STABILITY OF TRAVEL TIME EXPENDITURES AND BUDGETS – SOME PRELIMINARY FINDINGS

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

ABSTRACT

There has been discussion now for four decades on the issue of whether or not people around the world have a constant travel-time budget. Most of the research into travel-time budgets has used large aggregate data sets and has shown that average amounts of time spent travelling are on the order of 1 to 1½ hours. There have also been a number of studies that have failed to find evidence of constancy in travel-time budgets. In this paper, the authors report on some preliminary research that uses data from a panel of 200 households that provided GPS data for a period of 7 days. In the research to date, the analysis deals only with evidence from one wave of the panel, to determine whether there is evidence over a period of one week of stability in travel-time expenditures. The data set provides very precise times of travel for each person for up to 7 consecutive days of travel. The analysis looks at travel time expenditure on a daily basis per person and then aggregates this to a week.

BACKGROUND

There has been discussion now for four decades on the issue of whether or not people around the world have a constant travel-time budget. There have been many proponents of this concept, especially Szalai (1972), Zahavi (1973,1974), Zahavi and Ryan (1980), Zahavi and Talvitie (1980), Schaefer and Victor (1997), and Schaefer (2000) to name a few. Most of the research into travel-time budgets has used large aggregate data sets and has shown that average amounts of time spent travelling are on the order of 1 to 1½ hours (Downs, 2004). There have also been a number of studies that have failed to find evidence of constancy in travel-time budgets, such as the studies of Kitamura et al. (1992), Purvis (1994), Levinson and Kumar (1995), and Levinson and Wu (2005), among others. Analysis of the US Nationwide Household Travel Surveys between 1983 and 2001 suggested that, if stable travel time budgets exist, then travel-time budgets in the US might be increasing by about 2 minutes per person per year (Toole-Holt et al., 2005). This latter finding does not, however, run in the face of Zahavi's original work, since Zahavi also postulated that while travel-time budgets may be more or less constant across the population at any given time, he also expected that the constant value would change over time.

The policy significance of the notion of a travel time budget is enormous. As Zahavi (1974) suggested, if people have a stable daily travel time budget, then this would suggest that travellers do not 'save' travel time as a result of improvements to the transport system, but that any time saved in one trip would be applied to other or additional travel. In the same way, other policies, such as Voluntary Travel Behaviour Change (Marinelli and Roth, 2002; Taylor and Ampt, 2003), which may lead to time savings over a day, are also likely to result in increased travel for other purposes elsewhere during the day or the week, so that the individual still tends to expend close to their travel time budget. Moreover, additional time spent on travel, e.g., as a result of increasing congestion, would be drawn from and would reduce the time spent in other travel. As pointed out by van Wee, Rietveld, and Meurs (2002), the existence of stable travel time budgets would suggest that none of technological changes, economic growth, nor transport policies will change total travel volumes. They may result in changes in the patterns of travel, but not in the overall total amount of travel. Indeed, one could conclude that, as population continues to grow, the total volume of travel will grow proportionately, irrespective of the technologies for transport, the state of the economy, or the direction of policies. What transport policies and investments would be more likely to do, if stable travel time budgets do exist, would be to shift travel both spatially and temporally, with the probability that some of the shifts would take place between weekdays and weekend days, whilst others may take place within the same day.

Zahavi (1974) also proposed that there is a stable travel cost budget and suggested a simple model of transport, which he developed into the Unified Mechanism of Travel (UMOT) which is based on the simple relationship that:

$$\frac{TCB}{TTB} = v \cdot c$$

where TCB = Travel Cost Budget
TTB = Travel Time Budget
v = average speed of travel
c = cost per unit distance travelled

It would be interesting and useful to explore the extent to which this model is supported by empirical data, especially in the event that data are available over a period of time for the same individuals, so that possible changes in average speed of travel and/or cost per unit distance travelled could be examined to see if there is a constancy in the ratio. Zahavi did not explore at length the impacts on the Travel Cost Budget of changes in the real value of money or in incomes in real terms. However, one could readily deduce that there could be two equally plausible situations. On the one hand, the travel cost budget may be a constant fraction of disposable income, while on the other hand, it may be a fixed amount of money in real terms. In the first case, real changes in income will lead to real changes in the travel cost budget, in direct proportion to the changes in real income. In the second case, real changes in income will not lead to any change in the real travel cost budget and the only changes in the monetary amount of the travel cost budget that would be seen would be those resulting from changes in the value of the monetary unit (i.e., inflation or deflation).

While the travel cost budget issues are clearly of relevance to this overall research, they have not been pursued as yet in the research reported in this paper, but are anticipated for the future. This paper concentrates on the first part of this model – the travel time budget.

BUDGET VERSUS EXPENDITURES

One of the potential difficulties with the notion of travel time and travel cost budgets is how to observe a budget. What one can fairly readily observe is what a person is actually willing to expend. However, whether this expenditure is within or exceeds the desired budget is not likely to be easy to determine. All of the previous empirical work that has been conducted on the question of travel time budgets has, in fact, fallen into the trap of equating observed expenditure with budget. In this respect, those who have analysed travel time budgets using highly aggregate data from various metropolitan areas around the world have probably been more or less correct in the conclusions they have drawn, whilst those who have undertaken more disaggregate analysis of travel time expenditures, but mislabelled them as budgets are more clearly in error.

Suppose that people do, in reality, have travel time budgets. Suppose further that there is variability in the population in the size of the travel time budget, so that some people may have a larger travel time budget and some a smaller one. Because a travel time budget is perhaps a little less critical than a financial budget, it is probably reasonable to suppose that, on some days, a person may exceed their budget, while on other days they will compensate by keeping total travel time expended well below the budget, so that they average out to spending about their actual travel time budget. This would tend to mean that highly aggregate analysis of travel time expenditures would be likely to produce more or less an estimate of the average travel time budget of people. The reason for this is that, in a snapshot of data, there should be a reasonably symmetrical distribution of people exceeding their budgets and people expending significantly below their budgets. Overall, however, the central tendency of the data should be towards spending the budget, and this is what one would expect aggregate statistics to show.

In contrast, even if every person has the same travel time budget as every other person, if day-to-day expenditures of travel time vary around the budget, then a disaggregate analysis of travel time expenditures would lead one to conclude that there is no evidence to support the notion of a constant travel time budget based on examining daily travel time expenditure, because each individual, seen at one point in time only, would be likely to have expended differing amounts of travel time on the day on which each was observed. Thus, a disaggregate analysis of travel time expenditures on one-day data would tend to show that there is no constancy in these travel time expenditures. If, moreover, people have different travel time budgets from one another, then this will add further variability to the data on travel time expenditures, so that a disaggregate analysis of one-day data would depart even further from demonstrating any constancy across the population. Yet, the finding that there is variability in daily travel time expenditures, as clearly outlined here, does not provide any evidence to refute the notion that people have a fixed travel-time budget.

The focus of the current research is on disaggregate analysis of multi-day data. As a result, it must be recognised that each day's data for an individual will show what that individual expended by way of travel time for a given day. There is likely to be variation from day to day in expenditure for the reasons indicated in the previous paragraphs. It is important, therefore, to consider what data are available and how these data might be used to explore the issue of travel time budgets.

REGRESSION TO THE MEAN

One issue that must be addressed before analysing the data is that of regression to the mean. In general, regression to the mean states that, if a first observation of some phenomenon tends to take an extreme value, subsequent measurements will tend to be less extreme and therefore closer to the mean (Galton, 1886; Weisstein, 1999). However, for regression to the mean to hold true, the underlying attribute must be largely the result of random events. Thus, if one were to draw a random sample from a population and measure some attribute of the members of the sample, the running average that would be computed would be expected to move closer and closer to the mean, assuming that this running average were computed after each new sample member was measured. Sampling itself and the science of surveys depend on the fact that increasing the sample size permits one to make estimates of attribute means that become closer to the true population mean.

