Tollroads are only Part of the Overall Trip: the error of our ways in past willingness to pay studies

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Abstract

With rare exception, actual tollroad traffic in many countries has failed to reproduce forecast traffic levels, regardless of whether the assessment is made after an initial year of operation or as long as ten years after opening. Pundits have offered many reasons for this divergence, including optimism bias, strategic misrepresentation, the promise to equity investors of early returns on investment, errors in land use forecasts, and specific assumptions underlying the traffic assignment models used to develop traffic forecasts. One such assumption is the selection of a behaviourally meaningful value of travel time savings (VTTS) for use in a generalised cost or generalised time user benefit expression that is the main behavioural feature of the traffic assignment (route choice) model. Numerous empirical studies using stated choice experiments have designed choice sets of alternatives as if users choose a tolled route or a free route under the (implied) assumption that the tolled route is tolled for the entire trip. Reality is often very different, with a high incidence of use of a non-tolled road leading into and connecting out of a tolled link. In this paper we recognise this feature of route choice and redesign the stated choice experiment to account for it. Furthermore, this study is a follow up to a previous study undertaken before a new toll road was in place, and it benefits from real exposure to the new toll road. We find that the VTTS is noticeably reduced, and if the VTTS is a significant contributing influence on errors on traffic forecasts, then the lower estimates make sense behaviourally.

Key words: value of travel time savings, toll routes, free routes, choice experiment, errors in forecasts

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Introduction

The behavioural value of travel time savings (VTTS) is a critical parameter in the evaluation of road investment programs and toll roads in particular. Travel time savings remains the major *user* benefit associated with improvements to the road infrastructure. It is widely accepted as a major influence on traffic and revenue predictions for toll roads, where tolls are assessed by actual and potential users relative to the savings in travel time.

In recent years we have seen an increased incidence of actual traffic falling short of the traffic forecasts, often by as much as 50 percent (see Li and Hensher 2010 who review evidence from Australia and the USA). Flyvbjerg et al. (2003, 2006) and Bain (2009a, 2009b, 2011) in particular have investigated the many factors contributing to errors in forecasts, including a premature ramp up date, optimism bias, and changing land use that was not known at the time of the initial forecasts. In a review of practice, Bain (2011) suggested that two common trends have emerged. Although accurate at the aggregate (state or national) level, forecasting performance deteriorates rapidly (a) as the study area shrinks – towards the zone sizes typically used in transport modelling – and (b) as the forecasting horizon expands. Smith and Shahidullah (1995) calculate errors for 20-year small-area population projections lying between 25% and 35%. The global financial crisis has in more recent years also had an impact; however it is often suggested that the VTTS is a major contributing influence[1].

As a behavioural construct, the VTTS is linked to travel preferences, is sensitive to real use experiences on all roads, and in the context of toll roads to the use of specific tolled roads since a toll road was opened.[2] There is evidence to suggest that *ex post* experience is the best gauge of support or otherwise for a toll road, something which is often missing in the majority of tollroad studies. In 2012, the opportunity arose after the opening of a toll road in Australia, to revisit the VTTS for commuting and non-commuting travel in the presence of experience in using the road in particular and other toll roads in general, providing a more useful environment in which to reassess and update the VTTS.

This paper recognises that much of a so-called toll route trip is not on the tolled facility but on free routes that connect into the toll road. This distinction is important and differs significantly to most published[3] stated choice studies where the time/toll trade off is assumed to

[1] We recognise the findings of Brownstone *et al.* (2003), that their willingness to pay to reduce congested travel time is higher than previous stated preference results. However they focus of comparing real market RP and SP evidence, and while we acknowledge this difference and reasons offered, we would argue that our paper has a different focus. If we had a full RP market data like Brownstone et al., then we could establish whether our new SP based evidence (pivoted around real experience) produces findings that are higher or lower than RP evidence. We do not have such rich data; what we are able to do is recognise that the earlier evidence we report (Table 12) was not based on exposure to the tolled route of interest (since it was not constructed back then), and that in the intervening period we have also witnessed the global financial crisis.

[2] This is an important point in the context of the current study, which was undertaken to assess the extent to which VTTS have changed nine months after the opening of a new toll road in contrast to the earlier VTTS study before the specific tollroad was constructed. In the intervening period, we have experienced the global financial crisis.

[3] We were unable to locate any published papers in which such a distinction had been made in the past. One reviewer however alerted us to a number of unpublished reports authored by the Resource Systems Group (http://www.rsginc.com/) where similar toll/non-tolled time variations have been used to describe a route alternative.

occur over the total trip length, even when different traffic conditions are considered. By showing respondents different traffic conditions on both the tolled and non-tolled component of a trip, tests of differences in VTTS for the different road types can be undertaken which allows for a richer understanding of how drivers respond to the mix of feeder and egress travel time when compared to the time actually spent on a toll road. Such an understanding has major implications for the design of stated choice experiments dealing with route choice, as well as the possibility of quite different (lower) estimates of VTTS. Furthermore, this study is a follow up to a previous study undertaken before a new toll road was in place, and it benefits from real exposure to the new toll road, which is expected to condition preferences and lead to revised VTTS, if such estimates are indeed a function of offered levels of service.

The paper is organised as follows. We begin with an overview of the structure of the choice experiment. This is followed by documentation of the empirical context, the data collection approach, estimation of error component choice models for each trip purpose, the presentation of the set of VTTS and interpretation of the nonlinear functions that is required to obtain specific VTTS. We conclude with commentary on the new empirical evidence.

Approach

The stated choice experiment offers alternative trip options defined in terms of various travel times on the free *and* tolled parts of the door to door trip in a context that each sampled respondent has recently experienced. Travel time is disaggregated into free flow time (uncongested traffic conditions[4]) and slowed down time, the latter due to other vehicles in the traffic stream (congested traffic conditions). The levels of the attributes associated with the alternatives are based on a recent trip. Consistent with other toll road studies in Australia, the experiment included two cost components: the running cost associated with the trip and the toll cost.

One outcome of conducting the experiment in the manner described is that it is not possible to identify the toll road quality bonus, an additional source of user benefit obtained in previous studies that sought time-cost trade-offs under the 'pure toll' versus 'pure free' route options. In earlier studies, a dummy variable was constructed for routes in which a toll was present. In the current study however, the separation of travel times on free roads and toll roads means that any toll road quality bonus will be perfectly confounded with the toll route travel times. Any differences, however, between the VTTS for free road travel time and toll road travel time may be interpreted as a direct measure of what was previously described as the toll road quality bonus.

