THE TEMPORAL VARIABILITY OF PUBLIC TRANSPORT USAGE

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1. BACKGROUND

Before and After surveys are a common method of measuring the effect of specific policies and projects designed to cause changes in travel behaviour (Richardson et al., 1995). The Before survey establishes the situation before the change, while the After survey is designed to measure the situation after the policy or project has been implemented. For example, a large number of Travel Behaviour Change programs are now being run in various cities around the world. One such program is the Victorian TravelSMART Program, which has as its objective:

> *"to reduce the negative impacts of car travel through a reduction in vehicle trips and kilometres travelled, achieved through voluntary changes by individuals, households and organisations towards more sustainable travel choices".*

The Victorian TravelSMART Program follows on from other such projects conducted in other states of Australia (Ampt and Rooney, 1998; James et al., 1999) which have shown reductions in vehicle kilometres of travel of between 10% and 20%, accompanied by increases in public transport usage of between 10% and 20%. To provide demonstrable proof of the effectiveness of such programs, the Department of Infrastructure has engaged a consultant to provide independent Evaluation Services to determine the impact of the Victorian TravelSMART Program. As part of the evaluation, the consultant is required to conduct Before and After surveys to measure the impact of the implementation of the Victorian TravelSMART Program.

A previous paper (Richardson, 2003a) has addressed the issues that need to be considered in the design of such Before and After surveys, using the evaluation of the TravelSMART Program as a case study example. In that paper, specific reference was made to an analysis of the Coefficient of Variation of vehicle kilometres travelled over different periods of time by different travel units (persons and households), based on data from the MobiDrive 6-week travel survey in Germany (Axhausen et al., 2002). That analysis was used as an input into the specification of the sample sizes required to measure changes in vehicle-kilometres of car travel after the introduction of TravelSMART.

This paper will examine a different aspect of this problem, dealing with the measurement of changes in public transport usage as a result of the TravelSMART Program. Once again, a crucial input into these calculations is the temporal variability in public transport usage. Thos temporal variation in public transport usage will again be measured using the MobiDrive data, supported by an analysis of data for Melbourne using the Victorian Activity and Travel Survey (VATS) (Richardson and Ampt, 1995). This paper also reports on an analysis of data from a detailed survey of public transport patronage conducted in Melbourne in 1994 (Richardson, 2003b).

2. ANALYSIS OF THE MOBIDRIVE DATA

As noted elsewhere (Richardson, 2003a), in determining the required sample size for a Before and After survey, it is necessary to have an estimate of the inherent variability of the parameter to be measured. Unfortunately, most travel surveys collect only one day of travel data from each respondent, therefore providing no information on the temporal variability of travel patterns. One of the very few surveys to collect data from households across an extended period, from which longitudinal variability in travel behaviour can be estimated, is the MobiDrive survey conducted recently in Germany (Axhausen et al., 2002). The MobiDrive data contains information on 52,273 trips (from 334 people living in 146 households) over a period of 6 weeks in 1999. For each trip, the data contains (among other things) the date, mode, travel time and travel distance of each trip. Some summary statistics from MobiDrive, and the corresponding figures from the 1995 data from the Victorian Activity and Travel Survey (VATS 95) are shown in Table 1.

Table 1 Comparison of Travel Behaviour in Germany and Melbourne

MobiDrive	Daily Car Driver Travel			Daily Public Transport Travel		
	Trips	Distance	Minutes	Trips	Distance	Minutes
Household	2.7	28.4	50.9	1.2	9.7	32.3
Person	1.2	12.4	22.3	0.5	4.2	14.1

VATS 95	Daily Car Driver Travel			Daily Public Transport Travel		
	Trips	Distance	Minutes	Trips	Distance	Minutes
Household	4.5	43.1	83.4	0.7	7.4	16.0
Person	1.7	16.1	31.1	0.3	2.8	6.0

It can be seen that, compared to VATS 95, the MobiDrive respondents make less car driver trips (about 70% of VATS 95), but more public transport trips (about 50% more trips and distance). The public transport minutes in MobiDrive are much higher than VATS 95 (over twice as large) because the speed of public transport in the German survey (with its heavy reliance on trams and buses) is lower than in Melbourne (with its significant heavy rail system).

