households and over-represent 4-person households. They also under-represent non-car-owning households, while over-representing 2-car and 3+-car households. Both of these biases – household size and car ownership – are rather typical of surveys that relate to travel. As a result of the under-representation of one-person households, the panels have a slightly higher average household size than the census, and there is a higher proportion of workers per household in the panels than in the census. However, overall, the panel appears to be reasonably representative of the region from which it is drawn.

Table 3: Summary of the Demographics for the Three GPS Waves in South Australia with 2001 and 2006 Census Data*

Demographic (per household)	Value	2001 Census - All Households	2006 Census - All Households	Recruited households			Households Used in Analysis		
				Wave1	Wave2	Wave3	Wave1	Wave2	Wave3
Number of Persons	1	33.7%	32.8%	20.7%	18.5%	17.5%	20.6%	19.7%	16.4%
	2	34.2%	34.5%	35.1%	41.7%	37.3%	34.9%	35.8%	40.4%
	3	14.0%	14.1%	16.4%	16.9%	17.1%	16.3%	17.7%	14.9%
	4	12.1%	12.5%	21.6%	19.1%	21.5%	21.5%	20.7%	21.6%
	5+	6.1%	6.2%	6.3%	3.8%	6.6%	6.7%	6.1%	6.7%
Number of Vehicles	0	15.1%	14.4%	4.2%	2.7%	3.5%	4.2%	2.9%	2.9%
	1	44.1%	42.5%	30.7%	37.2%	33.8%	31.1%	35.6%	34.3%
	2	30.5%	32.1%	49.2%	42.0%	42.5%	49.0%	41.2%	40.6%
	3+	10.2%	11.1%	15.9%	18.0%	20.2%	15.8%	20.3%	22.2%
Average Number of Adults		1.90	1.97				2.08	2.08	2.11
Proportion of Population Adults		80.3%	80.5%				80.3%	80.3%	80.1%
Average Number of Children		0.47	0.48				0.51	0.51	0.52
Proportion of Population Children		19.7%	19.6%				19.7%	19.7%	19.9%
Average Number of Males		1.15 (48.5%)	1.19 (48.8%)				1.27 (48.7%)	1.25 (48.1%)	1.25 (47.5%)
Average Number of Females		1.22 (51.5%)	1.25 (51.2%)				1.34 (51.3%)	1.34 (51.9%)	1.38 (52.5%)
Average Number of Full-Time Workers		0.62	0.66				0.89	0.85	0.79
Average Number of Full-Time Students		0.40	0.45				0.53	0.55	0.50

* The South Australia census statistics are obtained by aggregating Port Adelaide Enfield (LGA45890) with Charles Sturt (LGA41060) and Holdfast Bay (LGA42600) to approximate the evaluation zone.

It is also worth noting that the demographics of the panel do not change significantly from one year to the next. There has been a small decrease in one-person households from wave 1 to wave 3 and a corresponding increase in two-person households from wave 1 to wave 3. There is also a marked loss of non-car-owning households between waves 1 and 2, which then stabilises at wave 3. On all other statistics, there is little change from wave 1 to wave 3. Hence, the make-up for attrition seems to have been successful in maintaining the demographic structure of the initial wave of the panel. However, weighting the data would have no effect on the results reported here, because the analysis is largely disaggregate in nature.

ANALYSIS OF THE DATA

The GPS data actually provide detailed path information of the travel undertaken by a household on each day of the survey. An example of two days of travel by a specific respondent is shown in Figures 1 and 2, taken from the smaller panel where respondents were carrying GPS devices for 28 days. To compare spatial patterns such as these was considered to be too complex a task at this stage of the analysis. In the wave 1 data, there are 310 persons providing 2,156 person days of travel; in wave 2, there are 645 persons providing 4,808 person days of travel; and in wave 3, there are 581 persons providing 2,974 person days of travel. The number of spatial patterns included in these data are likely to be somewhat overwhelming.