The question at issue here relates to observations of the amount of time spent in travelling by one individual, when measured repeatedly over a number of consecutive days. If these measurements of time spent travelling are found to fall closer to the mean as the length of time of observation is increased, is this a case of regression to the mean? We would suggest that it is not. The reason for this is that the time spent travelling each day by an individual is not a random event on each day, although it may be subject to random perturbations. Rather, to assume that such a finding is simply a statistical construct of regression to the mean is actually to apply the regression fallacy to the observations (Friedman, 1992). Possibly, the observations on travel-time budgets that have been put forward in the past from highly aggregate data are examples of regression to the mean, in that, if the travel times of a large number of individuals are averaged from random samples, these averages will tend towards some overall mean as a result of the independence of the sample measures and the tendency of regression to the mean. However, if disaggregate data are used to measure time spent in travelling and these measurements are repeated over a period of time, then a different conclusion arises, largely because the amounts of time spent travelling on each day are not independent random quantities.

In the case of repeated measurements of an individual over time, the successive observations of travel time are not a result of random events. Rather, if there is such a thing as a travel time budget, one would assume that, if an individual on the first day of observation happened to have spent much more time on travel than their budget would normally permit, then this individual would attempt, on the next day, to reduce the amount of time spent on travel. If this was again unsuccessful, then on the next and subsequent days, the individual would continue to attempt to make reductions in the amount of time spent travelling. If, on the other hand, the first observation of time spent travelling was much below the individual's budget, then it could be expected that much larger amounts of time might be spent on subsequent days, as the individual attempted to draw closer to his or her budget.

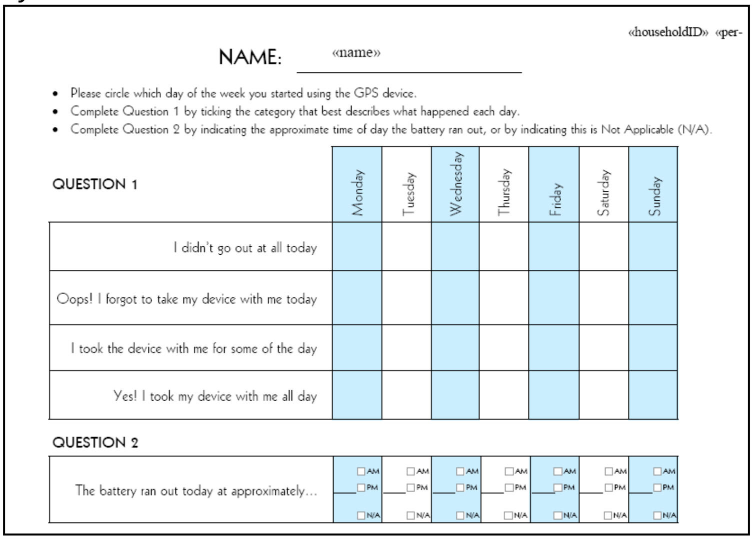
Therefore, the conclusion to be drawn is that a tendency of time spent travelling over a number of days for a specific individual to draw closer to a mean value is a behavioural construct and not a statistical construct. The question may still need to be addressed as to whether time spent travelling by an individual from day to day is entirely random, but once it is established that this is not so, then the conclusion of the preceding sentence holds. This also means that the present research on travel time budgets, which is, for the first time, based on multi-day and time-series data, is more likely to be able to substantiate whether or not a travel time budget actually does exist.

DESCRIPTION OF THE DATA

Over the past four years, ITLS has collected a large amount of data from households using Global Positioning System (GPS) devices to provide detailed and precise measurement of travel and activities. The GPS data in ITLS's possession offers a new opportunity to explore the concept of a travel-time budget, by looking at the totality of individual and household travel over a period of a week or longer, and to determine if there is evidence to support the hypothesis of a constant travel time budget, where the constancy may be established over a period such as a week or longer. Almost without exception, prior work on travel-time budgets has focussed on analysis of one-day data, whether at the aggregate or disaggregate level. Herein, possibly, lies the difference between aggregate region-wide studies that tend to support the notion of a travel-time budget and more disaggregate studies which tend to cast doubt on the concept. Possibly, the truth is that people have an average travel-time budget, but on a day-by-day basis, they may exceed their budget or travel for much less than their budget. This is clearly more likely, given that it is also known that most people do not travel at all on at least about one or two days per week.

The GPS survey conducted by ITLS involved all household members over the age of 14 carrying a personal passive GPS data logger for a period of seven days (or 15 or 28 days for a small sub-sample) to record all their travel. In addition to carrying the GPS devices, household members were asked to charge the device overnight every night and whenever else possible and to wait for the device to indicate that it had obtained a GPS signal before beginning a trip, whenever possible. In this paper, the authors report on some preliminary research that uses data from a panel of 50 households that provided GPS data for a period of 28 days. Furthermore, part of the 7-day survey and 15-day survey analysis results are also included here to provide further data support to supplement the accuracy of the GPS data collected in 28 days. Please note, in the rest of the paper, the 7-day survey panel is also called the ‘Main’ sample because it is the main panel for this GPS survey, and the 15-day and 28-day panels are called the ‘Add-on’ samples because they were an add-on from another project. In the research to date, the analysis deals only with evidence from one wave of the Add-on panel, to determine whether there is evidence over a period of one week, or more than one week, of stability in travel-time expenditures. While this is a small data set, it provides data on very precise times of travel for 79 persons for up to 28 consecutive days of travel. In fact, 60 individuals provided data on an average of 6 or more days per week for an entire 28-day period. The analysis looks at travel time expenditure on a daily basis per person and then aggregates this to a week and estimates the weekly average by person for weeks 1, 2, 3, and 4, and also combines weeks to determine if greater stability appears as the time period becomes longer.

One of the problems with the analysis of GPS data, however, is that there exists some doubt as to when sampled respondents did or did not travel at all. The GPS data will have certain days on which no travel is recorded. However, it is uncertain whether such days of no travel data are a result of the person not travelling anywhere on that day, of the device not being charged and therefore not recording any travel that day, or of the person forgetting to take the device with them. In subsequent data collection, ITLS has devised a short ‘GPS Status’ form on which people are asked to fill out what happened on each day of the survey with respect to the GPS device. For example, they can indicate that the device was carried all day, that the device appeared to run out of power by a certain time in the day, that the device was not carried for all or part of the day, or that the person did not travel that day. There is, of course, no validation check on such data. It is necessary to take the word of the respondent as being the best measure of truth in this case. An example of this ‘GPS Status’ form for a one-week survey is shown in Figure 1. ITLS has also developed versions of this for 15-day surveys although none were used with the 28-day surveys that were carried out by ITLS.



«householdID» «per-

NAME: «name»

- Please circle which day of the week you started using the GPS device.
- Complete Question 1 by ticking the category that best describes what happened each day.
- Complete Question 2 by indicating the approximate time of day the battery ran out, or by indicating this is Not Applicable (N/A).

QUESTION 1	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
I didn't go out at all today							
Oops! I forgot to take my device with me today							
I took the device with me for some of the day							
Yes! I took my device with me all day							

QUESTION 2							
The battery ran out today at approximately…	☐AM ☐PM ☐N/A	☐AM ☐PM ☐N/A	☐AM ☐PM ☐N/A	☐AM ☐PM ☐N/A	☐AM ☐PM ☐N/A	☐AM ☐PM ☐N/A	☐AM ☐PM ☐N/A

Figure 1: 'GPS Status' Form for a One-Week Survey

In the balance of this paper, we report on analysis of the results of this status card from both 7-day and 15-day data collection and then suggest ways to apply these results to a 28-day survey. Conclusions are also drawn as to the validity of what people report on these forms. Second, using the analysis results from the GPS Status form, we examine the evidence for travel time budgets from the 28-day data set.