The MobiDrive data was extracted from the files to calculate the number of trips and the time and distance covered by each mode by each person on each of their 42 travel days in the reporting period. Thus the data was reduced to a 42 by 334 matrix of person travel per day, a 42 by 146 matrix of household travel per day, a 6 by 334 matrix of person travel per week, and a 6 by 146 matrix of household travel per week. For each person (or household), the average amount of travel (trips, distance or minutes) was calculated across all days (or weeks). The standard deviation of these amounts were also calculated, and thence the Coefficient of Variation. In addition to calculating the values across all 42 days, an additional analysis considered the values segmented by days of the week. Thus, for example, as well as calculating the average and standard deviation of distance travelled as a public transport passenger across all 42 days, the average and standard deviation of distance travelled as a public transport passenger on the 6 Mondays (and Tuesdays etc) was also calculated.

The results are presented below for travel as a public transport passenger, using the three measures of travel given by number of trips, distance travelled and minutes spent travelling.

2.1 Variability of Person Trips as a Public Transport Passenger

2.1.1 Panel Survey Weekly Public Transport Trips per Person

In MobiDrive, the average number of public transport trips per person per week was 3.67. The average standard deviation of the number of public transport trips per week, across the 6 weeks for one person, was 1.67. The average Coefficient of Variation (CoV) was 46% (note that this is not simply 1.67/3.67, but rather is the average CoV calculated across each of the respondents). However, as shown in Figure 1, the CoV is a function of the average number of trips per person per week. Apart from those who don't use public transport at all (whose CoV is obviously zero), the CoV is highest for the infrequent public transport user and falls as the average number of public transport trips increases. The CoV is inversely related to the average number of public transport trips per person per week (T) by the equation: $CoV = 1.05/\sqrt{T}$

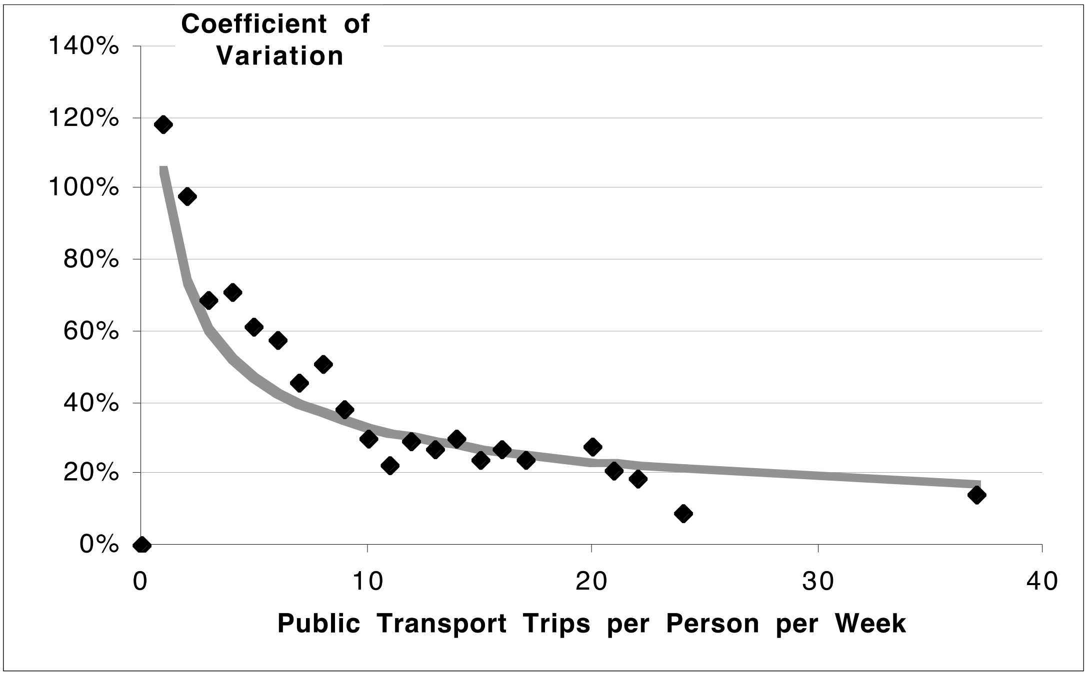

Figure 1 Coefficient of Variation of Public Transport Trips per Person per Week as a Function of Average Public Transport Trips per Person per Week

Since people in Melbourne make fewer trips by public transport than people in MobiDrive, it would be expected that the CoV of their weekly trip rate would be somewhat higher than in Mobidrive. Using the average weekly public transport trips per person in Melbourne (0.55) and MobiDrive (3.67) and the equation given above, the CoV of weekly public transport trips per person in Melbourne would be expected to be about 64% (i.e. 139% of 46%).