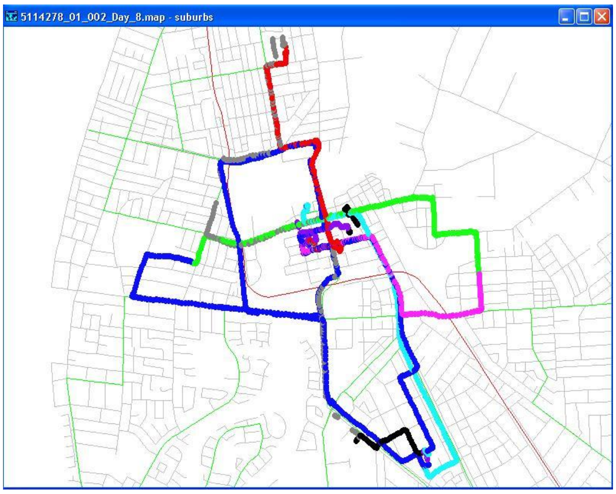

Figure 1: Day 8 for One Respondent

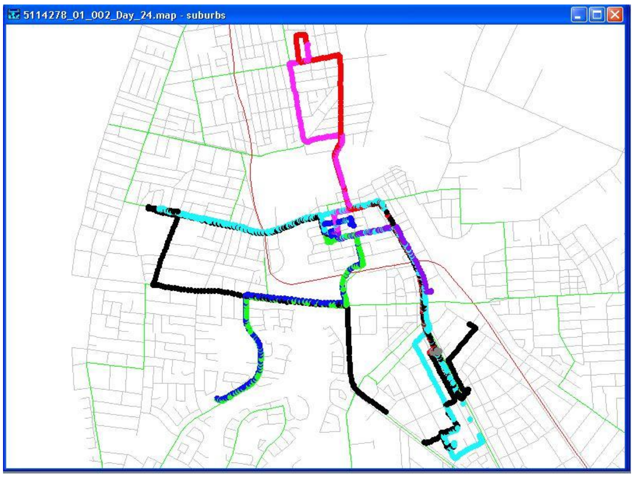

Figure 2: Day 24 for One Respondent

The strategy that was adopted for this study was, first, to group the travel of each respondent into tours, using the tour classification system put forward by Stopher et al. (2010) and reproduced here in Table 4. This procedure produced 3,310 tours for Wave 1, 6,215 tours for wave 2, and 4,564 tours for wave 3. The first step in the process of determining repetitiveness was to count the number of occasions on which the same tour type occurred on more than one day in each of the waves of data.

Table 4: Proposed Tour Type Classifications

Tour Type Number	Tour Description	Sequence
1	Simple work tour	h – w – h
2	Simple education tour	h – e – h
3	Simple shopping tour	h – s – h
4	Simple other tour	h – o – h
5	Complex work tour (including composite and multi-part work tours)	h – [w/o] – (– w/o –) – [w/o] – h
6	Complex education tour (including composite and multi-part education tours)	h – [e/o] – (– e/o –) – [e/o] – h
7	Complex shopping tour (including composite and multi-part shopping tours)	h – [s/o] – (– s/o –) – [s/o] – h
8	Complex work and education tour	h – [w/e/o] – (– w/e/o –) – [w/e/o] – h
9	Complex education and shopping tour	h – [e/s/o] – (– e/s/o –) – [e/s/o] – h
10	Complex work and shopping tour	h – [w/s/o] – (- w/s/o -) – [w/s/o] – h
11	Complex work, education, and shopping tour	h – [w/e/s/o] – [w/e/s/o] – (– w/e/s/o –) – [w/e/s/o] – h
12	Multi-part Other Tour	h – [o] – (– o –) – [o] – h

Having determined this count, for those days on which the same tour type was observed, the attributes of the tours were compared. If an identical tour pattern occurred and the total duration of the tour, the total travel time on the tour, the total activity time within the tour, and the time of day at which the tour started and ended were similar, then this would suggest that the travel patterns were repetitive. However, if any of these attributes were different from one occurrence of a tour to the next, then it could be assumed that the travel pattern was, in fact, different. To further elaborate on this, a few sample tour patterns that were thought to be essentially repeats and a few that were thought to be different were examined. From these results, conclusions could be drawn as to the amount of repetitiveness in weekly travel. Further, differences were examined between the 7-day and the 15-day data, so see if repetitions were more likely to be found over the longer period of 15 days of data.