ANALYSIS OF THE GPS STATUS FORM FOR 7-DAY AND 15-DAY DATA

There are four sets of data available for analysing the responses to the GPS Status form: two waves for a panel of about 45 households who carried devices for 15 days, and two waves for a panel of about 160 households who carried devices for 7 days. Results from these four panel waves are summarised in Table 1.

Table 1: Results of GPS Status Form for Four Panel Waves

Status	Wave 2 (7-day)	Wave 3 (7-day)	Wave 3 (15-day)	Wave 4 (15-day)	Average
Percent Stayed Home	9.8	9.2	10.9	11.2	10.3
Percent Forgot Device	6.3	3.5	6.6	2.4	4.7
Percent Took Device for Part Day	11.8	13.4	16.1	14.4	13.9
Percent Took Device for Whole Day	72.0	73.9	66.5	72.0	71.1
Number Person Days Reporting Status	3718	2055	791	250	N/A
Number Missing	1392 (27.2%)	241 (10.5%)	499 (38.7%)	185 (42.5%)	N/A
Total Sample Person Days	5110	2296	1290	435	N/A

The percentages in the first four rows of Table 1 relate to those completing the status form and therefore correct for differences in the proportions who completed the form from one wave to another. Table 1 shows that about 27 percent of respondents failed to complete the status form for the 7-day survey, whilst this increased to around 38 percent for the 15-day survey. Apart from this difference in response rate, the percentages for each status are remarkably similar between the four panel waves. They suggest that about 10 to 12 percent of people stayed home all day on any particular day, that around 6 percent (remarkably dropping to just over 2 percent for Wave 4 15-day data) forgot to take the device on a particular day (average of 4.7 percent), and that almost 14 percent took the device for part of the day. On average, about 71.1 percent of respondents who completed the form took the device for the entire day.

Madre et al. (2003) suggest that average non-mobility should be in the range of 8-15 percent, based on an analysis of about 400 travel surveys from around the world. The NHTS of 2001 (Stopher et al., 2008) showed 11.8 percent of person days being days with no travel. This latter is more directly comparable, because it is a survey that, like the panel waves used for the analysis of Table 1, covered both weekdays and weekend days. Therefore, comparing the number of days that people reported not travelling on the GPS Status form in the GPS surveys to the results of these other studies, it can be concluded that respondents to the GPS surveys have been at least equally as accurate in reporting this statistic as in the other travel surveys that have been reported in the literature, so that it can be assumed that about 11 percent of person days are no travel days (from the literature and the average of 10.3 percent in Table 1). On this basis, it also seems reasonable to conclude that about 5 percent of person days (4.7 percent in Table 1) are likely to be days on which the device was left at home, and that about 13 percent of days (13.9 percent in Table 1) will have incomplete travel reported.

If these statistics are to be applied to the 28-day panel, where a GPS Status form was not used, it is necessary to undertake further analysis. One would expect, from the above, that about 16 percent of possible travel days would be missing, with approximately one-third of these being days when the respondent left the device at home and two-thirds being genuine no travel days. However, a more in-depth analysis of the data shows that the completion of the status card does not always seem to correspond to what was measured by GPS. There are instances where a respondent indicated that he or she stayed at home all day, and yet the GPS has measured trips for that day. Similarly, this occurs also for some proportion of days when the GPS was supposedly left at home. On the other hand, there are a number of instances where the respondent reported taking the device for part or all of the day, but the GPS reported no travel. It seems quite plausible to assume that, when a respondent indicated either that they had taken the device with them all day or that they had taken it with them for part of the day, and no trips were recorded on the device, in fact this should have been reported as a day of no travel. For example, if a respondent filled out the status card at the end of the week, he or she might no longer recall whether or not he or she went out each day, but just recalls that he or she did not leave the device at home on any day that he or she travelled and therefore fill out the status card as having taken the device with them every day.

In the case of the Wave 3 Panel with the Add-on Wave 4 combined (these two waves were conducted at the same time of the year in the same geographic area but with different households), the results of the comparison of the status card with the number of trips recorded on the GPS device is shown in Table 2.

Table 2: Number of Trips Recorded by GPS versus Device Status Report

Number of Trips	Device Status					
	Stayed Home All Day	**Left Device at Home**	**Took Device for Part of Day**	**Took Device for Entire Day**	**Missing**	Total
0	189	64	50	129	137	569
1-5	20	11	192	978	196	1397
6-10	7	3	61	484	74	629
11-15	2	0	5	86	15	108
16-20	0	0	2	20	3	25
21 and over	0	0	1	1	1	3
Total	218	78	311	1698	426	2731

Looking at the overall distribution of numbers of trips by day and comparing these to the same distribution for Add-on Wave 2, for which the status card was not used, a chi-square test showed no significant difference in the distributions. These distributions are shown in Figure 2. Based on the lack of significant difference, the status card results from Main Wave 3 (plus add-on wave 4) can be assumed to be applicable to Add-on Wave 2 data, to determine the proportion of days with no travel recorded that might be genuine no travel days and the proportion that represent such things as forgetting to take the GPS device with the respondent. Two other distributions of interest are the distribution of the numbers of trips for those with status card missing versus the overall distribution for Wave 3 (plus add-on Wave 4) and the distribution of those with status card missing and the Add-on Wave 2 respondents. Again, neither of these distributions was significantly different from the one against which it was compared.

These results suggest two possibilities. First, the lack of a significant difference between the status card missing and the overall distribution for the augmented wave 3 data suggests that the data from this group can be assumed to be similar to those who completed the status card. This is helpful, because it allows an adjustment to be made on the zero trip counts among the different device status codes. Looking at the first four columns of Table 2, this suggests that the 137 respondent days with no trips and with the status code missing could be apportioned according to the distribution across the four status codes. I.e., it can be assumed that 43.7 percent genuinely stayed at home (status 1), that 14.8 percent left the device at home, 11.6 percent took the device for part of the day but would have recorded no trips, and that 29.9 percent claimed to have taken the device with them all day but recorded no trips. Assuming that only status 1 and 4 represent genuine no travel days, then it could be assumed that 73.6 percent of the 137 trips with missing status are genuine no travel days. Adding those 101 trips to the 189 with status 1 and 129 with status 4 leads to the assumption that 419 of the 569 days with no travel recorded represent genuine no travel days.

