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ESTIMATING THE VALUE OF PRIVATE TRAVEL TIME FOR NSW

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ABSTRACT

Between 2012 and 2015, TfNSW undertook a suite of Stated Preference (SP) surveys users to estimate values of travel time (VOT) for public transport and car users. A principal aim was to test the 40% wage rate assumption which has been the basis for valuing private car travel time in NSW since the late 1990s.

An Internet Panel survey was tested but produced poor quality responses from overly price sensitive respondents and was therefore discontinued. Instead, car users were interviewed at activity centres about a recent trip. Four surveys of public transport surveys were undertaken. The largest survey used self-completion questionnaires handed out and collected by surveyors on-board buses, trains and ferries. The three other PT surveys used interviewers with handheld computer tablets. The surveys were kept short and simple which enabled a large sample of 8,877 respondents and 71,000 choice observations to be achieved.

A conventional 'ratio of slopes' approach was used to estimate VOT for public transport. The car survey was designed to include a 'threshold' approach which outperformed the attributes approach and also provided a statistical distribution for the VOT.

The surveys supported a 40% wage rate assumption for private travel time by car and for commuting trips by public transport. However a lower VOT of around a quarter of the wage rate was estimated for non-commuting public transport travel. Part of the reason for the lower VOT for non-commuting trips was lower personal income. By standardising for income, some of the observed difference by mode and trip purpose was able to be removed.

The SP surveys were deliberately designed to test how VOT changed with trip length. It was found that although time and cost sensitivity declined as trip length increased, they both declined at a similar rate which left VOT largely unaffected.

1. Introduction

Many transport improvements aim to achieve the same transport task in less time and for road projects, the value of the time savings typically accounts for between 60% and 80% of total project benefit. Evaluating the benefit is therefore important and involves forecasting the time saving in minutes then valuing the saving in dollars. This paper is about valuing the time savings.

The valuation of travel time savings is either based on the marginal productivity of working time or on consumer behaviour usually via Stated Preference surveys. The actual value that is used in evaluations reflects evidence, policy and practicality. Evidence may be theoretical, empirical or both. Transport for NSW (TfNSW) produces its *'Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives'* (PGEATII) which includes a set of parameters for evaluating road and public transport projects. In terms of travel time, two sets of values are presented dependent on whether the employer 'pays' for the travel time (business travel) or whether the traveller pays (private travel).

The basic premise for business trips is that time spent travelling is unproductive with the 'opportunity cost' equal to the foregone working time and in PGEATII, business travel time is valued at $48.45/hr (2013/14 prices) based on 128% of average hourly earnings (AHE) comprising 135% of AHE less payroll tax of 7%.[1]

Private travel time is valued at 40% of AHE which derives from a 1997 Austroads workshop (Rainey, 1997). The workshop reviewed international evidence and decided to adopt 40% of AHE for car, public transport (including waiting time), walking and cycling. On this basis, PGEATII values car travel time at $15.14/hr (2013/14) based on a wage rate of $37.85/hr. The principal aim of the VOT study was to test the 40% wage assumption for private travel by car and public transport.

The rest of the paper is as follows. Section 2 reviews the literature. Section 3 summaries the TfNSW survey approach. Section 4 presents the car survey and Section 5 the public transport survey. Section 7 presents a trip weighted average value of time. Section 8 looks at the effect of fare concessions and income on the value of time. Section 9 looks at how constant the value of time is with distance. Section 10 presents a generalised cost comparison and Section 11 gives the main conclusions of the study.

2. Literature Review

Before the establishment of TfNSW, the value of travel time used for road and rail evaluations in NSW had different derivations. The road value was largely sourced from Austroads (2012) while the rail value was estimated by Stated Preference surveys of rail passengers. The result was a car value of time around 20% higher than rail.

The road value derived from an Austroads review undertaken in the mid-1990s of Australian and overseas research (particularly the UK). A consensus was reached at a 1997 Austroads workshop to value private travel time at 40% of average hourly earnings (AHE). Private travel time included private car, motorcycle, bicycle and pedestrian travel (including travel to and from work and recreational travel), waiting time and public transit and tourist passenger travel. Austroads has since updated the value biannually.