RESULTS OF THE ANALYSIS

It is important to note, at the outset, that the classification into tours is based on software that infers the purpose of each GPS trip. While this software does quite a good job of identifying work and education trips, it does not do so well with shopping trips, and all other trips are classified to other, if they are not clearly work, education or shopping. The reason for this is that the surveys requested respondents to report the workplace addresses for each worker in the household, the educational establishment addresses for each student in the household, and the two most frequently used grocery store addresses for the household. By geocoding these addresses and matching trip ends from the GPS data to the geocoded addresses, work and education addresses are matched relatively well, but there are many shopping trips that are made to locations other than the two most frequently used grocery stores, so that shopping trips cannot be identified as readily. There are also a few cases in which respondents either did not provide the requested address information, or provided it sufficiently inaccurately that geocoding was not possible. In these cases, there will again be a lack of match for the GPS data, so that the destinations may be classified as ‘other’, when in fact they are work, education, or shopping.

As a direct result of the relative difficulty of identifying shopping trips, there are likely to be fewer tours of type 3 than would be expected, with rather more of type 4. Similarly, tour types 10 and 11 are missing from the data, probably because any retail locations that were visited in the middle of a tour for work or education would have been at less frequently-used shopping locations than the ones that respondents identified. Table 5 shows the overall frequency of tour types by wave. In Table 5, the row that shows ‘No Tour’ indicates the number of person days on which no travel was recorded. The percentages are generally rather similar for each tour type among the three waves. The no travel days includes both genuine no travel days and days on which respondents did not take the GPS device with them. According to self reports on this, which were only obtained in waves 2 and 3, and for which not all respondents reported, about 56 percent in wave 2 and about 62.2 percent in wave 3 were genuine no-travel days. In 27.5 percent of cases in wave 2 and 23.6 percent of cases in wave 3, the respondent admitted to leaving the GPS device at home. The remaining cases in each wave were either missing data for the day on which no travel was made, or the respondent did not complete a record of what happened on each day. Overall, these figures suggest that the no travel days in wave 2 numbered 650, or 13.5 percent of the person days of travel, while in wave 3, they numbered 526, or 17.7 percent of the person days of travel. Given that these data sets include weekdays and weekend days, these figures do not seem too high. Indeed, if most people stay at home one day out of seven, then one would expect a figure of 14.3 percent no travel days. Therefore, the figures for both waves are around 1 day in 7 with no travel.

In Wave 1, all respondents were asked to carry GPS devices with them for 7 days. Table 6 shows the number of repetitions by tour type for wave 1. As can be seen from Table 6, there are relatively few repetitions of even the simple and complex work tours. There were a small number of people in the data set who provided less than 7 days of data, and they have been excluded from the counts in Table 6. Also, a few provided 8 days of data and have also been excluded. Therefore, all of the counts in Table 6 can be interpreted as the number of repetitions in 7 days. It should be noted that the right hand column is obtained by counting the total number of tours, e.g., for type 1 it is (33*1 + 24*2 + 13*3 + 4*4 + 5*2) = 146. Similarly, the row total is a result of multiplying the number in the body of the table by the number of repetitions.

Table 5: Frequency of Occurrence of Tour Types by Wave

Tour Type	Wave 1		Wave 2		Wave 3	
	Number	Percent	Number	Percent	Number	Percent
1 Simple Work	156	4.7	216	3.5	201	4.4
2 Simple Education	61	1.8	48	0.8	38	0.8
3 Simple Shopping	222	6.7	376	6.0	401	8.8
4 Simple Other	1,207	36.5	1,404	22.6	1,438	31.5
5 Complex Work	205	6.2	367	5.9	271	5.9
6 Complex Education	41	1.2	119	1.9	37	0.8
7 Complex Shopping	417	12.6	1,321	21.3	684	15.0
8 Complex Work and Education	64	1.9	219	3.5	95	2.1
9 Complex Education and Shopping	28	0.8	39	0.6	19	0.4
10 Complex Work and Shopping	0	0.0	0	0.0	0	0.0
11 Complex Work, Education and Shopping	0	0.0	0	0.0	0	0.0
12 Multi-part Other	346	10.5	946	15.2	534	11.7
No Tour	563	17.0	1,160	18.7	846	18.5
Total	3,310	100.0	6,215	100.0	4,564	100.0