2.1.2 Cross-Sectional Survey Weekly Public Transport Trips per Person

If we treat the MobiDrive data not as a panel survey, but as a series of repeated cross-sectional surveys, we can obtain an estimate of the likely variability in weekly public transport trips per person across the population. The mean, standard deviation and CoV of weekly public transport trips per person was obtained across all people in the survey for each of the six weeks of the survey. The average Coefficient of Variation (CoV) across the six weeks was 155%. This is far higher than the panel survey CoV of 46% for MobiDrive, and reflects the greater variability across people than within the same person over time. Using the same factor to account for the lower public transport trip rates in Melbourne, the cross-sectional CoV in weekly person trips is estimated to be about 216%.

2.1.3 Panel Survey Daily Public Transport Trips per Person

The average number of public transport trips per person *per day* was 0.52. The average standard deviation in the number of public transport trips per day, across the 42 days for one person, was 0.61. The average Coefficient of Variation (CoV) was 138% (compared to a CoV of 46% for public transport trips *per week*). However, as with public transport trips per week, the CoV is also a function of the average number of public transport trips per person per day. The CoV is inversely related to the average number of public transport trips per person per day (T) by the equation: $CoV = 1.17/\sqrt{T}$

Since people in Melbourne make fewer trips by public transport per day than people in MobiDrive, it would be expected that the CoV of their daily public transport trip rate would be somewhat higher than in Mobidrive. Using the average daily public transport trips per person in Melbourne (0.27) and MobiDrive (0.52) and the equation given above, the CoV of daily public transport trips per person in Melbourne would be expected to be about 191% (i.e. 138% of 138%).

2.1.4 Cross-Sectional Survey Daily Public Transport Trips per Person

By treating the MobiDrive data as a series of repeated cross-sectional surveys, we can obtain an estimate of the variability in daily public transport trips per person across the population. The average Coefficient of Variation (CoV) for daily public transport trips between the 344 people across the 42 days was 227%. This is again far higher than the panel survey CoV of 138% for MobiDrive, and reflects the greater variability across people than within the same person over time. Using the same factor to account for the lower public transport trip rates in Melbourne, the cross-sectional CoV in daily person public transport trips is estimated to be about 314%.

This estimate can be compared with a direct estimate using the VATS 95 data, since VATS 95 is indeed a cross-sectional survey of daily trips. The mean number of public transport trips per person per day in VATS 95 is 0.27, the standard deviation of public transport trips per person per day in VATS 95 is 0.89, giving a CoV of 331% (compared to the 314% estimated from the adjusted MobiDrive data).

2.1.5 Panel Survey Daily Public Transport Trips per Person (stratified by day of the week)

The preceding analysis of daily public transport trip rates in a panel survey has made no distinction between the days of the week, i.e. it has simply calculated the variability across all 42 days making no distinction, for example, between weekdays and weekends. It is well-known, however, that there are significant variations in public transport travel across the days of the week. In a panel survey, this variation can be removed from the design by ensuring that households are approached on the same day of the week in each wave of the panel, thereby ensuring that differences observed in the waves are not simply due to a change in day of week between the waves for that household. The variability in public transport trip rates on the same day of the week across the 6 weeks of the MobiDrive data was therefore investigated.