Unlike previous toll road studies conducted to date in Australia, we also include an attribute representing the number of traffic lights the driver passed through (whether they were forced to stop or not) during the recent trip. This represents a significant advance in the methodology in that it allows one to also value how much drivers are

[4] We want to be able to recognise the value of a trip when travel time is unimpeded by traffic levels causing slowed down travel time. A large number of VTTS studies decompose the trip time into categories designed to capture potential differences in the marginal (dis)utility of travel time. Free flow (or uncongested) time is one such component and like the other components (e.g., slowed down time) there is the potential to save such time by choosing a tolled route over a free route if the tolled route saves total time as well as changes the composition of time in favour of a higher proportion of free flow time in the time mix for a given level of travel time. The logic for a higher marginal disutility associated with a minute of slowed down time is linked to the perception of the qualitatively different level of dissatisfaction in sitting in slowed traffic compared to a minute of free flow traffic time.

willing to pay to avoid traffic lights, a reason often cited as a benefit from choosing a tolled route. For toll road operators, the value of avoiding traffic lights will in part be associated with what was previously identified as the toll road quality bonus.

We identify the recent trip attributes (as shown in Figure 1), and then pivot the levels of the alternatives (Route A and Route B) off of these reported (i.e., perceived) levels. The selected attributes were based on previous study experience with the composition of times and costs (see for example Hess et al. 2008) but with the additional interest in distinguishing between the time and cost composition of the tolled route.

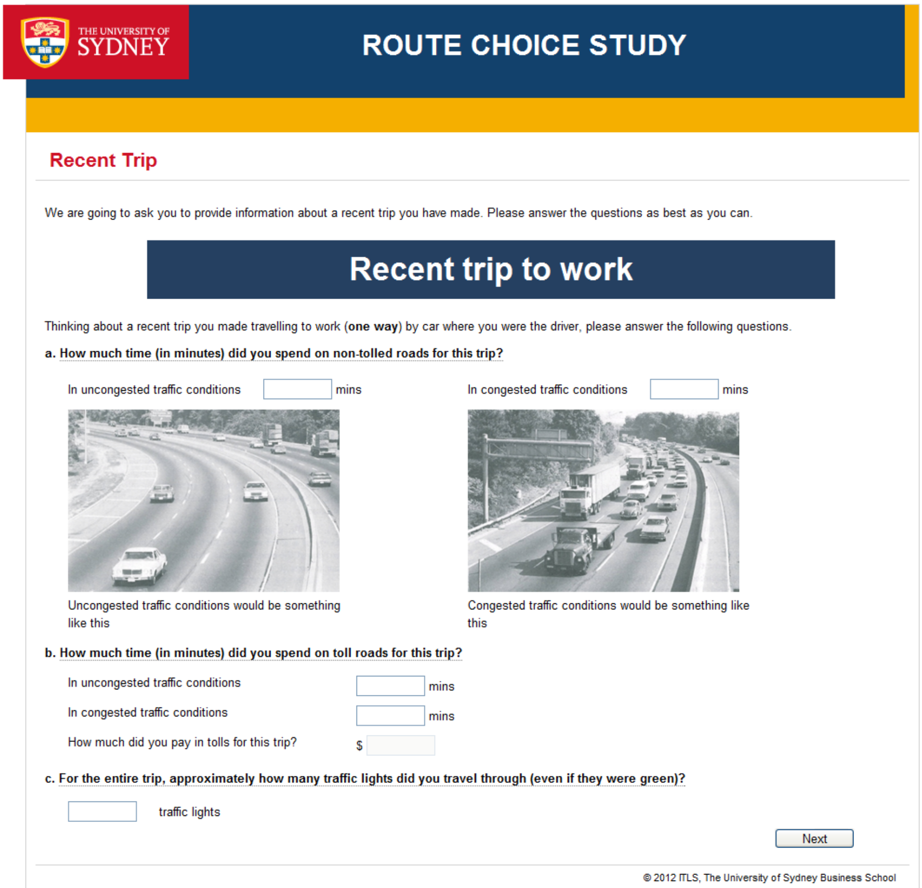


Figure 1: Recent Trip Details

An example of a pivot design where the respondent used the tolled road during the recent trip is given in Table 1, with the equivalent design strategy in Table 2 where the person did not use a tolled road as part of their recent trip. The difference in design is a consequence of having or not having a toll value to pivot around. The same 24 choice tasks were used for all respondents in order to minimise the likelihood that the design would influence the results (a phenomenon known as demand characteristics or demand induced effects; see Orne 1959, 1969). The design is a D-optimal design (see Rose and Bliemer 2009) utilising priors obtained from a large pilot study involving over 250 respondents collected from another Australian capital city six months prior. Details of pivot designs are given in Rose et al. (2008) and Rose and Bliemer (2009).

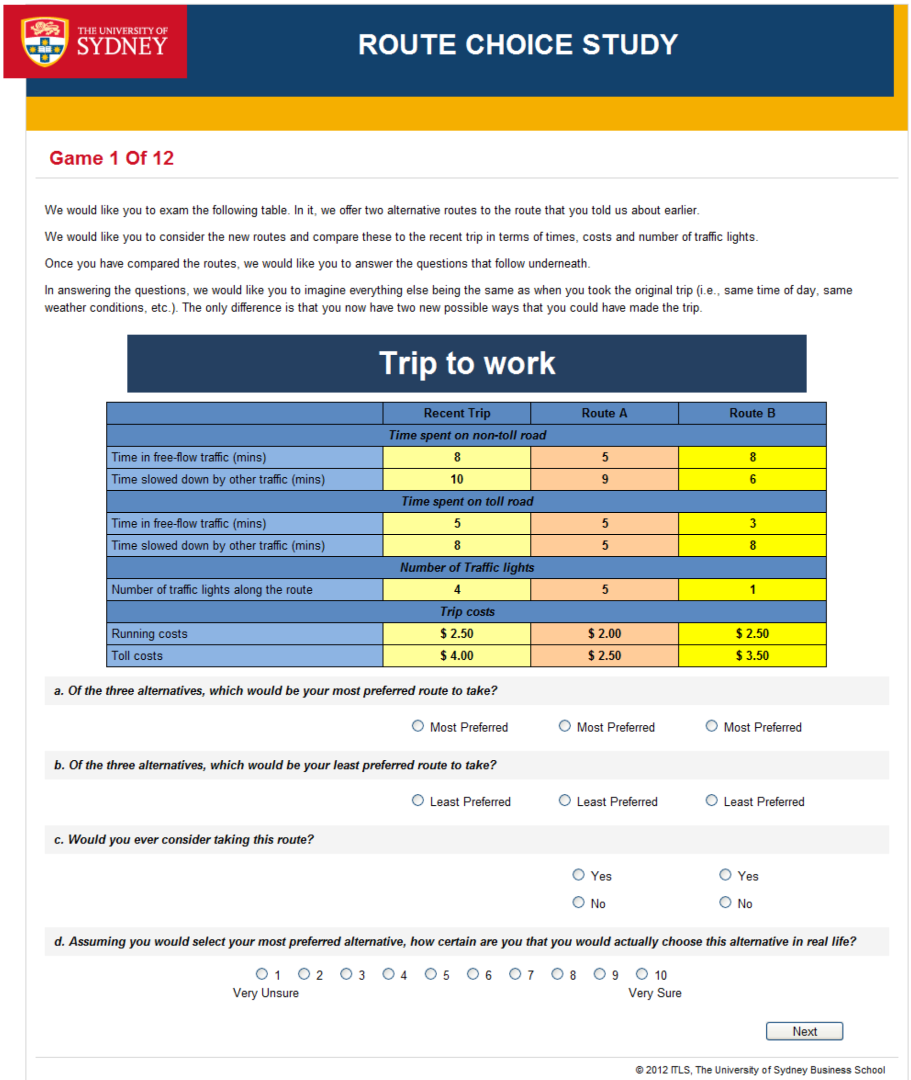
Table 1: Choice Experiment Design when a Toll is reported for the Recent Trip