Table 6: Repetitions of Tour Types for Respondents in Wave 1

Tour Type	Number of Repetitions								
	1	2	3	4	5	6	7	8+	Total Tours
1 Simple Work	33	24	13	4	2	0	0	0	146
2 Simple Education	18	6	3	4	1	0	0	0	60
3 Simple Shopping	85	36	15	3	0	1	0	0	220
4 Simple Other	48	52	39	39	28	24	12	37	1,180
5 Complex Work	40	26	16	8	6	0	0	0	202
6 Complex Education	21	7	2	0	0	0	0	0	41
7 Complex Shopping	98	50	32	9	7	5	1	0	402
8 Complex Work and Education	26	8	4	1	1	0	0	0	63
9 Complex Education and Shopping	14	1	1	2	0	0	0	0	27
12 Multi-Part Other	80	52	21	13	8	1	0	0	345
TOTAL	463	262	146	83	53	31	15	37	2,686

However, this is only part of the story of repetitiveness. Table 6 shows only which tour types are repeated during the 7 days of recording of GPS data. However, the characteristics of those tours may be quite different from one time to another. To analyse this, we computed for each person the mean and standard deviation of the tour distance, the tour travel time, the activity time in the tour, and the total duration of the tour. We then computed for each person and tour type the coefficient of variation (cv) for those tours that were repeated 3 or more times in the week-long period. If the cv was 0.25 or less, this was considered to indicate little variation in the characteristic from one repetition to another, while if it was greater than 0.75, this was considered to be large variation. The choice of these values is somewhat arbitrary, but is based on the idea that, if the standard deviation in the characteristic is less than one quarter of the mean, then this generally shows a rather small variation from one tour to another. Variations of between one quarter and three-quarters of the mean would seem to be moderate variation, while in excess of three-quarters seems to indicate that there is considerable variation from one repeat to another. Table 7 shows the results of this analysis for those deemed to vary little (i.e., cv of 0.25 or less). As before, the last two columns show the total number of tours involved (i.e., from multiplying the number in the cell by the number of repeats of the tour), whilst all other numbers in the table refer to the number of times that a tour of a specific type had the number of repetitions shown at the head of the column.

Perhaps not too surprisingly, Table 7 shows that when there are several repetitions of a tour, there are very few that are similar on all of distance, travel time, activity time, and total duration. Among those tours that were repeated only three times, there are a reasonably large proportion of close repetitions of at least some of the tour characteristics. There are also more repetitions for both simple and complex work tours and both simple and complex education tours, which is also not unexpected. Overall, however, out of 1,699 tours that were tested on characteristics, only 224 were a close match on distance, 192 on travel time, 182 on total duration, and 63 on activity time. The vast majority of these – 132 on distance, 108 on travel time, 42 on activity time, and 72 on total duration – occurred with only 3 repetitions.

Table 7: Repetitions of Tour Types with Similar Characteristics for Respondents in Wave 1

Tour Type	Characteristic	Number of Repetitions						Total Tours	TOTAL from Table 6
		3	4	5	6	7	8+		
1 Simple Work	Distance	10	0	1	0	1	0	42	65
	Travel Time	8	1	1	0	1	0	40	
	Activity Time	5	0	0	0	0	0	15	
	Tour Duration	6	1	0	0	0	0	22	
2 Simple Education	Distance	2	3	1	0	0	0	23	30
	Travel Time	1	2	0	0	0	0	11	
	Activity Time	2	1	0	0	0	0	10	
	Tour Duration	2	2	1	0	0	0	19	
3 Simple Shopping	Distance	4	1	0	1	0	0	22	63
	Travel Time	2	0	0	0	0	0	6	
	Activity Time	1	0	0	0	0	0	3	
	Tour Duration	1	0	0	0	0	0	3	
4 Simple Other	Distance	6	0	0	0	0	0	18	1,028
	Travel Time	2	5	1	0	1	0	38	
	Activity Time	1	0	0	0	0	0	3	
	Tour Duration	3	4	2	0	1	0	42	
5 Complex Work	Distance	8	3	4	0	0	0	56	110
	Travel Time	7	0	3	0	0	0	36	
	Activity Time	2	3	1	0	0	0	23	
	Tour Duration	5	3	4	0	0	0	47	
6 Complex Education	Distance	2	0	0	0	0	0	6	6
	Travel Time	2	0	0	0	0	0	6	
	Activity Time	1	0	0	0	0	0	3	
	Tour Duration	1	0	0	0	0	0	3	
7 Complex Shopping	Distance	5	0	0	0	0	0	15	204
	Travel Time	7	0	0	0	0	0	21	
	Activity Time	1	0	0	0	0	0	3	
	Tour Duration	5	1	2	0	0	0	29	
8 Complex Work and Education	Distance	1	0	0	0	0	0	3	21
	Travel Time	1	0	0	0	0	0	3	
	Activity Time	1	0	0	0	0	0	3	
	Tour Duration	0	0	1	0	0	0	5	
9 Complex Education and Shopping	Distance	1	0	0	0	0	0	3	11
	Travel Time	1	0	0	0	0	0	3	
	Activity Time	0	0	0	0	0	0	0	
	Tour Duration	0	0	0	0	0	0	0	
12 Multi-Part Other	Distance	5	4	1	0	0	0	36	161
	Travel Time	5	2	2	0	0	0	33	
	Activity Time	0	0	0	0	0	0	0	
	Tour Duration	1	1	1	0	0	0	12	
All Tour Types	Distance	44	11	7	1	1	0	224	1,699
	Travel Time	36	10	6	0	2	0	192	
	Activity Time	14	4	1	0	0	0	63	
	Tour Duration	24	12	11	0	1	0	182	