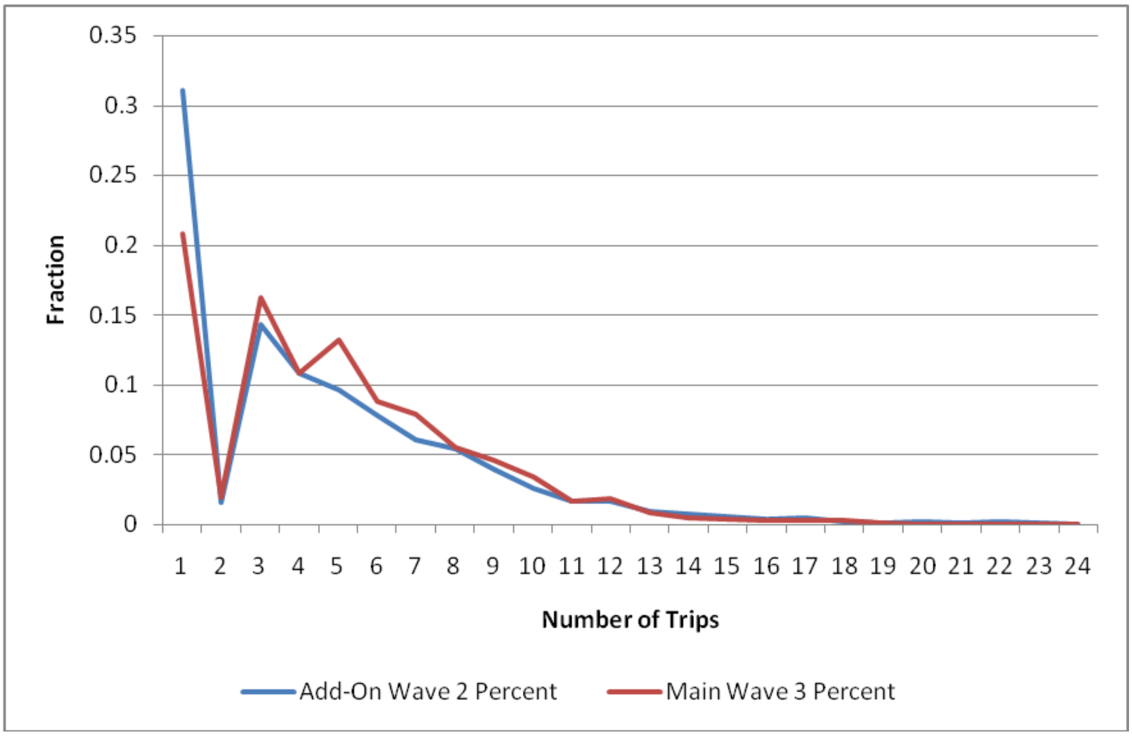


Figure 2: Comparison of Add-on Wave 2 and Main Wave 3 Distributions of Numbers of Trips

Second, this also suggests that, for Add-on Wave 2, the same proportion of no travel days can be assumed to be applicable to the number of person days with no travel. Thus, of the 676 person days with no trips appearing, it can be assumed that 497 represent genuine no travel days and should be factored into the averages of travel time per day, whilst the remaining 179 person days with no travel recorded must be assumed to be missing data. This is helpful for aggregate analysis of Add-on Wave 2 data but requires further assumptions to be made for any disaggregate analysis. In the latter case, it will be necessary to assume that specific days of no travel within each person's record is either genuine or not. This presents a rather more 'heroic' assumption than the aggregate assumptions and suggests that refinement, if possible, should be made. To refine this analysis, the augmented Wave 3 data were examined in more detail to determine the frequency with which non-genuine no travel days arose in relation to the total number of no travel days by person. In other words, this amounts to the assumption that people tend either to take their GPS devices with them most or all of the time, or that they are sloppy about the survey task and may forget to take their device more often.

After extensive analysis of the no travel days and the device status from Wave 3, assumptions were made for the Add-on Wave 2 data. We decided that it would not be reasonably possible to separate those days for which we have GPS data into partial and complete days. Hence, status 3 was assumed not to occur in the Add-on Wave 2 data; it was assumed that, if the device was left at home part of the day, it was left at home for the entire day, so code 2 would be appropriate. Therefore, if GPS data were present in Add-on Wave 2, a simulated code of 4 was assigned to each day. It was then necessary to divide those days for which no trips were recorded between code 1 and code 2. This is important because code 1 would count as a valid day of no travel, whereas code 2 would be interpreted as a missing value for travel and would have to be omitted from the calculation of travel-time budgets.

Several analyses were undertaken and attempts were made to develop some type of a model to assign the status code, but the modelling effort was not successful. In the end, the decision that was made was to use a series of steps to assign the appropriate device code. From an analysis of Wave 3, it was found that people were much more likely not to travel all day on Sundays, followed by Saturdays and then Mondays. This is shown in Table 3.

Table 3: Distribution of No Travel and Device Left at Home by Day of Week – Wave 3

Day of the Week	Stayed Home All Day	Left Device at Home	Total
Sunday	60	9	69
Monday	31	8	39
Tuesday	20	15	35
Wednesday	18	14	32
Thursday	21	6	27
Friday	20	11	31
Saturday	48	15	63
TOTAL	218	78	296

An examination of the data also showed that it was more likely that a single day of no travel in the data was a day on which the person had not gone out all day, whereas when there were several consecutive days of apparent no travel, this was more likely to be a case of forgetting to take the device along. Therefore, a combination of steps were taken in which the status was more likely to be 1 on Saturday, Sunday, and Monday, and was more likely to be 2 if there was a block of days of no travel, or if the days were in the middle of the week. This process resulted in 457 of the 676 no travel days being assigned a code of 1, for a genuine no travel day, and 219 being assigned a code of 2, indicating that the data were simply missing. These numbers provide a slightly higher proportion of missing data than the Wave 3 data suggested, which was felt to be appropriate, given that Add-on Wave 2 involved a 28-day GPS task, which is considerably longer than the 7 and 15 days in Wave 3.

ANALYSIS OF TRAVEL TIME EXPENDITURES AND BUDGETS

Analysing the data from Add-on Wave 2, which provides about 28 days of GPS data for each of 72 individuals, it is possible to examine the evidence that may be available for travel time budgets. Overall, aggregating the GPS data to each person day, the mean time spent travelling by these 72 persons is 53.6 minutes per day, which is a bit lower than the supposed average of about 60 to 75 minutes, but is certainly within the expectations from prior work on travel time budgets and expenditure. This value, however, is very much subject to assumptions about genuine and non-genuine travel days. If a larger proportion of days for which no travel was recorded are assumed to be a result of not taking the GPS device, then this value would increase. At the person level, the lowest average amount of travel time spent on a day is 13.91 minutes, and the largest average amount of time spent is 137.3 minutes. The standard deviation of the average time per person is 27.26 minutes, which is quite small. Figure 3 shows the distribution of average travel time expenditures per day for the 72 persons who provided useable data.

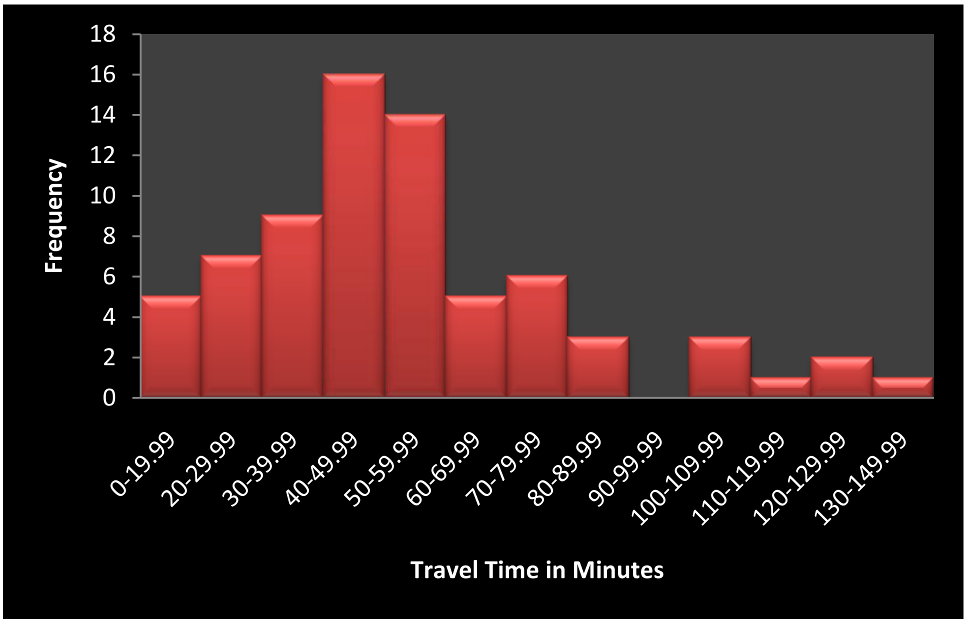


Figure 3: Distribution of Average Daily Travel Time Expenditures

In this chart, it is rather clear that the mode of this distribution is for 40 to 49.99 minutes and 50 to 59.99 minutes has the second highest frequency of occurrence. The median is also in the 40-49.99 minutes category. Figure 4 shows the distribution of daily travel expenditures for this sample. The result is, as expected, quite different from the mean plot shown in Figure 3. The mean is very close to the division between the fourth category (40 to 49.99 minutes) and the fifth category (50 to 59.99 minutes).