	Route A							Route B						
	Non-toll route		*Toll route*					*Non-toll route*		*Toll route*				
Game	**Free flow**	**Slowed down**	**Free flow**	**Slowed down**	**Traffic lights**	**Petrol cost**	**Toll cost**	**Free flow**	**Slowed down**	**Free flow**	**Slowed down**	**Traffic lights**	**Petrol cost**	**Toll cost**
1	-25%	5%	-25%	-10%	-3	5%	-25%	-10%	-40%	-25%	-40%	1	-40%	5%
2	-25%	-10%	-25%	-25%	1	-10%	5%	-10%	-10%	-10%	-10%	-3	-25%	-40%
3	5%	-40%	-10%	-40%	-1	5%	-10%	-40%	5%	-40%	5%	-1	-40%	-25%
4	-10%	-40%	-40%	-10%	1	-40%	-40%	-25%	-10%	5%	-25%	-3	5%	5%
5	-10%	-25%	5%	5%	-1	-40%	5%	-25%	-25%	-40%	-40%	-1	5%	-40%
6	-40%	-10%	-25%	-40%	-3	-25%	-10%	5%	-25%	-10%	5%	1	-10%	-25%
7	5%	5%	-10%	-10%	1	-10%	-25%	-40%	-40%	-10%	-25%	-3	-25%	-10%
8	5%	-25%	5%	-25%	-3	-40%	-40%	-40%	5%	-25%	-10%	1	-10%	5%
9	-40%	-40%	-10%	5%	-1	-10%	-25%	5%	5%	-25%	-40%	-1	-25%	-10%
10	-10%	5%	-40%	-25%	-3	-25%	5%	-25%	-25%	5%	-10%	1	5%	-40%
11	-25%	-25%	-40%	5%	-1	5%	-10%	-10%	-10%	5%	-25%	-1	-40%	-25%
12	-40%	-10%	5%	-40%	1	-25%	-40%	5%	-40%	-40%	5%	-3	-10%	-10%

Table 2: Choice Experiment Design when a Toll is not reported for the Recent Trip

	Route A							Route B						
	Non-toll route		*Toll route*					*Non-toll route*		*Toll route*				
Game	**Free flow**	**Slowed down**	**Free flow**	**Slowed down**	**Traffic lights**	**Petrol cost**	**Toll cost**	**Free flow**	**Slowed down**	**Free flow**	**Slowed down**	**Traffic lights**	**Petrol cost**	**Toll cost**
1	-40%	0%	10%	10%	-1	-10%	$2.00	-40%	0%	5%	8%	-1	-25%	$6.00
2	-60%	-40%	5%	10%	-3	5%	$8.00	-20%	-40%	10%	8%	-1	-40%	$2.00
3	0%	-20%	8%	8%	-1	-25%	$2.00	-60%	-40%	8%	10%	-3	5%	$8.00
4	-60%	-60%	10%	5%	1	-40%	$8.00	0%	-20%	5%	5%	-3	-10%	$4.00
5	-20%	-20%	5%	5%	-1	-10%	$4.00	-20%	-40%	8%	10%	1	-40%	$6.00
6	0%	-40%	8%	10%	-3	-40%	$6.00	-60%	-20%	10%	5%	1	5%	$4.00
7	-20%	-60%	8%	5%	-1	5%	$2.00	-20%	0%	8%	8%	-1	-40%	$8.00
8	-40%	-60%	10%	8%	1	-25%	$6.00	-40%	-20%	5%	10%	-1	-25%	$2.00
9	0%	0%	8%	8%	-3	-25%	$2.00	-60%	-60%	5%	10%	1	-25%	$8.00
10	-60%	-20%	5%	5%	-3	-40%	$4.00	0%	-60%	8%	8%	1	5%	$8.00
11	-40%	0%	10%	10%	-3	5%	$6.00	0%	-60%	10%	5%	1	-10%	$4.00
12	-20%	-40%	5%	8%	1	-10%	$4.00	-40%	0%	10%	5%	-3	-10%	$6.00

An example of a stated choice screen is shown below as Figure 2. Rank-ordered choices have been shown to provide richer preference information compared to pick one or partial rankings mechanisms (Chapman and Staelin 1982, Hausman and Ruud 1987). To date, the most common approach to obtain full preference rankings has involved asking respondents to rank numerically a given set of alternatives. Recent advances in survey design for stated choice experiments suggest that obtaining a ranking from an iterative set of best-worst choices offers significant advantages in terms of cognitive effort (Auger, Devinney, and Louviere 2007; Cohen 2009; Flynn et al. 2007; Louviere and Islam 2008). As such, in addition to the standard choice response (the most preferred option), we included a response mechanism to reveal the respondents perceived worst alternative. As such, respondents selected both their most and least preferred routes out of the three presented. There is a growing literature that recognises the additional behavioural information in the best and worst response mechanism (e.g., Marley and Louviere 2005, Marley and Pihlens 2012).


THE UNIVERSITY OF SYDNEY

ROUTE CHOICE STUDY

Game 1 Of 12

We would like you to exam the following table. In it, we offer two alternative routes to the route that you told us about earlier.

We would like you to consider the new routes and compare these to the recent trip in terms of times, costs and number of traffic lights.

Once you have compared the routes, we would like you to answer the questions that follow underneath.

In answering the questions, we would like you to imagine everything else being the same as when you took the original trip (i.e., same time of day, same weather conditions, etc.). The only difference is that you now have two new possible ways that you could have made the trip.