A similar analysis was performed for the other two waves. The results of the number of repetitions in the second wave are shown in Table 8 in the same format as for Table 6. However, an improvement over the analysis of wave 1 is possible here, because respondents now had a form to complete indicating whether or not they took the GPS device with them for part or all of the day, did not travel at all on that day, or left the device at home. In Table 8, the data are restricted to those that reported that they took the device with them all day. In this table, we have also included all respondents, irrespective of the number of days for which data were recorded. A similar pattern emerges in Table 8 to that observed in Table 6, with the exception that there are now a few more reports of more than 8 repetitions. However, this is not surprising, since Table 6 contained data only from people who carried their devices for 7 days, while Table 8 includes people who carried their devices for up to 15 days. Indeed, what is surprising in Table 8 is that there is not a higher proportion of repeats. For example, there are no repetitions of simple work tours in excess of 7, and complex work tours are repeated only up to 5 times. A closer examination of the data (not shown in any of the Tables in this paper) reveals that those who carried the device for 7 days had no more than 6 repetitions of simple work tours, and that 1 of the repetitions of 6 simple work tours and the one repetition of 7 were both from 15-day respondents.

Table 8: Repetitions of Tour Types for Respondents in Wave 2

Tour Type	Number of Repetitions								
	1	2	3	4	5	6	7	8+	Total Tours
1 Simple Work	55	23	9	8	2	2	1	0	189
2 Simple Education	13	3	1	1	1	0	1	0	38
3 Simple Shopping	71	45	12	5	1	0	0	0	222
4 Simple Other	90	69	28	19	19	8	6	31	947
5 Complex Work	43	28	16	13	14	6	1	1	321
6 Complex Education	11	10	2	4	3	1	3	1	104
7 Complex Shopping	89	73	56	39	26	28	8	7	979
8 Complex Work and Education	30	17	4	9	4	4	3	0	177
9 Complex Education and Shopping	7	3	5	0	0	0	0	0	28
12 Multi-Part Other	110	81	38	22	15	8	0	9	680
TOTAL	519	352	171	120	85	57	23	50	3,685

Table 9 shows a similar reporting of the number of times that tours repeated 3 or more times in the period also had very similar coefficients of variation on each of the four characteristic variables of tour distance, tour travel time, tour activity time, and tour duration. As can be seen from Table 9, the results are very similar to those in Table 7. In looking at both Tables 7 and 9, it should be kept in mind that, if travel was as repetitive as it is assumed to be, then most tour types should be repeated at least 5 times in Table 7 and there should be repeats of up to 10 times in Table 9. In fact, only Tour Type 12 has a repeat of as many as 10 times in Table 9, and no tour types do in Table 7.