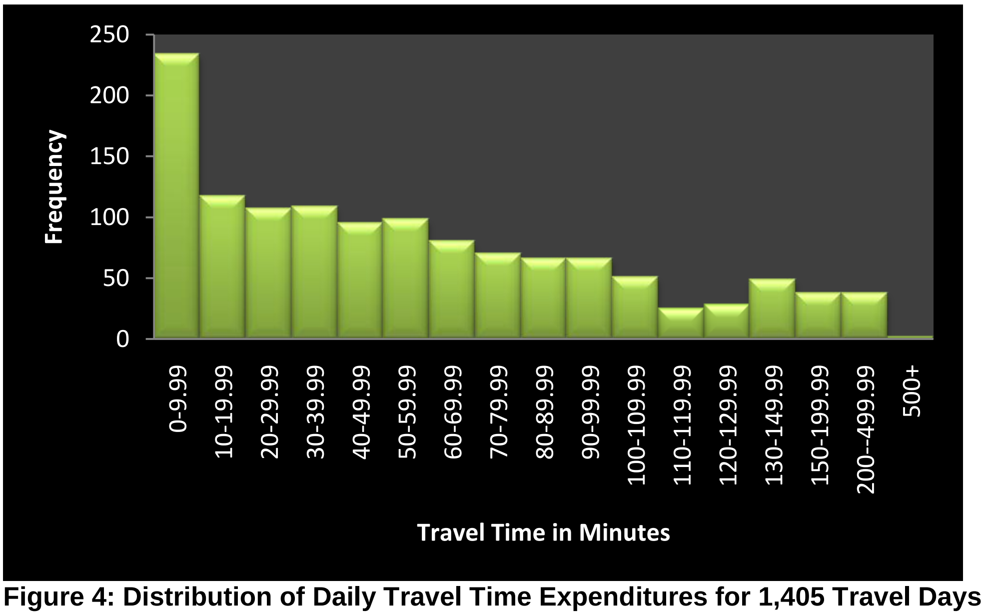


Figure 4: Distribution of Daily Travel Time Expenditures for 1,405 Travel Days

In this case, the mean value is over 60 minutes and is determined from just those days on which travel took place (the no-travel days were omitted from this graph to allow the scale to be of reasonable size, since there are over 400 no travel days). The travel times have been grouped identically to the previous exercise, except that there are now 16 categories, because individual days of travel include values up to over 700 minutes.

Because most prior work on travel-time budgets has concerned weekday travel only, the next two figures, Figure 5 and Figure 6, exclude weekend days. In this case, the overall average time spent travelling per day is 60.8 minutes, showing, as expected, the larger value for weekdays as opposed to all days. Figure 5 shows that the distribution over all persons and weekdays is less peaked than for all days (Figure 3).

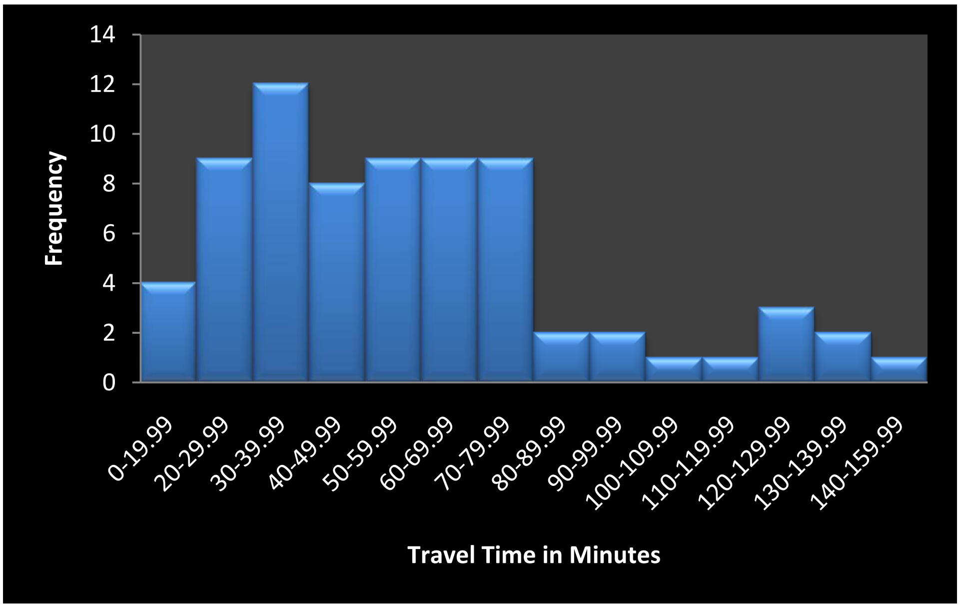


Figure 5: Distribution of Average Daily Time Expenditures for Weekdays Only

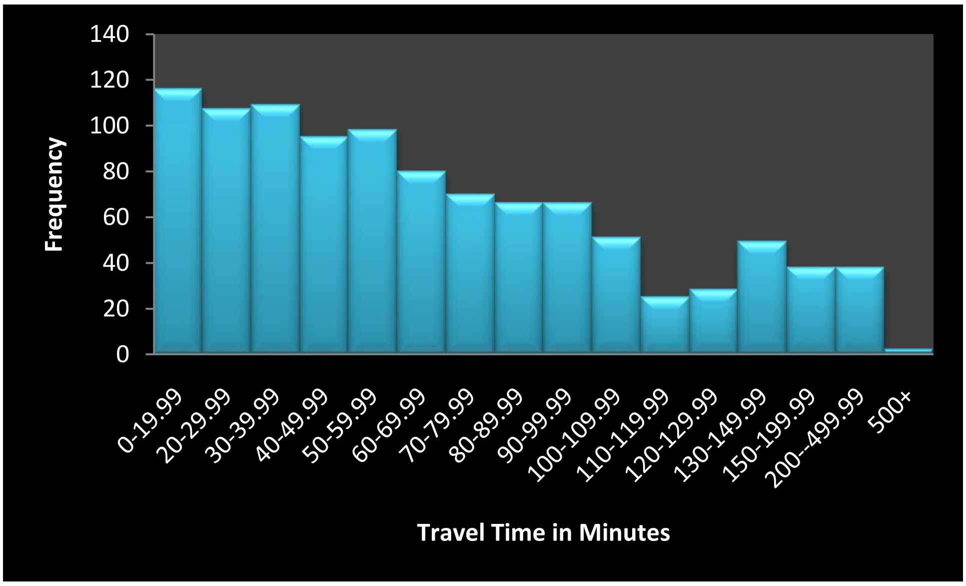


Figure 6: Distribution of Daily Travel Time Expenditures for 1,045 Weekday Travel Days

From Figure 5, the mode has shifted downwards to the category of 30-39.99 minutes, but the mean has shifted up to the 50 to 59.99 minute category. Figure 6 shows a distribution that is much more similar to Figure 4 and the mean has increased only slightly from all days to weekdays.