Trip to work

	Recent Trip	Route A	Route B
Time spent on non-toll road			
Time in free-flow traffic (mins)	8	5	8
Time slowed down by other traffic (mins)	10	9	6
Time spent on toll road			
Time in free-flow traffic (mins)	5	5	3
Time slowed down by other traffic (mins)	8	5	8
Number of Traffic lights			
Number of traffic lights along the route	4	5	1
Trip costs			
Running costs	$ 2.50	$ 2.00	$ 2.50
Toll costs	$ 4.00	$ 2.50	$ 3.50

a. Of the three alternatives, which would be your most preferred route to take?

○ Most Preferred ○ Most Preferred ○ Most Preferred

b. Of the three alternatives, which would be your least preferred route to take?

○ Least Preferred ○ Least Preferred ○ Least Preferred

c. Would you ever consider taking this route?

○ Yes ○ Yes
○ No ○ No

d. Assuming you would select your most preferred alternative, how certain are you that you would actually choose this alternative in real life?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10
Very Unsure Very Sure

Next

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Figure 2: Illustrative Stated Choice Screen

Additional questions were also asked regarding toll road usage as shown in Figure 3.

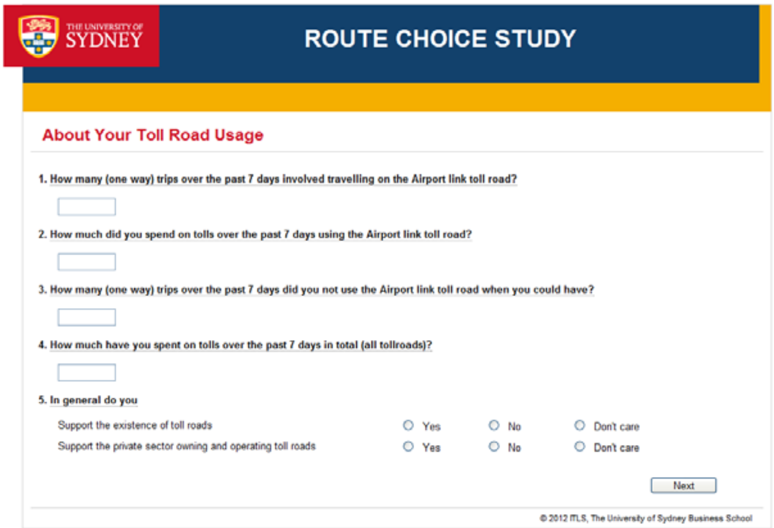

Figure 3: Toll Road Usage Question

The Sample

This paper focuses on commuting and non-commuting trips undertaken during peak periods, and given the specific context, distinguishing between trips that are to the airport and those to other locations in the catchment area[5]. Trips to the airport are separated into those where a person is embarking on air travel, for either business or non-business travel, and those where someone is meeting or dropping of an air passenger. Employees at the airport are included in the sample of commuters; however employer business trips are not explored in this study.

Given time and budget constraints, we opted for an internet survey, using a consumer panel. Recent evidence suggests that a consumer panel can deliver a representative sample, given appropriate quota criteria is applied (see Hatton McDonald et al. 2010, Lindhjem and Navrud 2011). We have drawn on the Pure Profile panel (www.pureprofile.com) which has many thousands of participants in the study area. In total, we undertook 496 internet surveys, comprising 196 commuters (including those travelling for business trips via the airport), and 300 non-commuters (including air leisure trips). The final sample after data cleaning consisted of 189 commuters and 295 non-commuters. With 12 choice games per respondent, this gives a total of 2,268 observations for the commuter model segment and 3,540 observations for the non-commuter trip segment. This sample size is substantial and more than sufficient to obtain statistically robust estimates of VTTS.

The final sample used for purposes of analysis comprised 178 commuters travelling to work, 11 persons travelling to the airport to undertake a business air trip, 156 non-commuters travelling in the local area for non-work related activities such as shopping, visiting friends and relatives, and personal business; 43 persons travelling to the airport to undertake a non-business air trip; and 96

[5] The study focused on a catchment area in a major capital city in Australia which serves the major domestic and international airport as well as local communities. There are at least two routes to the airport, and one is a new tolled road.

persons dropping someone off at the airport or picking up someone from the airport[6].
A screening question was used to establish eligibility to participate. It states that someone must have travelled in the morning peak (7am-10am), and could have potentially, or actually did, use the study area toll road[7].

Descriptive Statistics

An overview of the socio-demographics of data is provided in Table 3. The average age for each trip segment was almost identical with the exception of airport business trip respondents who were in general younger than other respondents. Overall however, the average age of respondents was 52.74 years. The average income for the sample was approximately $72,939 per annum, with respondents travelling to the airport for work purposes reporting the highest income level, and those undertaking general non-commuting trips having the lowest reported income levels. The commuting sample consisted of slightly more males than females, whilst the non-commuter segment was dominated by female respondents.

Table 3: Descriptive statistics by Trip Purpose Segment

		Age		Income		Gender (1 = female)	
Trip segment	**Number**	**Average**	**Std Dev.**	**Average**	**Std Dev.**	**Average**	**Std Dev.**
Commuter	156	52.50	12.55	$74,251	$49,881	0.49	0.50
To airport for a business trip	11	45.82	13.28	$92,272	$59,973	0.45	0.52
Non-commuter	156	53.94	13.49	$68,944	$51,080	0.59	0.49
To airport for a leisure trip	43	50.98	14.73	$72,441	$61,551	0.60	0.49
To airport to drop off/pickup	96	52.75	12.75	$75,364	$50,022	0.57	0.50
Grand Total	**462**	**52.74**	**13.15**	**$72,939**	**$51,616**	**0.55**	**0.50**

Of the non-commuting sample, the majority of trip purposes consisted of travel to the airport either for the purposes of picking up or dropping off someone or for travel (listed as other or social recreation). The next highest reason for non-commuting trips was for the purpose of visiting friends, followed by social recreation purposes. Table 4, presents the breakdown of reported non-commuting trip purposes.

Table 4: Non-commuter by trip purpose

Purpose	Number	Percent
Shopping	39	13.00%
Visit friends	62	20.67%
Education	4	1.33%
Personal Bus	21	7.00%
Social rec	54	18.00%
Other (including trips to airport)	120	40.00%

[6] Seven commuters and five non-commuters were excluded from the sample due to the provision of unlikely data for the recent trip. For example, one respondent reported travelling through 10,000 traffic lights, whilst another reported travelling through 321 traffic signals during their recent trip. Another respondent reported having to pay $110 in tolls whilst another reported a trip consisting of 90 minutes spent in congested travel conditions on a toll road (the remaining travel times were all zero). Whilst it is likely that these values represented data entry errors on behalf of the respondent, these respondents were excluded from the analysis to ensure the validity of both the sample and the results.
[7] A brief snapshot of the current set of published profile questions is available at www.pureprofile.com.