Although not documented here, wave 3 showed very similar results. Thus, these three waves, which were shown earlier in Table 3 to represent a reasonably unbiased sample of the population of Western Adelaide1, present some very interesting evidence about the repetitiveness of travel behaviour. Overall, one can conclude that repetitiveness through the week is generally limited to two or three times at most and that tour patterns that occur only once or twice in a period of a week account for around one-third of all tours. Second, among tour types that are repeated, most do not have similar characteristics. Among tour types that are repeated three or more times in a week, simple work tours show by far the highest (as might be expected) similarity on travel distance and travel time, but tend not to be very similar on activity time or overall duration (the latter following naturally from the former). From the wave 1 data, about 65 percent of simple work tours were similar on distance and time, while in wave 2, almost 80 percent were similar on distance, but 55 percent on travel time. In the wave 1 data, a similar result appeared for simple education tours, with 77 percent being similar on distance, although only 37 percent were on travel time. In wave 2, however, less than 50 percent of simple education tours were similar and the majority of

1 By reasonably unbiased, it should be noted that the biases are generally very similar to those in most household travel surveys, i.e., towards car owning households, and away from one-person households.

simple education tours were not repeated. No other tour type in wave 1 or wave 2 approached 50 percent repetitive characteristics.

Looking at the overall statistics across all tour types, tour distance is again the characteristic that shows similarity the most, but only 13 percent of wave 1 and 19 percent of wave 2 show similar travel distance, while the other characteristics are repeated less often (travel time at 11 and 18 percent; activity time at 4 and 9 percent; and tour duration at 11 and 18 percent). All of these percentages are based on just the number of tours that occur at least three times. If the number of tours that occur only once or twice are added, then the percentages drop quite dramatically, as shown in Table 10. On an overall basis, Table 10 shows that less than 12 percent of tours appear to be repeated, based on any of the attributes used here.

Table 9: Repetitions of Tour Types with Similar Characteristics for Respondents in Wave 2

Tour Type	Characteristic	Number of Repetitions						Total Tours	TOTAL from Table 8
		3	4	5	6	7	8+		
1 Simple Work	Distance	6	7	1	2	1	0	70	88
	Travel Time	4	6	1	0	1	0	48	
	Activity Time	4	0	0	0	0	0	12	
	Tour Duration	5	2	0	0	0	0	23	
2 Simple Education	Distance	1	0	1	0	0	0	8	19
	Travel Time	1	0	1	0	0	0	8	
	Activity Time	1	1	0	0	0	0	7	
	Tour Duration	1	1	0	0	0	0	7	
3 Simple Shopping	Distance	7	0	0	0	0	0	21	61
	Travel Time	7	0	0	0	0	0	21	
	Activity Time	1	0	0	0	0	0	3	
	Tour Duration	4	0	0	0	0	0	12	
4 Simple Other	Distance	6	4	0	0	0	1	42	719
	Travel Time	6	3	1	0	0	0	35	
	Activity Time	1	0	0	0	0	0	3	
	Tour Duration	1	3	0	0	0	0	15	
5 Complex Work	Distance	8	8	5	3	0	1	107	222
	Travel Time	6	7	5	3	0	1	97	
	Activity Time	2	3	4	2	0	0	50	
	Tour Duration	7	6	8	3	0	0	103	
6 Complex Education	Distance	1	1	0	1	1	1	29	73
	Travel Time	1	1	0	1	1	0	21	
	Activity Time	0	1	0	1	0	0	10	
	Tour Duration	1	3	1	1	0	0	26	
7 Complex Shopping	Distance	7	5	2	3	1	0	76	744
	Travel Time	11	8	3	2	2	0	106	
	Activity Time	5	4	2	4	0	0	65	
	Tour Duration	8	4	8	5	1	0	117	
8 Complex Work and Education	Distance	1	5	1	1	0	0	34	113
	Travel Time	1	5	1	1	0	0	34	
	Activity Time	1	4	1	0	0	0	24	
	Tour Duration	2	8	3	0	0	1	61	
9 Complex Education and Shopping	Distance	0	0	0	0	0	0	0	15
	Travel Time	0	0	0	0	0	0	0	
	Activity Time	1	0	0	0	0	0	3	
	Tour Duration	0	0	0	0	0	0	0	
12 Multi-Part Other	Distance	7	5	4	1	0	2	85	408
	Travel Time	8	5	1	1	0	2	71	
	Activity Time	7	4	0	0	0	0	37	
	Tour Duration	6	7	3	0	0	1	71	
All Tour Types	Distance	44	35	14	11	3	5	472	2,462
	Travel Time	45	35	13	8	4	3	440	
	Activity Time	23	17	7	7	0	0	214	
	Tour Duration	35	34	23	9	1	2	435	