The average number of public transport trips per person per day is still 0.52 (as observed earlier when all 42 days were considered together). However, the average standard deviation in the number of public transport trips per day, when each day of the week has been considered as separate strata, is reduced to 0.42 (compared to 0.61 when all 42 days are considered together). The average Coefficient of Variation (CoV) was therefore 61% (compared to a CoV of 138% when all 42 days are considered together). However, as with trips per day across all 42 days, the CoV is also a function of the average number of trips per person per day. The CoV is inversely related to the average number of public transport trips per person per day (T) by the equation: $CoV = 0.95/\sqrt{T}$

Using the average daily public transport trips per person in Melbourne (0.27) and MobiDrive (0.52) and the equation given above, the CoV of daily public transport trips per person in Melbourne, after ensuring that the same day of the week is used in each wave of the panel survey, would be expected to be about 85% (i.e. 139% of 85%). (note that these calculations are not relevant to repeated cross-sectional surveys, since each household is only surveyed once in a repeated cross-sectional survey).

A summary of the Coefficients of Variation for public transport trips per person is given in Table 2.

Table 2 Variability in Person Public Transport Trips in Germany and Melbourne

Weekly Trips per Person	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	3.67	---	3.67	1.89
Standard Deviation	1.67	---	5.66	---
Coefficient of Variation	46%	---	155%	---
Adjustment Factor	139%	---	139%	---
Adjusted CoV	---	64%	---	216%
Daily Trips per Person	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	0.52	---	0.52	0.27
Standard Deviation	0.61	---	1.05	0.89
Coefficient of Variation	138%	---	227%	331%
Adjustment Factor	138%	---	138%	---
Adjusted CoV	---	191%	---	314%
Daily Trips per Person (stratified by day of week)	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	0.52	---	---	---
Standard Deviation	0.42	---	---	---
Coefficient of Variation	61%	---	---	---
Adjustment Factor	139%	---	---	---
Adjusted CoV	---	85%	---	---

The estimation of the CoV for Melbourne is provided only as an example of how the MobiDrive results can be transferred to another region. A similar transformation has also been applied to the MobiDrive results to estimate temporal variability of public transport trip rates in Singapore, where the average public transport trip rates are higher than in Germany. To use the above results for any city, one only needs to know the average public transport trip rate in the new city, and then scale the MobiDrive CoV by the square root of the ratio of the MobiDrive public transport trip rate to the new city public transport trip rate, such that lower CoVs are obtained in cities with higher public transport trip rates, and vice versa.

2.2 Variability of Household Trips as a Public Transport Passenger

The preceding section has considered the variability in the number of public transport trips undertaken by a person on a daily or weekly basis. However, the Before and After surveys may be conducted on the basis of an entire household's travel patterns before and after the implementation of TravelSMART, in which case information is required about the variability in public transport trip rates on a household basis. This section therefore repeats the previous analysis, but uses the household as the unit of analysis. Since the commentary would be very similar for this section as in the previous section, only the main results are presented in tabular format in Table 3.

Table 3 Variability in Household Public Transport Trips in Germany and Melbourne

Weekly Trips per Household	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	8.42	---	8.42	5.14
Standard Deviation	2.87	---	11.09	---
Coefficient of Variation	49%	---	133%	---
Adjustment Factor	128%	---	128%	---
Adjusted CoV	---	62%		170%
Daily Trips per Household	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	1.19	---	1.19	0.73
Standard Deviation	1.09	---	1.95	1.79
Coefficient of Variation	142%	---	184%	244%
Adjustment Factor	127%	---	127%	---
Adjusted CoV	---	181%		235%
Daily Trips per Household (stratified by day of week)	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	1.19	0.73	---	---
Standard Deviation	0.78	---	---	---
Coefficient of Variation	75%	---	---	---
Adjustment Factor	127%	---	---	---
Adjusted CoV	---	95%	---	---

2.4 Variability of Person Distance Travelled as a Public Transport Passenger

The preceding sections have used public transport trips as one measure of travel by public transport. This section will use the distance travelled by public transport as another measure of travel by public transport. As before, the analysis will be performed for persons and households, daily and weekly, and for panel and cross-sectional surveys. Once again, since the commentary would be very similar for this section as in the original section, only the main results are presented in tabular format in Table 4.

2.5 Variability of Household Distance Travelled as a Public Transport Passenger

The preceding section has considered the variability in the distance travelled as a public transport passenger by a person on a daily or weekly basis. This section repeats the previous analysis, but uses the household as the unit of analysis. The main results are presented in tabular format in Table 5.