Table 5 presents the descriptive statistics for the times, costs and number of traffic lights passed in the sample data. On average, commuters and non-commuters reported spending the majority of the trip on non-tolled roads (68.4 percent of the total trip time for commuters and 67.4 percent for non-commuters). On average, less than six minutes from the total average 43.78 minute commuting trip is spent in slowed down traffic conditions for commuters and less than five minutes of the 43.1 non-commuter trip. Non-commuters reported more time in free flow conditions than commuters, despite both segments making trips during the morning peak. Both trip segments reported an average of 8 to 9 traffic lights along their recent travel route, whilst petrol costs and toll costs were approximately the same across segments.

Table 5: Trip attributes by trip purpose (times are in minutes and costs in 2012 $Aud)
FFT = free flow time, SDT = slowed down time

	Commuter				Non-Commuter			
	Mean	Std Dev.	Min	Max	Mean	Std Dev.	Min	Max
FFT Free route	15.30	9.72	0	53	18.56	13.62	0	90
SDT Free route	14.65	13.82	0	63	10.64	14.14	0	84
FFT Toll route	7.93	8.71	0	53	9.21	8.33	0	53
SDT Toll Route	5.90	8.71	0	63	4.89	7.95	0	53
Traffic lights	8.32	7.66	0	46	8.92	9.14	0	51
Petrol cost	3.59	2.14	0.5	9.5	3.37	2.16	0.5	9.5
Toll cost	3.72	2.65	0	16	3.79	3.06	0	21

Questions were also asked about toll road usage and support (see Figure 3). Table 6 reports the descriptive statistics for the commuter and non-commuter segments in relation to road usage along the corridor in the past seven days.

Table 6: Reported road usage along corridors

	All trips for individuals sampled as a Commuter				**All trips for individuals sampled as a Non-Commuter**			
	Did make		**Could have made**		**Did make**		**Could have made**	
	Number trips	**Cost**	**Number trips**	**Cost**	**Number trips**	**Cost**	**Number trips**	**Cost**
Average	1.13	3.67	2.12	7.34	0.69	2.98	0.95	5.83
Median	0	0	0	2.2	0	0	0	0
Std Dev.	2.08	6.45	3.64	11.24	1.12	6.72	1.92	10.75
Min	0	0	0	0	0	0	0	0
Max	10	40	20	56	8	80	14	80

Approximately 42 percent of commuters reported supporting toll roads, matched exactly by the number who reported not supporting toll roads. About 15 percent of commuters reported not caring one way or the other. When asked about private public partnerships (PPPs) and toll roads however, a clear majority of respondents reported not supporting PPPs in the provision of toll roads. More non-commuters support the construction of toll roads (though not a majority), however like commuters, this support drops significantly when PPPs are involved in their construction. The exact results are given in Table 7 for these questions (see Figure 3 for the specific questions asked).

Table 7: Toll road and PPP support

	Commuter		*Non-Commuter*	
	Support toll roads	Support PPPs	Support toll roads	Support PPPs
Yes	42.41%	17.80%	46.00%	21.67%
No	42.41%	54.97%	35.67%	48.33%
Don't care	15.18%	27.23%	18.33%	30.00%

Model Results

A number of models were estimated. Table 8 reports the best models found for both segments. The observed component of utility is defined in equation (1).

$$V_{ref\,(\textbf{Best choice})} = ASC_{ref} + \beta_{fftf} x_{fftf\,(ref)} + \beta_{sdtf} \log(x_{sdtf\,(ref)}) + \beta_{fftt} x_{fftt(ref)} + \beta_{sdtt} \log(x_{sdtt(ref)}) + \beta_{tl} x_{tl(ref)} + \beta_{pc} x_{pc(ref)} + \beta_{tc} \log(x_{tc(ref)})$$

$$V_{sp1(\textbf{Best choice})} = ASC_{sp1} + \beta_{fftf} x_{fftf\,(sp1)} + \beta_{sdtf} \log(x_{sdtf\,(sp1)}) + \beta_{fftt} x_{fftt(sp1)} + \beta_{sdtt} \log(x_{sdtt(sp1)}) + \beta_{tl} x_{tl(sp1)} + \beta_{pc} x_{pc(sp1)} + \beta_{tc} \log(x_{tc(sp1)}) + \eta_{(best)}$$

$$V_{sp2(\textbf{Best choice})} = \beta_{fftf} x_{fftf\,(sp2)} + \beta_{sdtf} \log(x_{sdtf\,(sp2)}) + \beta_{fftt} x_{fftt(sp2)} + \beta_{sdtt} \log(x_{sdtt(sp2)}) + \beta_{tl} x_{tl(sp2)} + \beta_{pc} x_{pc(sp2)} + \beta_{tc} \log(x_{tc(sp2)}) + \eta_{(best)}$$

$$V_{ref\,(\textbf{Worst choice})} = -\begin{pmatrix} ASC_{ref} + \beta_{fftf} x_{fftf\,(ref)} + \beta_{sdtf} \log(x_{sdtf\,(ref)}) + \beta_{fftt} x_{fftt(ref)} + \beta_{sdtt} \log(x_{sdtt(ref)}) \\ + \beta_{tl} x_{tl(ref)} + \beta_{pc} x_{pc(ref)} + \beta_{tc} \log(x_{tc(ref)}) \end{pmatrix}$$

$$V_{sp1(\textbf{Worst choice})} = -\begin{pmatrix} ASC_{sp1} + \beta_{fftf} x_{fftf\,(sp1)} + \beta_{sdtf} \log(x_{sdtf\,(sp1)}) + \beta_{fftt} x_{fftt(sp1)} + \beta_{sdtt} \log(x_{sdtt(sp1)}) \\ + \beta_{tl} x_{tl(sp1)} + \beta_{pc} x_{pc(sp1)} + \beta_{tc} \log(x_{tc(sp1)}) \end{pmatrix} + \eta_{(worst)}$$

$$V_{sp2(\textbf{Worst choice})} = -\begin{pmatrix} \beta_{fftf} x_{fftf\,(sp2)} + \beta_{sdtf} \log(x_{sdtf\,(sp2)}) + \beta_{fftt} x_{fftt(sp2)} + \beta_{sdtt} \log(x_{sdtt(sp2)}) \\ + \beta_{tl} x_{tl(sp2)} + \beta_{pc} x_{pc(sp2)} + \beta_{tc} \log(x_{tc(sp2)}) \end{pmatrix} + \eta_{(worst)}$$

(1)

Where *ref* refers to the reference (recent trip) alternative, *sp1* is the stated preference route A, *fftf and fftt* are free flow times on a free road and toll road respectively, *sdtf and sdtt* are slowed down times on a free road and toll road respectively, *tl* is the number of traffic lights, *pc* is petrol cost and *tc* is toll cost. η is an error component associated with either the best (1st choice) or worst (2nd choice). As is common practice with best-worst choice data, the observation for the worst choice is assumed to be the negative of the best choice data. Under this assumption, preferences for the least preferred choice are assumed to be the negative inflection of preferences for the most choice (e.g., Marley and Louviere 2005, Marley and Pihlens 2012).