Table 10: Rates if Repetitiveness By Tour Type for Waves 1 and 2

Tour Type	Characteristic	Wave 1		Wave 2	
		Percent of 3+ Repeats	Percent of All Tours	Percent of 3+ Repeats	Percent of All Tours
1 Simple Work	Distance	64.6%	28.8%	79.5%	37.0%
	Travel Time	61.5%	27.4%	54.5%	25.4%
	Activity Time	23.1%	10.3%	13.6%	6.3%
	Tour Duration	33.8%	15.1%	26.1%	12.2%
2 Simple Education	Distance	76.7%	38.3%	42.1%	21.1%
	Travel Time	36.7%	18.3%	42.1%	21.1%
	Activity Time	33.3%	16.7%	36.8%	18.4%
	Tour Duration	63.3%	31.7%	36.8%	18.4%
3 Simple Shopping	Distance	34.9%	10.0%	34.4%	9.5%
	Travel Time	9.5%	2.7%	34.4%	9.5%
	Activity Time	4.8%	1.4%	4.9%	1.4%
	Tour Duration	4.8%	1.4%	19.7%	5.4%
4 Simple Other	Distance	1.8%	1.5%	5.8%	4.4%
	Travel Time	3.7%	3.2%	4.9%	3.7%
	Activity Time	0.3%	0.3%	0.4%	0.3%
	Tour Duration	4.1%	3.6%	2.1%	1.6%
5 Complex Work	Distance	50.9%	27.7%	48.2%	33.3%
	Travel Time	32.7%	17.8%	43.7%	30.2%
	Activity Time	20.9%	11.4%	22.5%	15.6%
	Tour Duration	42.7%	23.3%	46.4%	32.1%
6 Complex Education	Distance	100.0%	14.6%	39.7%	27.9%
	Travel Time	100.0%	14.6%	28.8%	20.2%
	Activity Time	50.0%	7.3%	13.7%	9.6%
	Tour Duration	50.0%	7.3%	35.6%	25.0%
7 Complex Shopping	Distance	7.4%	3.7%	10.2%	7.8%
	Travel Time	10.3%	5.2%	14.2%	10.8%
	Activity Time	1.5%	0.7%	8.7%	6.6%
	Tour Duration	14.2%	7.2%	15.7%	12.0%
8 Complex Work and Education	Distance	14.3%	4.8%	30.1%	19.2%
	Travel Time	14.3%	4.8%	30.1%	19.2%
	Activity Time	14.3%	4.8%	21.2%	13.6%
	Tour Duration	23.8%	7.9%	54.0%	34.5%
9 Complex Education and Shopping	Distance	27.3%	11.1%	0.0%	0.0%
	Travel Time	27.3%	11.1%	0.0%	0.0%
	Activity Time	0.0%	0.0%	20.0%	10.7%
	Tour Duration	0.0%	0.0%	0.0%	0.0%
12 Multi-Part Other	Distance	22.4%	10.4%	20.8%	12.5%
	Travel Time	20.5%	9.6%	17.4%	10.4%
	Activity Time	0.0%	0.0%	9.1%	5.4%
	Tour Duration	7.5%	3.5%	17.4%	10.4%
All Tour Types	Distance	13.2%	8.3%	19.2%	12.8%
	Travel Time	11.3%	7.1%	17.9%	11.9%
	Activity Time	3.7%	2.3%	8.7%	5.8%
	Tour Duration	10.7%	6.8%	17.7%	11.8%

CONCLUSIONS

The conclusions to be drawn from this analysis are several. The repetitiveness that underlies all travel demand modelling that is done in current practice, is clearly not present when one looks at evidence from GPS collected data on people's travel patterns. These are the most objective data that have ever been available for assessing travel patterns and repetitiveness, since standard household travel surveys rely on self-reporting, even in those instances where multi-day data have been collected. While certain travel patterns, in terms of the purposes of a series of trips, are repeated with moderate frequency, repetition on a daily basis throughout the week does not happen. Even where a trip pattern, as evidenced by the same tour type, occurs several times in a week, the attributes that are often used in travel demand modelling, are rarely repeated to any degree of closeness. Only simple work tours (a trip from home to work and then back from work to home) and simple education tours (a trip to a place of education and back to home again) show some relatively high degree of repetitiveness in distance and travel time. However, even these tours show quite low levels of repetitiveness of activity time and total duration of the tour.