Table 4 Variability in Person Public Transport Distance in Germany and Melbourne

Weekly Kilometres per Person	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	29.6	---	29.6	19.1
Standard Deviation	19.3	---	56.0	---
Coefficient of Variation	91%	---	188%	---
Adjustment Factor	124%	---	124%	---
Adjusted CoV	---	113%	---	234%
Daily Kilometres per Person	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	4.22	---	0.5	2.73
Standard Deviation	6.85	---	12.41	12.67
Coefficient of Variation	237%	---	318%	463%
Adjustment Factor	124%	---	124%	---
Adjusted CoV	---	294%	---	395%
Daily Kilometres per Person (stratified by day of week)	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	4.22	---	---	---
Standard Deviation	4.25	---	---	---
Coefficient of Variation	64%	---	---	---
Adjustment Factor	124%	---	---	---
Adjusted CoV	---	79%	---	---

Table 5 Variability in Household Public Transport Distance in Germany and Melbourne

Weekly Kilometres per Household	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	68	---	68	52
Standard Deviation	36	---	105	---
Coefficient of Variation	76%	---	155%	---
Adjustment Factor	114%	---	114%	---
Adjusted CoV	---	86%		177%
Daily Kilometres per Household	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	9.7	---	9.7	7.4
Standard Deviation	12.8	---	21.8	23.0
Coefficient of Variation	159%	---	245%	310%
Adjustment Factor	114%	---	114%	---
Adjusted CoV	---	182%		280%
Daily Kilometres per Household (stratified by day of week)	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	9.7	7.4	---	---
Standard Deviation	8.6	---	---	---
Coefficient of Variation	80%	---	---	---
Adjustment Factor	114%	---	---	---
Adjusted CoV	---	91%	---	---

2.6 Variability of Person Travel Time as a Public Transport Passenger

The preceding sections have used public transport trips and distances travelled as measures of travel by public transport. This section will use the travel time as a public transport passenger as another measure of travel by public transport. As before, the analysis will be performed for persons and households, daily and weekly, and for panel and cross-sectional surveys. Once again, since the commentary would be very similar for this section as in the original section, only the main results are presented in tabular format in Table 6.

Table 6 Variability in Person Public Transport Travel Time in Germany and Melbourne

Weekly Minutes per Person	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	111	---	111	41
Standard Deviation	56	---	178	---
Coefficient of Variation	89%	---	161%	---
Adjustment Factor	164%	---	164%	---
Adjusted CoV	---	145%	---	263%
Daily Minutes per Person	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	15.8	---	15.8	5.9
Standard Deviation	20.5	---	35.1	21.6
Coefficient of Variation	230%	---	249%	367%
Adjustment Factor	164%	---	164%	---
Adjusted CoV	---	377%	---	408%
Daily Minutes per Person (stratified by day of week)	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	15.8	---	---	---
Standard Deviation	13.5	---	---	---
Coefficient of Variation	63%	---	---	---
Adjustment Factor	164%	---	---	---
Adjusted CoV	---	103%	---	---

2.7 Variability of Household Travel Time as a Public Transport Passenger

Finally, this section repeats the previous analysis of public transport travel; time, but uses the household as the unit of analysis. The main results are presented in tabular format in Table 7.

Table 7 Variability in Household Public Transport Travel Time in Germany and Melbourne

Weekly Minutes per Household	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	253	---	253	112
Standard Deviation	101	---	355	---
Coefficient of Variation	71%	---	140%	---
Adjustment Factor	150%	---	150%	---
Adjusted CoV	---	107%		210%
Daily Minutes per Household	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	36.2	---	36.2	16.0
Standard Deviation	37.1	---	65.0	41.7
Coefficient of Variation	183%	---	200%	260%
Adjustment Factor	150%	---	150%	---
Adjusted CoV	---	276%		300%
Daily Minutes per Household (stratified by day of week)	Panel Survey		Cross-sectional Survey	
	MobiDrive	Melbourne	MobiDrive	Melbourne
Average	36.2	16.0	---	---
Standard Deviation	26.1	---	---	---
Coefficient of Variation	77%	---	---	---
Adjustment Factor	150%	---	---	---
Adjusted CoV	---	115%	---	---

2. ANALYSIS OF VARIABILITY AT THE ROUTE LEVEL

The previous sections have examined the temporal variability of public transport usage at the level of the individual or the household. This section looks at the issue from another perspective, and examines the variability in public transport patronage at the route level. This analysis uses data from a large-scale origin-destination interview survey conducted on National Bus Company (NBC) buses in Melbourne in 1994. On 52 days in April and May of 1994, all passengers boarding buses on 38 NBC routes in Melbourne were counted and interviewed to ascertain their origin and destination. The count data has been used in this study to estimate the variability of patronage on each of there routes over this period.