Models are estimated using error component logit models to accommodate differences in preferences across traveller in respect of unobserved components. In both cases, the error components model also allowed for the pseudo panel nature of the stated choice data (see Train 2009). The same model specification was found to provide a statistically superior model fit for both data sets compared to other functional forms for the attribute set. The model form involved taking the natural logarithm of the slowed down times for both the tolled and non-tolled routes, and the toll cost attributes. Other non-linear specifications, including taking the squares of the attributes, exponentials, and interaction effects, were also tested but found to result in significant decreases in model fits. The attribute transformations used resulted in significant model fit improvements over models that assumed simple linear in the utility model specifications. Both final models provide excellent model fits with adjusted pseudo ρ^2 values of 0.677.

All parameters are of the expected sign and statistically significant, with the exception of a constant term for Route A in the commuter model. The slowed down time as a logarithmic transformation and number of traffic light attributes makes for a direct comparison of the parameter estimates difficult. We leave this comparison to the later section discussing the VTTS results.

Table 8: Model results (times are in minutes and costs in 2012 $Aud)
FFT = free flow time, SDT = slowed down time.
The error components parameter estimates are the standard deviations of the latent random effects

		Commuter		*Non-Commuter*	
	Note	***Par.***	***(t-ratio)***	***Par.***	***(t-ratio)***
Reference Constant	-	-1.129	(-2.81)	-1.517	(-4.79)
SP1 dummy (1,0)	-	0.090	(1.60)	0.107	(2.98)
FFT Free route	-	-0.048	(-8.80)	-0.062	(-22.64)
SDT Free route	log	-0.712	(-6.84)	-0.749	(-7.97)
FFT Toll route	-	-0.041	(-4.92)	-0.050	(-7.36)
SDT Toll Route	log	-0.494	(-4.32)	-0.421	(-3.80)
No. Traffic lights	-	-0.092	(-5.94)	-0.083	(-6.78)
Petrol cost	-	-0.298	(-14.17)	-0.313	(-18.58)
Toll cost	log	-1.966	(-36.11)	-2.313	(-44.66)
	Error component				
EC (best)	(SP1,SP2)	3.496	(7.78)	3.293	(10.39)
EC (worst)	(SP1,SP2)	1.525	(10.90)	1.594	(15.91)
	Model fit				
LL(0)		-8127.42		-12685.66	
LL(β)		-2616.99		-4095.88	
ρ^2		0.678		0.677	
Adj. ρ^2		0.677		0.677	
AIC		1.159		1.16	
Respondents		189		295	
Observations		4536		7080	
Parameters		11		11	

Two error components are reported, both associated with the hypothetical routes A and B. The reason for this is because the best/worst data were exploded such that each choice task provided two observations for model estimation purposes. Separate error components were fitted to the best and worst choice observations (see Equation 1). The statistically significant error components suggest that respondents were less consistent in their choices related to the two hypothetical alternatives (i.e., higher unobserved variances) relative to the reference alternative, consistent with other literature.

Values of Travel Time Savings

The estimates of VTTS for each trip purpose are summarised in Table 9. These estimates can be applied in a traffic assignment model to each road link, where the calculated weighted average VTTS per trip is based on the mix of time on tolled and non-tolled sections.

The marginal WTP as the measure of VTTS describes how much the cost attribute, x_c, would be required to change given a one unit change in an attribute, x_k, such that the change in total utility will be zero. The marginal WTP is calculated by taking the ratio of the derivatives of both the attribute of interest and cost, which in the case of a linear in the attributes indirect utility specification is given by Equation (2).

$$WTP_k = \frac{\Delta x_k}{\Delta x_c} = \frac{\frac{dV_{nsj}}{dx_k}}{\frac{dV_{nsj}}{dx_c}} = \frac{\beta_k}{\beta_c}. \qquad (2)$$

where V_{nsj} is the utility for respondent *n* in choice task *s* for alternative *j*, and β_k and β_c are the marginal (dis)utilities for the attribute of interest and cost respectively. Calculation of the marginal WTP values in the current study is complicated by two considerations. Firstly, the existence of two cost components requires that a weighted average cost be calculated for the denominator in Equation (2). Secondly, the logarithmic transformation of several attributes, including the toll cost, requires a different treatment of the marginal WTP than is typically the case.

When either cost or the attribute of interest is transformed in some way, as is the case in the Table 8 model results, it becomes necessary to calculate the derivatives *with respect to all parts of the indirect utility function* where the attribute appears[8]. Thus, for example, suppose attribute x_l enters into utility as a linear in the attribute effect (e.g., consider the number of traffic lights attribute in Table 8 as described in Equation (1)) whilst x_c enters the indirect utility function both as a linear and as a log transformation (as per the parameters for cost in Table 8). The marginal WTP for a one unit increase in x_l then becomes

$$WTP_{tl} = \frac{\frac{d}{dx_{tl}}\left(\beta_{tl}x_{tl} + \beta_{pc}x_{pc} + \beta_{tc}\log(x_{tc})\right)}{\frac{d}{dx_c}\left(\beta_{tl}x_{tl} + \beta_{pc}x_{pc} + \beta_{tc}\log(x_{tc})\right)} = \frac{\beta_{tl}}{\frac{\left(\beta_{pc}x_{pc} + \beta_{tc}\right)}{\left(x_{pc} + x_{tc}\right)}}. \qquad (3)$$

The weighted average cost parameter is now a non-linear function of the trip related petrol and toll costs. As such, the marginal WTP values will vary according to these costs (i.e., the marginal WTP and VTTS values will not be a fixed value).