The Australian National Guidelines on Transport System Management includes values of travel time for use in demand forecasting and project appraisal, ATC (2006). For private car travel (driver and passenger) the Austroads 40% wage rate value is given. For bus and train, a value

[1] Business travel time includes travel for all modes, including taxi, hire and reward bus as well as light commercial, heavy rigid and articulated commercial vehicles.

of $10/hr was recommended based on a review of Australasian stated preference market research studies. A set of travel time multipliers cover walking, waiting, crowding and reliability. The multipliers being greater than one imply higher dollar values of time.

Great Britain has probably done more thinking and research about the value of time than any other country. At the end of the 1960s, a decision was made for all publicly funded projects to use a single standard value for non-working travel time based on *"the average income of travellers on the journey to work and is updated using the growth in disposable income per head of the population",* (Nichols, 1975). Based on work by the Ministry of Transport, the standard value of time was set at one quarter of the average gross wage rate and was assumed to grow proportionately with income. Appropriate corrections were recommended (MAU Note 179, p 25) to convert to household income such that the value of adult travel time was set at 19% of gross household income (assuming 2,000 hours per working year). In 1987, the Department of Transport increased the standard value to 43% of average hourly earnings of full time adult employees and updated the value in proportion to the change in real income, (UKDoT, 1987).

In 2014-15, a national survey costing a reported £2 million (Aus$3.4 million) was undertaken by Arup (2015) to estimate values of time for private and employee business travel by car and PT. The study recommended the same value for car, bus, rail and other public transport for private travel but different values for business travel: "*due to [private] values reflecting some self-selectivity between modes whereas for business travel, the value should be mode-specific as we interpret differences between modes to be real differences".* For commuting a value of £11.21/hr (Aus$19.29/hr was recommended and for 'other purpose' private travel a value of £5.12/hr (Aus$8.81/hr). A set of travel time multipliers were estimated that apply to the 'base' values. For PT, standing, particularly in 'densely packed' conditions, increases the value of time. For car commuting, a multiplier of 0.51 applies to the VOT for free flow travel, 0.72 for light congestion and 1.37 for heavy congestion (for other trips, the values were 0.47, 0.83 and 1.89). Thus commuting in light traffic congestion would be valued at Aus$13.88/hr. The survey also estimated reliability ratios (the ratio of the standard deviation over the mean travel time) for car travel of 0.33 for car commuters, 0.35 for other private trips and 0.42 for employee travel.

The USA Department of Transport (2011) gives different values of time for business and personal travel but the same values by mode. Business travel time is valued at the median hourly gross wage with personal travel valued at half the median household hourly income. Exceptions are air and high speed rail for which travel time is valued 250% greater for business travel and 190% greater for personal travel than other modes.

Transport Canada (1994) adopts 50% of the average wage for private travel for all modes and trip purposes. Business travel time is valued at 100% of the average hourly employee cost by mode. As a result, bus and rail business travellers have a lower value than car drivers. The Canadian guidelines also state that a lower value for business travel can be adopted when work can be done during the journey.

Until 2013, the NZ Transport Agency based its values on a national Stated Preference survey conducted in 2001 by Beca (2002). The survey produced values of time that were higher for car users than for bus and train users. The value for commuting was NZ$7.80/hr for car drivers, NZ$5.85/hr for car passengers and NZ$4.70/hr for seated bus and train passengers (NZ$6.60 standing).[2] For 'other' private travel, the values were NZ$6.90 for car drivers, NZ$5.20/hr for car passengers and NZ$3.05 for seated bus and train passengers. Thus the PT values were 60% of the car driver value for commuting and 44% for 'other' trips.[3]

In 2012, a large scale survey of 12,557 bus and train users was undertaken in Auckland, Christchurch and Wellington by Douglas Economic (2016) which estimated a value of time of NZ$9.09/hr. This value was 50% higher than the $6/hour in the Economic Evaluation Manual.[4] In 2013, NZTA decided to adopt the same value for private travel time for public transport and car in a July 2013 NZTA Circular for economic appraisal purposes with the common value taken from the Beca car value of time. Thus for 2017, the value for commuting was NZ$11.47/hr (147% of the 2002 value). For demand forecasting purposes, the 2001 'behavioural values' updated for consumer price inflation remain the recommended values.