In considering the four figures shown here, it is apparent that the averaging of travel times over the four weeks of observation tends to produce a distribution that would be consistent with an approximate budget, whereas the distributions of the individual daily travel expenditures appear to be just that – a distribution of expenditures that gives very little clue to the budget. However, to pursue this notion further, it seems appropriate to see what happens if the data are averaged by week, by two-week period, or even by three-week period, to try to see whether this idea that averaging over some period of time seems to reflect a budget rather than the individual expenditures, and to get an idea over what time the averaging needs to take place to reflect the budget. This notion of averaging to produce a budget is based on the idea that, if an individual has a real fixed budget, then on a day-to-day basis, the individual may sometimes overspend and sometimes underspend their budget. However, if the budget is real, then over some period of time, the actual expenditures should average out to the budget, or to some percentage under the budget if the individual is in a situation in which it is possible to achieve their desired activities without expending all of the budget. For this exploration, and in keeping with prior work that has generally been based on weekday travel only, weekend days are excluded from the analysis. There is also some potential that the weekends may be more variable, because of the discretionary nature of most weekend travel, so that inclusion of weekend days may make it more difficult to reach a stable average within the four weeks of data available.

Figures 7, 8, and 9 show the mean travel times by week for the 72 individuals in the data set. What is apparent in these three graphs is that there is still some marked variability from week to week in the travel time expenditures.

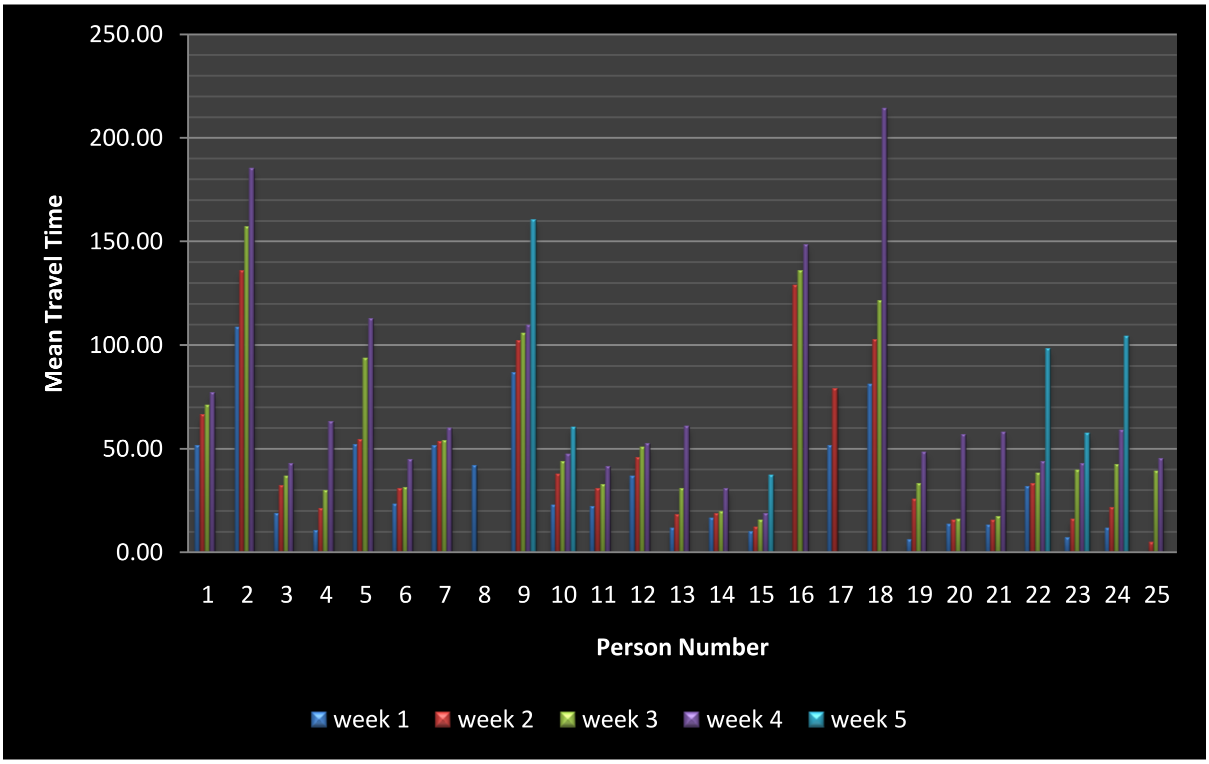


Figure 7: Week by Week Variation in Average Travel Time Expenditure (First Third of Data)

However, there is also a clear indication that, for many respondents, the average amount of time spent daily on weekday travel looks fairly constant. It is also interesting to note that the weekly averages are generally approaching somewhere around 60 minutes or so.

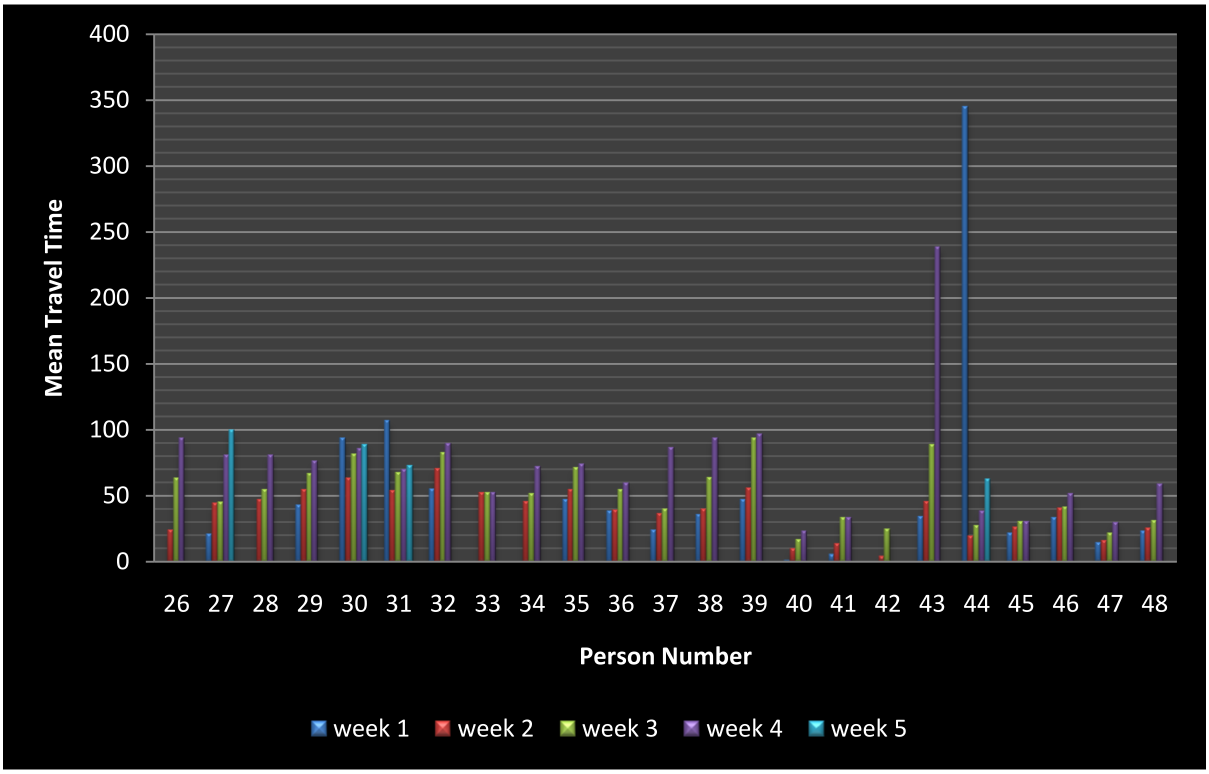


Figure 8: Week by Week Variation in Average Travel Time Expenditure (Second Third of Data)