The 52 survey days were divided into 3 groups; 24 working days on which schools were in class, 17 working days on which schools were on holidays, and 11 days which were weekends or public holidays. For the 24 working days when schools were in class, the number of boarding passengers on each route in each hour of the day (between 6am and 11 pm) was extracted from the data, from which the average and standard deviation of patronage within each hour over the 24 days was calculated. The Coefficient of Variation was then calculated, and is plotted as a function of the average hourly patronage in Figure 2.

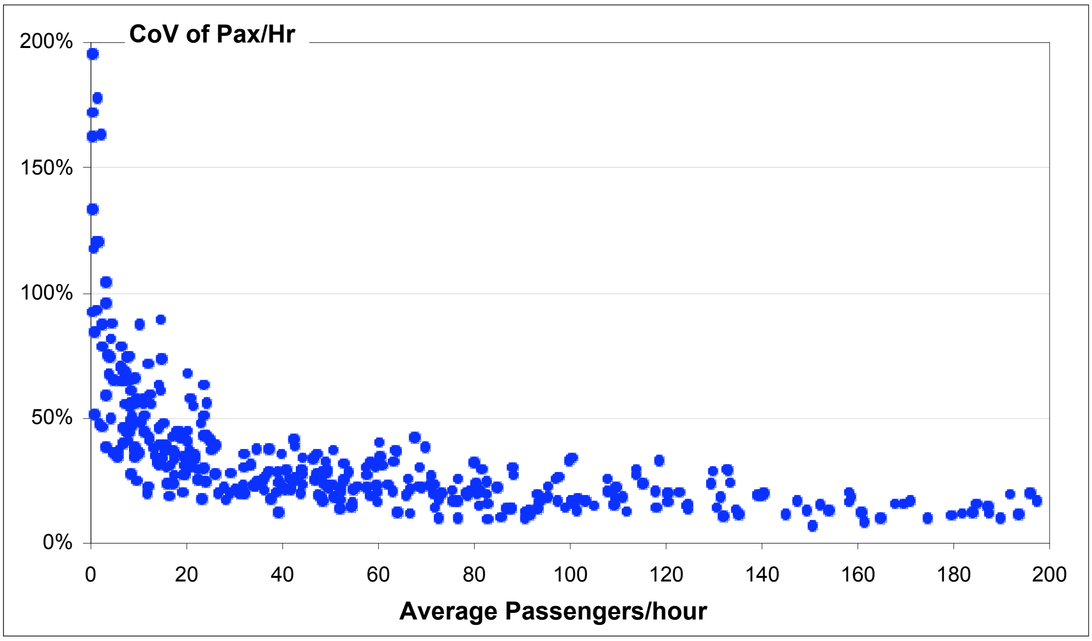

Figure 2 Coefficient of Variation of Public Transport Patronage per Hour as a Function of Average Route Patronage per Hour

It can be seen that it follows a similar pattern to that shown earlier in Figure 1 for the CoV of weekly public transport trips per person. Indeed, the line of best fit is given by the equation: $CoV = 1.60/\sqrt{T}$, which is the same type of inverse square root relationship found with the MobiDrive data. Thus, high patronage routes, like high frequency travellers, have less relative variability in their patronage over time.

3. REQUIRED SAMPLE SIZE FOR BEFORE & AFTER SURVEYS

Given the estimates of temporal variability described above, this section considers the required sample size for a survey that measures public transport usage before and after the implementation of TravelSMART, or any other program designed to change public transport patronage levels. Assume, for the moment, that the survey will be a longitudinal panel survey with the primary objective of measuring total kilometres of public transport use undertaken by all persons in a household in a week. Assume that the intention of the Before and After surveys is to test whether there has been an increase in public transport kilometres after implementation of the TravelSMART program. Assume that the required increase is 10% of public transport kilometres.