In summary, it has become the norm to adopt a single value of time for reasons of 'equity'.[5] As Nash comments this is not without allocative bias: *"the British approach, again like many others, attempts to allow for equity considerations by using common values of time, risk of accidents and environmental amenity regardless of income. This might have been reasonable at a time when appraisal was mainly applied to road schemes which were paid for by the government but gave time savings to users, but now that appraisal is often applied to schemes which trade-off time savings against money cost (e.g. whether to replace buses with higher priced light rail services, whether to reduce road congestion by means of road pricing), it may be highly misleading. It would be quite possible for the appraisal to conclude that the scheme was desirable on the basis of a standard value of time, when according to the actual values of the users it was not (or vice versa)."* (Nash, 2010, p. 9)

3. TfNSW Value of Travel Time Study

TfNSW began a program of market research in 2012 to estimate values of time for private travel. The principal aim was to assess the Austroads 40% hourly wage assumption.

Different questionnaires and survey methods were used for car and public transport. The car survey was carried out by interviewers at activity centres using computer tablets with the SP framed about a recent trip.

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[2] Traffic congestion increased the values for car (but not for bus) up to a maximum additional cost of $2.75/hr for drivers and $2.05/hr for passengers. Pedestrian and cyclist travel time was valued (assumed not estimated) at $6.60/hr for commuters and $4.25/hr for 'other' travel.

[3] NZTA provides update factors annually based on the Consumer Price Index. CPI has been shown to underestimate the growth in (nominal) value of time however. Wages and Income indices more closely match observed trends, see Douglas and Karpouzis (2011).

[4] https://www.nzta.govt.nz/assets/resources/research/reports/565/565-Pricing-strategies-for-public-transport-summary-story.pdf

[5] It could be argued that a single value has been used in Business Cases because the 40% wage rate 'car value' increases the PT VOT and in so doing increases the economic return for public transport projects that might otherwise struggle to get over the BCR hurdle of 1.0.

Four surveys of public transport surveys were undertaken. The largest used self-completion questionnaires handed out and collected by surveyors on-board buses, trains and ferries. The three other PT surveys used interviewers with tablet computers. Both surveys were kept short and simple and altogether obtained 8,877 responses providing over 70,000 choice observations.

Like most VOT studies, the surveys were designed as 'same mode' choices. Car respondents compared sets of car trips, bus respondents compared sets of bus trips and ferry respondents compared sets of ferry trips. There were no 'between mode' choices where respondents might compare a car trip with a bus trip.

Using 'within mode' choices avoided 'confounding' response to the cost and time trade-offs by modal preferences. A review by Douglas and Wallis (2013) of Australasian studies conducted over more than two decades found that "*generally, those SP studies that presented 'same mode' choices (e.g. bus v bus) produced less variable estimators (a lower standard error in relation to the mean estimate) than studies that presented 'different mode' choices (e.g. bus v car). The probable reason is that 'same mode' choices focus attention on the trade-off of time versus cost and are less prone to respondents consistently choosing one alternative (for example car over bus) irrespective of the fares and times shown for bus".* There will, of course, be circumstances when both modal preference parameters and values of time are required. One such study was a 'sister' to the Value of Time surveys. Douglas and Jones (2016) estimated a set of demand parameters for Inner Sydney to be used in a public demand forecasting model. The SP allowed for variations in trip length (10 to 40 minutes), type of mode (bus, rail and light rail) and quality of mode. However in order to do this, a full factorial design of 243 choices was required with interviewers using laptop computers to implement it. Although the survey was successful, it was more expensive to undertake than a self-completion survey and also, given its success, there was no need to estimate additional modal preferences in the Value of Time study. Thus all the VOT surveys were within mode.

4. Car Stated Preference Survey

The car SP survey took a year to develop and implement, starting with a literature review followed by the sequential testing of three designs (including several variants).[6] The final design included travel time variability in order to accommodate the peer reviewer (despite the added complexity for respondents). A review of alternative variability measures recommended the standard deviation of travel time. Several ways of presenting variability to respondents were considered with the presentation used in the Netherlands Value of Time study considered the best (which had used focus groups to optimise the design), Significance (2012). Accordingly, five travel times were shown with each time having an equal chance of occurring. The distribution was symmetrical with two times higher and two times lower than the mid-point time (20% and 40% higher/lower).