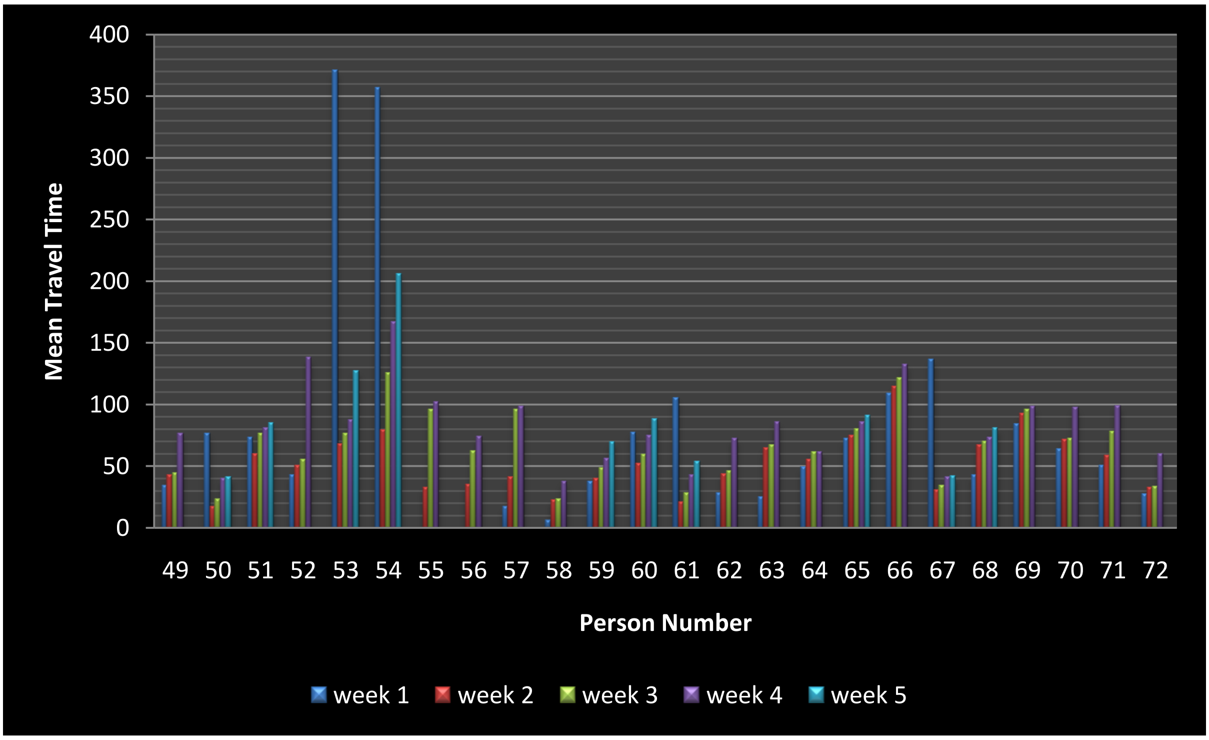


Figure 9: Week by Week Variation in Average Travel Time Expenditure (Last Third of Data)

In the next step of the analysis, averages were obtained for successive two-week periods, i.e., for weeks 1 and 2, weeks 2 and 3, and weeks 3 and 4. The results in terms of the daily average travel time on weekdays for the 72 respondents are shown in Figures 10, 11, and 12.

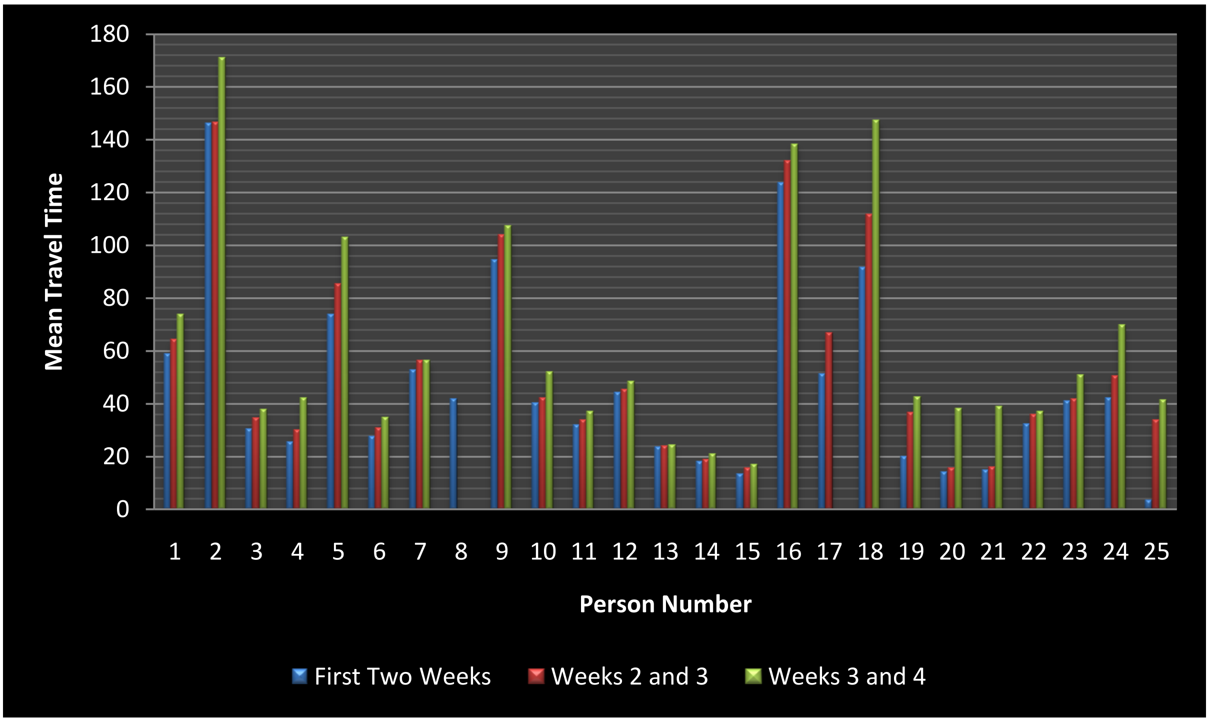


Figure 10: Average Daily Travel Time Expenditure Averaged Over Two Weeks (First Third of Data)