For trip modelling, there is somewhat more repetitiveness for travel time than there is for activity time and total tour duration, although none of these are as strongly repetitive as would be expected for modelling from one-day data to be statistically sound. For activity modelling, the repetitiveness is clearly much less than that for trip modelling, especially when one looks at the very low levels of repetitiveness of activity duration and, as a result, the total duration of the tour. As a broad conclusion, it must be stated, therefore, that the underlying assumption that travel is repetitive from day to day is demonstrated in these data as being highly suspect. If results of this type are found to be generally true from a variety of other urbanised areas, then the assumption that one day of data from households is all that is required to model their travel behaviour is clearly untenable.

Research is now underway to separate weekday and weekend data to explore if there is more repetitiveness on weekdays than on weekends. However, given that one would expect that, if tours were repeated on most weekdays, there would be at least 4 or 5 repetitions in 7-day data and 8 to 10 repetitions in 15-day data, and that repeats of this much are actually very rare in the data, it would not appear likely that segmenting the days will lead to substantially different conclusions. Further, while the research has used the tour as a basis to assess repetitiveness, the lack of repetitiveness of attributes such as distance and travel time are suggestive that even the trips that make up a tour are not repeated frequently.

REFERENCES

Bowman, J. and Ben-Akiva, M. (2001). Activity-based disaggregate travel demand model system with activity schedules, Transportation Research Part A: Policy and Practice, 35(1), 1-28.

Goodwin P.B., R. Kitamura and H. Meurs, (1990). Some principles of dynamic analysis of travel behavior. In: Jones P (ed) Developments in Dynamic and Activity-Based Approaches to Travel Analysis (pp. 56-72). Avebury, Aldershot: Oxford Studies in Transport.

Hensher D.A., N.C. Smith, F.M. Milthorpe, and P.O. Barnard, (1992). Dimensions of Automobile Demand: A Longitudinal Study of Automobile Ownership and Use. Amsterdam: North Holland.

Huff, J.O. and S. Hanson, (1986). Repetition and variability in urban travel. Geographical Analysis, 18 (2), 97–113.

Huff, J.O. and S. Hanson, (1990). Measurement of habitual behavior: examining systematic variability in repetitive travel. In: Jones, P. (Ed.), Developments in Dynamic and Activity-Based Approaches to Travel Analysis. Gower Publishing Co., Aldershot, England, pp. 229–249.

Kitamura, R., (1990). Panel analysis in transportation planning: An overview. Transportation Research 24A (6), 401-415.

Mahmassani, H.S., (1997). Dynamics of commuter behaviour: recent research and continuing challenges. In: Understanding Travel Behavior in an Era of Change, first ed. Pergamon, Elsevier Science, Inc., Tarrytown, NY, pp. 279–313.

O'Fallon, C. And C. Sullivan,(2009). Trends in Trip Chaining and Tours: Analysing Changes in New Zealanders' Travel Patterns Using the Ongoing NZ Household Travel Survey. Wellington, Pinnacle Research & Policy Ltd, Wellington.

Pas, E.I., (1988). Weekly travel-activity behavior. Transportation, 15, 89–109.

Pas, E.I. and F.S. Koppelman, (1987). An examination of the determinants of day-to-day variability in individual’s urban travel behaviour. Transportation, 14, 3–20.

Pas, E. and S. Sundar, (1995). Intrapersonal variability in daily urban travel behaviour: Some additional evidence, Transportation, 22 (2), 135-150.

Schlich, R. (2001). Analyzing intrapersonal variability of travel behavior using the sequence alignment method. Paper presented at the European Transport Conference, Cambridge, September.

Stopher, P.R. and A.H. Meyburg (1975). Urban Transportation Modeling and Planning, D.C. Heath: Lexington Books, Lexington, MA, p. 27.

Stopher, P., K. Kockelman, S.P. Greaves, and E. Clifford (2008). Reducing Burden and Sample Sizes in Multiday Household Travel Surveys, Transportation Research Record 2064, pp. 12-18.

Stopher, P.R., Y. Zhang, J. Zhang, and B. Halling (2009). Results of an Evaluation of TravelSmart in South Australia, paper presented to the 32nd Australasian Transport Research Forum, Auckland, September.

Stopher, P., Q. Jiang, and Y. Zhang (2010). Tour-based Analysis of Multi-Day GPS data, paper submitted to the WCTR Conference, Lisbon, July.