The market research company and the peer reviewer suggested an internet panel (IP) to provide the respondents. However concerns arose from the literature about a possible underestimation. For example, the Netherlands Value of Time (Significance, op cit) estimated a value of time

[6] A longer description of the development of the car survey is provided in Douglas and Legaspi (2018).

for IP respondents that was half that of non IP respondents. The UK Value of Time study also deliberately avoided IP surveys preferring recruitment at petrol stations.

As a test, the rail SP survey was converted to an IP survey. The rail survey had already been undertaken onboard trains using self-completion paper questionnaires and had estimated a value of time of $14.23/hr for 709 commuters travelling to/from work.

Table 1: Value of Time for Rail Commuters estimated by Internet Panel and On-board Survey

Estimate	Onboard Self Completion (SC)	Internet Panel (IP)	IP/SC
Value of Time $/hr	14.23	9.87	-31%
Percent VOT >$12/hr^	61%	38%	-38%
Annual Income $kpa	60	78	30%
Fare Concession %	16%	14%	-13%
Respondents	709	74	-

^ 135 onboard and 29 IP answered a choice question of paying $2 to save 10 minutes. The difference was significant at the 95% confidence level (t=2.3).

A total of 125 journey-to-work rail commuters who were members of an IP and who had a residence within metropolitan Sydney was obtained. 25 of these responses were removed by the survey company for compliance reasons such as 'speedsters' (too quick a response) and incomplete answers. Of the remaining 100 responses, 22 were considered highly dubious given their response to some of the context questions. As an example, origin and destination stations of Aberdeen and Bathurst were given which would have meant an unbelievably long commute! The two stations were at the top of the drop down list.

The value of time for the remaining 78 IP respondents was $9.87/hr. The value was 31% lower than the $14.23/hr for the 709 self-completion survey commuters and this was despite their incomes being 30% higher ($78k IP versus $60k on-board self-completion). Thus, as with the Netherlands study, the IP gave a significantly lower value of time and the same reason was considered valid. That is, members of IP are likely to be more price/cost focussed perhaps reflecting their membership of an IP as an income supplement.

It was therefore decided to undertake the car survey with interviewers using hand-held tablets at 'activity centres'. Figure 1 shows two of the six interview locations.

In total, 613 completed interviews were obtained (which exceeded the target of 500). Most were undertaken between in early December 2015. Interviews were undertaken on weekdays and on a Saturday between the hours of 9am and 4pm (85%) 4pm and 6pm (11%) and evening (3%).[7]

[7] Some of the Pilot surveys were able to be include in the Main Survey were undertaken between July and November 2015.