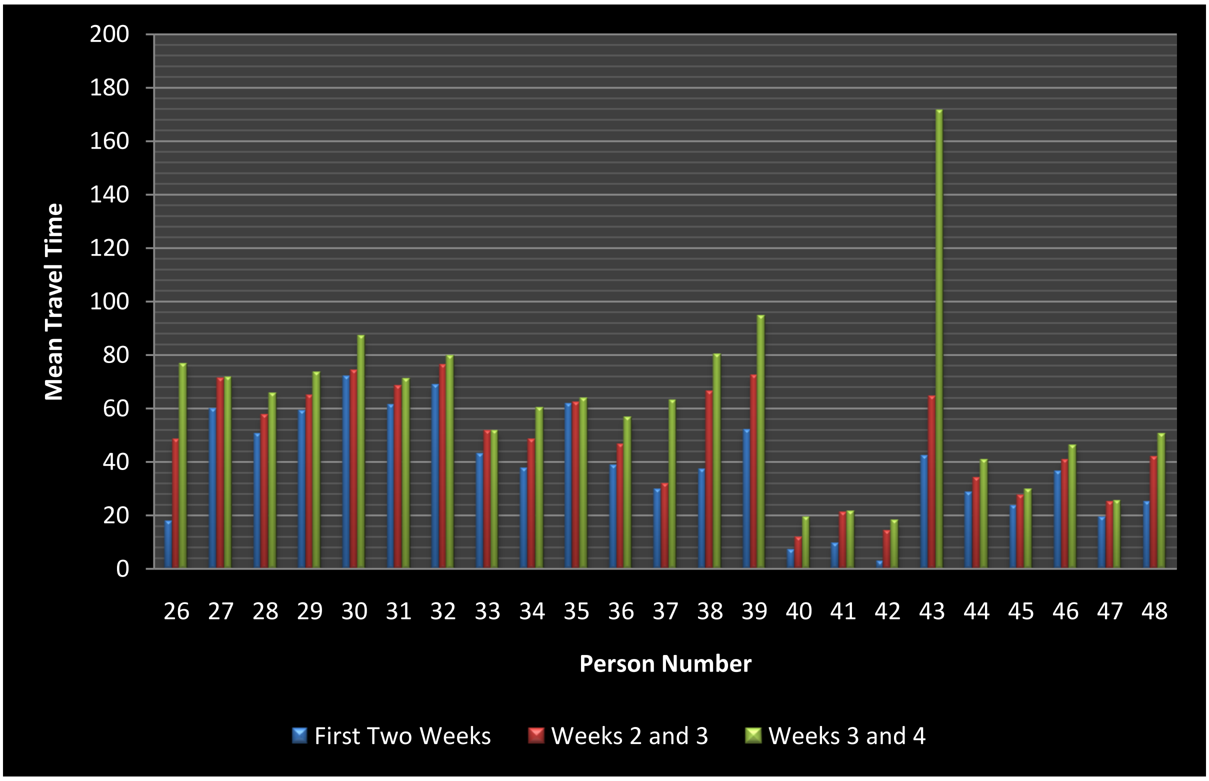


Figure 11: Average Daily Travel Time Expenditure Averaged Over Two Weeks (Second Third of Data)

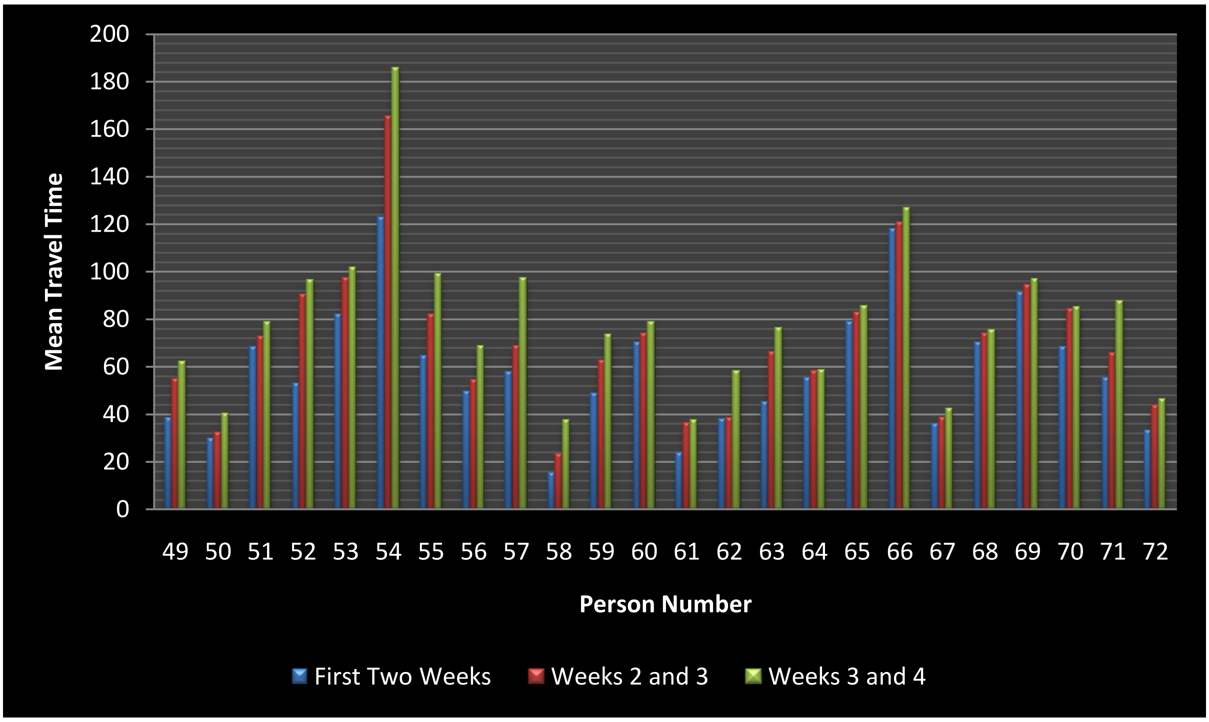


Figure 12: Average Daily Travel Time Expenditure Averaged Over Two Weeks (Last Third of Data)

Figures 10 through 12 show much more consistency from fortnight to fortnight in the daily averages of travel time expenditures, suggesting that two weeks may be a sufficient length of time to observe to obtain relatively stable estimates of average daily travel time expenditures, which may, in turn, approximate a travel time budget for most people. There are probably no more than about eight or ten individuals who show a marked variation in the average travel times, which represents about 10 percent of the data. In other words, for about 90 percent of respondents, a two week average of daily weekday travel time seems to stabilise over the period of observation for this data set. For this grouping of data, the average daily travel time is about 57.5 minutes. The standard deviation of the mean is about 33.3 minutes. As can be seen from Figures 10 through 12, there are a few individuals who average a travel time expenditure of over 100 minutes, while there are also a few who average less than 20 minutes.

CONCLUSIONS

While the analysis reported in this paper is rather preliminary in nature, it does suggest some initial conclusions and suggests some directions for further research. Among the conclusions that are suggested by this research, the concept of a constant travel time budget appears to be well worth exploring further, especially using the more precise data available from GPS measurement. Certainly, the aggregation of the GPS data continues to provide evidence of an overall average of daily travel time expenditure of somewhere close to one hour per day. Second, the analysis reported here also suggests that one week of data may not be sufficient to estimate an individual's travel time budget, but that two weeks of data may be sufficient in most cases. There is still evidence that even a two-week average will, in about 10 percent of cases, provide a misleading value of the average daily travel time expenditure. Third, the analysis suggests that averaging daily travel time expenditures over two or more weeks may be a feasible way of measuring an apparent travel-time budget.

In terms of further work, the first and clearest issue to emerge from this analysis is that, with GPS measurement, it is critical to determine on which days respondents do not leave home, and on which days they leave home but forget to take the GPS device with them. Without more accurate data on which days for which no travel is recorded by the GPS are genuine no-travel days, an accurate average travel time expenditure cannot be determined. As a result of the analyses performed for this research, we have already surfaced the need to redesign the form that asks people to report the status of their use of a GPS device on each day of the survey. Second, it would be useful to explore larger data sets than the one used in this research and then to include analysis of the demographics of the respondents to determine differences, for example, between workers and those not employed, as well as other categories, such as gender differences and life cycle differences. For this research, the data set was too small to permit such analysis to be undertaken with any statistical confidence. Third, it may also be useful to look at averaging over three weeks, to see the extent to which this may introduce further stability in estimates. The research documented in this paper and the research that is yet needed has considerable potential impact on transport policy, as discussed in the opening of this paper. The existence of stable travel-time budgets would suggest that different policies and strategies are needed, if the intent is to reduce use of the car and encourage and increase use of public transport and active transport modes. These policies and strategies would need to be formulated with the idea in mind that people have a fixed amount of time that they are willing to travel and expectations about how far they can travel, so that substitution of other alternatives to the car will need to allow similar or greater distances to be covered.

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