In order to calculate a sample size, it is necessary to estimate the variability of the parameter to be measured. Assuming a longitudinal panel survey, it is therefore necessary to estimate the variability of public transport kilometres within a household from week to week. Based on the MobiDrive survey data, and adjusted for Melbourne conditions, the Coefficient of Variation of weekly public transport kilometres (over a 6-week period) has been estimated as 86% (see Table 5 above).

The required sample size for hypothesis testing in before and after surveys (Richardson et al., pg 122) is given by:

$$n = \frac{2\left(z_{\alpha} + z_{\beta}\right)^2\left(\sigma^2\right)}{\Delta^2}$$

where n =.required sample size
α =.the probability of making a Type I error
β =.the probability of making a Type II error
s =.the standard deviation of the parameter to be tested
Δ = the required difference in the parameter to be tested

Assuming that α=β=5%, s = 86% (of the mean) and Δ = 10% (of the mean), then the required sample size is about 1617. This calculation assumes that the sample is being drawn from an infinite, or at least very large, population. However, in the TravelSMART project the size of the population of households in each of the study areas is relatively small (about 1500 households in each of three study areas). With such a small population (N), it is necessary to multiply the estimated sample size (n) by a Finite Population Correction Factor (FPCF), where:

$$\text{FPCF} = \frac{1}{1 + n/N}$$

With a population of only 1500 households, the required sample size is reduced to 778. That is, in order to measure a statistically significant increase of 10% in weekly household public transport kilometres in the after survey (when the inherent variability of weekly household public transport kilometres is 86% of the mean), a sample size of 778 households would be required in both the before and after surveys.

The above calculation has been based on a number of specific assumptions, namely:

- Type of Survey: Panel
- Variable being Measured: Public-transport-kilometres
- Unit of Measurement: Households
- Period of Measurement: One week
- Coefficient of Variation of Parameter: 86%
- Detected Difference (Δ): 10% of mean
- Probability of making a Type I error (α): 5%
- Probability of making a Type II error (β): 5%

By varying some of these parameters, we can see that, for a specific set of conditions (i.e. detecting a 10% change in travel with a confidence level of 95%, from a population of 1500 households in each study area), the sample sizes shown in Table 8 would be required as a function of the type of survey (panel or cross-sectional survey), the unit of measurement (person or household), the quantity being measured (trips, kilometres or minutes, the time period of the survey (week, day or matched day-of-week), and the mode being measured (car or public transport) (the sample sizes for car travel have been extracted from Richardson (2003a)).

Table 8 Sample Sizes Required for Various Before and After Survey Designs

	Car			Public Transport		
	Trips	Kilometres	Minutes	Trips	Kilometres	Minutes
Panel Survey						
Person						
Week	119	279	234	556	972	1129
Day	547	909	810	1261	1389	1430
Matched DOW	453	590	504	1196	1164	1278
Household						
Week	110	242	168	539	778	931
Day	510	726	648	1237	1239	1375
Matched DOW	410	586	471	1085	1077	1200
Repeated Cross-sectional Survey						
Person						
Week	947	1123	990	1306	1332	1364
Day	1112	1270	1165	1401	1436	1440
Household						
Week	582	758	597	1210	1227	1297
Day	762	998	825	1332	1378	1393

Several features emerge from this comparison. Firstly, the sample size required to detect a 10% change in public transport use is much higher than the sample size required to detect a 10% change in car use (in a city like Melbourne where car use is much higher than public transport use – the reverse was found in Singapore where public transport use is higher than car use). Secondly, larger sample sizes are generally required to detect changes in either distance travelled or travel time than in trips undertaken. Thirdly, larger sample sizes are required to detect changes from repeated cross-sectional surveys than from a panel survey. Fourthly, larger sample sizes are required to detect changes when using a daily travel diary compared to using a weekly travel diary (although this difference can be substantially reduced in a panel survey by maintaining the same day of the week for each household in later waves of the panel). Finally, larger sample sizes are required to detect changes from person travel data than from household travel data.