When the attribute of interest is treated as a natural logarithm (e.g., as with the slowed down times), then the marginal WTPs become

[8] Note that the log transformation affects the total variation in the dependent variable, namely the probability of choosing an alternative via the utility expression associated with each alternative.

$$WTP_{sdtf} = \frac{\frac{d}{dx_{sdtf}}\left(\beta_{sdtf}\log(x_{sdtf}) + \beta_{pc}x_{pc} + \beta_{tc}\log(x_{tc})\right)}{\frac{d}{dx_c}\left(\beta_{sdtf}\log(x_{sdtf}) + \beta_{pc}x_{pc} + \beta_{tc}\log(x_{tc})\right)} = \frac{\beta_{sdtf} / x_{sdtf}}{\frac{\left(\beta_{pc}x_{pc} + \beta_{tc}\right)}{\left(x_{pc} + x_{tc}\right)}}. \quad (4)$$

To illustrate the calculation of the WTP values, using equation (4) for slowed down time, consider for example, the commuter segment parameters (Table 8) and average values (Table 5). Firstly, the weighted average cost parameter must be calculated, as per equation (5) which is the denominator of equation (4).

$$\beta_c = \frac{\left(\beta_{pc}x_{pc} + \beta_{tc}\right)}{\left(x_{pc} + x_{tc}\right)} = \frac{(-0.298 \times 3.59 - 1.966)}{(3.59 + 3.72)} = -0.415. \quad (5)$$

The VTTS for slowed down time on a non-tolled part of the route[9] , for example, would be calculated via Equation (4), as given in (6).

$$WTP_{x_{sdt(non-toll)}} = \frac{\Delta x_{sdt(non-toll)}}{\Delta x_c} = \frac{-0.712 / 14.65}{-0.415} \times 60 = \$7.03 \quad (6)$$

For the free flow time on the non-tolled part of the route, the VTTS/hr is calculated as equation (7).

$$WTP_{x_{fft(non-toll)}} = \frac{\Delta x_{fft(non-toll)}}{\Delta x_c} = \frac{-0.048}{-0.415} \times 60 = \$6.94 \quad (7)$$

Table 9 summarises the VTTS per person hour for the various time components and marginal WTP for reducing the traffic lights along a route calculated at the sample average times and costs reported in Table 5. Confidence intervals calculated using the Krinsky and Robb (1986, 1990) method are also presented (n.b., the VTTS reported in the table are the medians calculated from the Krinsky and Robb simulations). As is to be expected, for the times associated with the non-tolled section of the route and tolled section of the route, the VTTS is higher for time spent in slowed down time than for free flow route travel times. Nevertheless, it is interesting to note that the VTTS for time spent in free flow conditions on a tolled section of a trip is lower than the VTTS for both free flow and slowed down time on a non-tolled section of a trip. This suggests that respondents are not willing to pay as much to save time spent in free flow

[9] The choice experiment offers a total trip described in terms of four time components (two describing that part of the trip on the road that is not tolled, and two associated with that part of the trip on the road that is tolled) and two cost components. The running cost is a parameter that applies to the petrol outlaid for the entire (four time component) trip; whereas the toll cost is incurred for part of the trip (i.e., two components only). However, behaviourally, we are making the reasonable assumption that individuals evaluate the marginal disutility of each component of time relative to the overall cost of the trip; in particular, they do not evaluate the travel time of the part of the trip that does not incur a toll against the petrol cost only. Importantly the choice experiment does not offer a fully free vs. a fully tolled route; rather travellers are offered trip alternatives which have differing compositions of free and tolled sections.

conditions on a tolled part of a trip than they are to save either free flow and slowed down time on a non-tolled part of a trip.

Table 9: VTTS estimates for commuting and non-commuting trips at sample medians
FFT = free flow time, SDT = slowed down time

	Commuter			*Non-Commuter*		
	VTTS /person hr	Lower 95%	Upper 95%	VTTS /person hr	Lower 95%	Upper 95%
FFT Free route	\$6.86	\$5.40	\$8.36	\$7.89	\$7.26	\$8.55
SDT Free Route	\$7.01	\$5.02	\$8.96	\$8.96	\$6.81	\$11.10
FFT Toll route	\$5.96	\$3.59	\$8.36	\$6.38	\$4.73	\$8.08
SDT Toll Route	\$12.12	\$6.48	\$18.01	\$11.03	\$5.28	\$16.92
	WTP /light	Lower 95%	Upper 95%	WTP /light	Lower 95%	Upper 95%
Traffic lights	\$0.22	\$0.15	\$0.30	\$0.18	\$0.13	\$0.23

Table 9 reveals, however, that commuters and non-commuters are willing to pay a premium to avoid congested traffic conditions on a tolled section of a trip. Since the opening of the new toll road, the traffic conditions are such that very little traffic congestion is likely to be experienced by road users. As such, road users would most likely only be willing to pay tolls at the lower rate (the FFT Toll route value). If experience suggests that toll roads may save say 10 minutes for a given journey, for example, then the appropriate toll to charge given the VTTS would be \$0.99 (see Equation 8) based on an average trip, assuming they are saving time under free flow conditions, compared to \$2.02 if the 10 minutes saved consisted solely of congested slowed down time on the tolled section of the trip (see Equation 9).

$$WTP_{x_{fft(toll)}} = \frac{\Delta x_{fft(toll)}}{\Delta x_c} = \frac{-0.041}{-0.415} \times 10 = \$0.99 \quad (8)$$

$$WTP_{x_{sdt(toll)}} = \frac{\Delta x_{sdt(toll)}}{\Delta x_c} = \frac{-0.494/5.9}{-0.415} \times 10 = \$2.02 \quad (9)$$

Independent of the specific values applied, several comments are required. Firstly, the VTTS for commuters appear lower than those for non-commuters for all but congested slowed down time spent on toll roads. This is however potentially misleading, and caution in interpretation is required. Firstly, the values reported in Table 9 are based on the average sample times and costs. Table 10 presents the VTTS for both the commuter and non-commuter segments calculated under two different travel time and cost assumptions. The first scenario shown assumes the average travel time and costs obtained from the commuter sample, whilst the second scenario assumes the times and costs derived from the non-commuter sample. For example, the mean time spent in free flow traffic conditions on the free route for commuters was reported to be 15.30 minutes compared to 18.56 for non-commuters (see Table 5). The parameter estimates for commuter and non commuter models are repeated in the table (in the column headed Est. Par.) after which the log-transformed estimates are presented (in the columns titled Trans. Par.). The VTTS and marginal WTP to avoid traffic lights are calculated for both the commuter and non-commuter models for both data scenarios. Note that these values differ slightly to those reported in Table 9, which were calculated as the median from a series of simulations. The results in the current table are calculated using the transformed parameter estimates, and hence represent and average estimate and not a median. The light grey columns in the table represent the application of the correct model to the corresponding sample values (i.e., the commuter model applied to the commuter sample averages and the non-commuter model applied to the non-commuter sample averages), whilst the remaining cells represent the application of the model to the other data sets sample averages. As can be seen, the VTTS and marginal WTP for avoiding traffic lights will depend upon the specific values associated with the trip undertaken.