Traded off against these sample size advantages, however, is the fact that some of the parameters requiring smaller sample sizes are also more difficult to obtain. For example, panel survey data is more difficult to obtain (with full control of other biases) than repeated cross-sectional data. Weekly travel diaries are more burdensome than daily travel diaries. Getting travel data from all household members is more difficult than getting data from one member of the household.

By comparison with Richardson (2003a), which estimated sample sizes for measuring changes in household vehicle use, this paper has shown that significantly larger sample sizes are required for measuring changes in public transport use. This is particularly the case in Australia, compared to Germany, because of the lower proportion of public transport trips in Australia. The situation would vary in other cities, depending on the overall level of use of public transport.

CONCLUSIONS

The purpose of this paper was to obtain a quantitative understanding of the underlying temporal variation in travel by public transport, as a precursor to the design of a Before & After survey to measure changes in the use of public transport. This was obtained by a detailed analysis of the MobiDrive data from Germany, and the estimation of Coefficients of Variation in key travel parameters for the Melbourne situation. The results were then compared with some estimates of variability of public transport patronage at the route level.

A major finding was that the Coefficient of Variation of public transport usage at the person, household and route level was an inverse function of the square root of the level of usage.

Following this analysis, the paper estimated the required sample size for a survey that measures trips, kilometres and travel time for public transport travel before and after the implementation of a program to change levels of public transport usage, such as TravelSmart. Sample sizes were calculated for different Types of Survey, Units of Measurement, Periods of Measurement, Coefficients of Variation of the Parameters of Interest, the desirable Detectable Difference in the before and after surveys, the Probability of making a Type I error (α) and the Probability of making a Type II error (β).

Several features emerged from this analysis. Firstly, the sample size required to detect a 10% change in public transport use is much higher than the sample size required to detect a 10% change in car use. Secondly, larger sample sizes are generally required to detect changes in either distance travelled or travel time than in trips undertaken. Thirdly, larger sample sizes are required to detect changes from repeated cross-sectional surveys than from a panel survey. Fourthly, larger sample sizes are required to detect changes when using a daily travel diary compared to using a weekly travel diary (although this difference can be substantially reduced in a panel survey by maintaining the same day of the week for each household in later waves of the panel). Finally, larger sample sizes are required to detect changes from person travel data than from household travel data.

Traded off against these sample size advantages, however, is the fact that some of the design parameters enabling smaller sample sizes also make the survey more difficult to conduct. For example, panel survey data is more difficult to obtain (with full control of other biases) than repeated cross-sectional data. Weekly travel diaries are more burdensome than daily travel diaries. Getting travel data from all household members is more difficult than getting data from one member of the household.

It is clear from the analysis and calculations in this paper that measuring changes in public transport use requires significant sample sizes, especially in situations where the current level of public transport use is not very high.

REFERENCES

Ampt L., and Rooney A. (1998). Reducing the impact of the car: a sustainable approach TravelSmart Adelaide. **Proceedings 22nd Australasian Transport Research Forum**, pg 805

Axhausen, K.W., Zimmermann, A., Schönfelder, S., Rindsfüser, G. and Haupt, T. (2002). "Observing the rhythms of daily life: A six-week travel diary". **Transportation**. 29(2), pp 95-124.

James B., Brög W., Erl E., and Funke S. (1999). Behaviour Change Sustainability from Individualised Marketing. **Proceedings 23rd Australasian Transport Research Forum**, pg 549

Richardson, A.J. (2003a). Temporal Variability of Car Usage as an Input to the Design of Before & After Surveys. Paper submitted for presentation at the **82nd Annual Meeting of the Transportation Research Board**, Washington DC. (also available at www.tuti.com.au/publications).

Richardson, A.J. (2003b). Estimating Average Distance Travelled from Bus Boarding Counts. Paper submitted for presentation at the **82nd Annual Meeting of the Transportation Research Board**, Washington DC. (also available at www.tuti.com.au/publications).

Richardson, A.J. and Ampt, E.S. (1995). "The Application of Total Design Principles in Mail-Back Travel Surveys", **7th World Conference of Transport Research**, Sydney (also available at www.tuti.com.au/publications).

Richardson, A.J., Ampt, E.S. and Meyburg, A.H. (1995). **Survey Methods for Transport Planning**. Eucalyptus Press, Melbourne.