Table 10: VTTS estimates for hypothetical commuting trip
FFT = free flow time, SDT = slowed down time

Scenario 1: average commuter levels

			Commuter			Non-Commuter		
	Mean x_k	**Note**	**Est. Par.**	**Tran. Par.**	**WTP**	**Est. Par.**	**Tran. Par.**	**WTP**
FFT Free route	**15.30**	Linear	-0.048	-0.048	$6.93	-0.062	-0.062	$7.91
SDT Free route	**14.65**	Log	-0.712	-0.049	$7.02	-0.749	-0.051	$6.52
FFT Toll route	**7.93**	Linear	-0.041	-0.041	$5.92	-0.05	-0.050	$6.38
SDT Toll Route	**5.90**	Log	-0.494	-0.084	$12.10	-0.421	-0.071	$9.11
Traffic lights	**8.32**	Linear	-0.092	-0.092	$0.22	-0.083	-0.083	$0.18
Petrol cost	**3.59**	Linear	-0.298	-0.298	-	-0.313	-0.313	-
Toll cost	**3.72**	Log	-1.966	-0.528	-	-2.313	-0.622	-
Weighted average Cost	**7.31**	-	-	-0.415	-	-	-0.470	-

Scenario 2: average non-commuter levels

	Mean x_k	**Note**	**Est. Par.**	**Tran. Par.**	**WTP**	**Est. Par.**	**Tran. Par.**	**WTP**
FFT Free route	**18.56**	Linear	-0.048	-0.048	$6.94	-0.062	-0.062	$7.91
SDT Free route	**10.64**	Log	-0.712	-0.067	$9.68	-0.749	-0.070	$8.98
FFT Toll route	**9.21**	Linear	-0.041	-0.041	$5.93	-0.05	-0.050	$6.38
SDT Toll Route	**4.89**	Log	-0.494	-0.101	$14.61	-0.421	-0.086	$10.98
Traffic lights	**8.92**	Linear	-0.092	-0.092	$0.22	-0.083	-0.083	$0.18
Petrol cost	**3.37**	Linear	-0.298	-0.298	-	-0.313	-0.313	-
Toll cost	**3.79**	Log	-1.966	-0.519	-	-2.313	-0.610	-
Weighted average Cost	**7.16**	-	-	-0.415	-	-	-0.470	-

Secondly, the fact that the non-commuter VTTS appear to be higher than those of the commuting segment may also be the result of the sampling rule applied for the study. It is typically assumed that many non-commuting trips are undertaken outside of peak travel times. In this present study, the non-commuting trips were sampled solely from trips undertaken in the morning peak travel period[10]. It is therefore likely that non-commuters travelling in this time period are under some form of scheduling constraint, otherwise they would have travelled at a less congested time. This is borne out by the large number of non-commuting trips going to/from the airport either for the purposes of leisure air travel or for picking up or dropping another party. Such trips are likely to require that the driver arrive at the airport at a very specific time, similar to those travelling to work. The assumption that non-commuting trips of this nature are more flexible than commuting trips may not hold. For this reason, we are comfortable with this finding, which indeed may be an important finding for VTTS research.

[10] The focus on the peak period was imposed by the consulting firm who commissioned us to undertake this study.

For completeness, Table 11 reports the weighted average VTTS values based on the sample times and costs (Table 5). For example, the combined free flow travel time (i.e., *fftf* + *fftt*) and time spent on non-tolled roads (i.e., *fftf* + *sdtf*) are reported in Table 11, which differs to the values reported in Table 9 which provides the VTTS for each component calculated separately. Such conversions are necessary to allow for a comparison of VTTS with previous studies which do not separate the mix of times by roads for a single trip. These values are reported for an average (sample) trip and hence, should be adjusted when applied to other data. Nevertheless, it is interesting to note that the VTTS reported in the table are substantially lower than those reported in a 2006 study in the same catchment area prior to the opening of the new toll road (see Table 12). The weighted average VTTS for commuters is 42.3 percent (8.24/19.46) of that reported in the 2006 study and 49.7 percent for non-commuters (8.19/16.47), ignoring inflation. This represents a significant decrease in the VTTS over the past six years.

Table 11: VTTS estimates for non-commuting

	Commuter			*Non-Commuter*		
	VTTS /hr	Lower 95%	Upper 95%	VTTS /hr	Lower 95%	Upper 95%
Free flow time	$6.55	$5.45	$7.68	$7.39	$6.74	$8.05
Slowed down time	$8.48	$6.13	$10.89	$9.61	$7.18	$12.04
Free route time	$6.93	$5.72	$8.15	$8.28	$7.38	$9.19
Toll route time	$8.58	$5.78	$11.39	$7.99	$5.82	$10.19
Weighted average VTTS	$8.24	$7.00	$9.51	$8.19	$7.18	$9.20

Table 12: VTTS estimates from 2006 study

Attribute	Commuter Peak	Non-Commuter Peak
Weighted average VTTS	$19.46	$16.47
Free Flow	$15.84	$13.71
Slowed down	$18.31	$16.75
Stop Start Crawl	$23.81	$19.56

Conclusions

The focus of the study is on the derivation of VTTS for a newly opened toll road. Data were collected from respondents representing both commuter and non-commuting trips. In comparison to a similar study undertaken in 2006, the VTTS for both segments are close to half those found in the 2006 study[11].

Several explanations might exist for such a significant drop in the VTTS values; however the most likely candidate explanations are that respondents now have real life experience with the toll road and hence understand better the true costs and benefits of the road, and in addition, post the initial assessment of the VTTS (undertaken prior to construction and opening on the new toll road), there has

[11] In ongoing research, we are investigating the role that data associated with the supplementary question in Figure 2 might play, namely “Assuming you would select your most preferred alternative, how certain are you that you would actually choose this alternative in real life?” This is not considered in the current paper given the focus on the redefinition of the attribute components.

been a change in preferences given exogenous events such as the global financial crisis.

Furthermore we suggest that a more accurate representation of the mix of tolled and non-tolled road links in defining the door-to-door 'tolled route' alternative enables a behaviourally more realistic assessment of the gains in travel time attributable to the road links that are free and those that require payment of a toll. We have found in another study[12] that a similar lowering of the VTTS estimates is obtained. From the evidence produced by these two studies, we cannot lay claim to the tolled and non-tolled road link distinction being a major contributing factor in lowering VTTS compared to other candidate causes; however we suggest that this makes good methodological sense in all future stated choice studies involving toll roads.

The empirical findings are refreshing in the sense of aligning with what we reasonably believe is a contributing influence to high traffic forecasts compared to actual traffic levels; however it now adds a new element of concern about the extent to which traffic forecasts are sufficiently attractive to parties being asked to participate in funding toll road projects. Given the desire to increase accuracy of the major source of risk associated with investing in urban toll roads, this suggests that a different funding model may be required. The alternative might well be a debt financed model resident within the public sector, with future prospects of equity finance if the evidence on actual traffic levels bears sufficient appeal to warrant equity contributions.

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