Figure 1: Two of the Six Locations where Car Surveys were undertaken

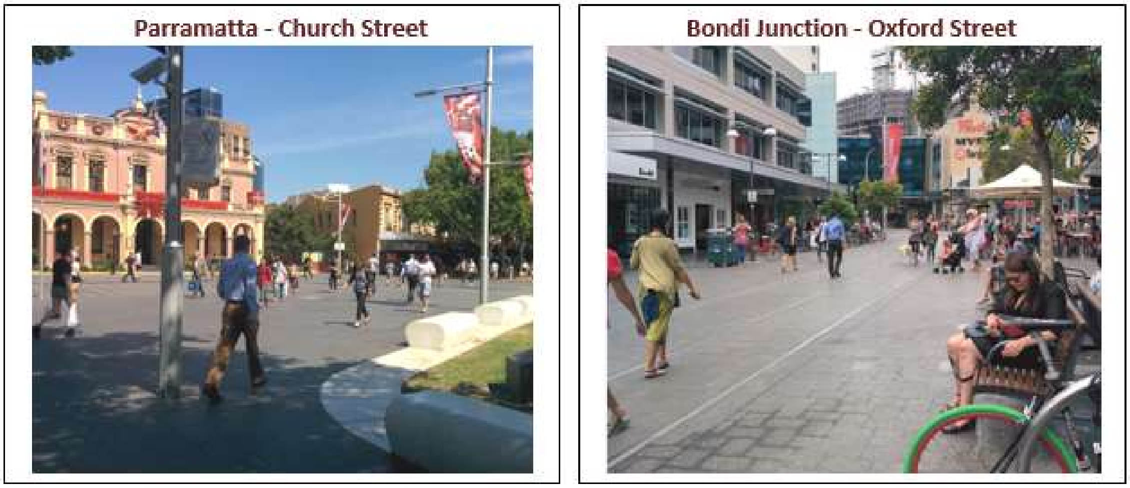


Table 2: Car Sample Size by Survey Location

#	Centre	Location	Area Code	Target Interviews	Actual Interviews
1	Parramatta	Church Street	SYD	75	168*
2	Bondi Junction	Oxford Street	SYD	75	75
3	Chatswood	Victoria Avenue	SYD	75	81
4	Hurstville	Forest Road near rail station	SYD	75	76
5	Newcastle	Hunter Street Mall^	N&W	100	107
6	Wollongong	Crown St Mall	N&W	100	106
All			Total	500	613

*includes 89 pilot survey interviews ^Water side along Honeysuckle Drive and Wharf Road near Queens Wharf

The survey had a 'soft' target of 50% commuting to or from work (JTW) and 50% 'other' with commuting trips targeted first. A set of socio-economic, demographic and travel questions were included to assess the sample and explain response. The questions were either 'general' (e.g. age group) or specific to the trip that the SP was referenced. Table 3 presents a summary. Distinctions were made between Sydney respondents and those in Newcastle and Wollongong (N&W) and between commuting and other trips.

Potential respondents who never paid any car costs were screened out. For those that did pay, 70% normally paid all the costs, 18% normally paid some costs and 13% sometimes paid some costs.

Passengers were asked about how long the trip took (one way) to determine which of six trip length SP sets the respondent completed. Respondents were only asked to consider trips longer than 15 minutes and for 95 respondents, the minimum 15 minutes was given. The maximum time was 10 hours (600 minutes) but there were only 20 respondents whose trip took over 2 hours. The average time was 40 minutes and the median time was 30 minutes.

To assess travel time variability, passengers were asked about their quickest and slowest times. Sixty respondents could not answer because they made insufficient trips. For those who did answer, the quickest trip was 20% shorter and the slowest trip was 46% longer than the typical time.

Table 3: Sample Profile

Profile	Summary
Trip Purpose	47% Commuting to/from work, 53% 'other' (including 17% Shopping, 15% Visiting Friends and Relatives and 7% Personal Business).
Gender	38% Female and 62% Male.
Age	Average age was 38. Under 18s were not surveyed. 52% were aged between 18 and 34. 5% were over 64.
Car Ownership	60% owned a car and were the only user, 27% owned and shared and 13% did not own a car. Newcastle and Wollongong respondents were more likely to own a car and be the only user than Sydney respondents (69% v 55%).
Share of Car Costs	70% always paid all the car costs, 18% always pay some and 13% sometimes paid some.
Drivers Licence	4% did not have a drivers licence and answered the survey as a passenger.
Trip Day	70% made the reference trip on a weekday and 30% at the weekend.
Trip Time	54% made the reference trip in the peak (36% AM & 18% PM) and 46% outside the peak (37% inter-peak and 9% evening).
Driver/Passenger?	529 made the reference trip as a driver (85%) and 89 (15%) as a passenger.
Car Occupancy	The average car occupancy was 1.7 (1.3 for commuting and 2.0 for other trips). 56% travelled alone, 28% with one other person, 10% with two others, 4% with 3 others and 1% with 4 others.
Trip Frequency	68% made the reference trip regularly (more than once per week), 26% made the trip occasionally (>2 per year) and 5% made the trip rarely (once a year or first time).
Trip Length (mins)	Trip length ranged from 15 minutes (the minimum) to 10 hours. The average was 40 minutes with a standard deviation of 45 minutes. Commuting trips tended to be shorter (34 mins) than other trips (46 mins).
Trip Time Variability	60 did not answer since they rarely made the reference trip which reduced the typical time to 35 minutes. The longest time was 46% greater (51 mins) and the shortest time was 20% faster (21 mins) than the typical time.
Petrol Cost	Petrol cost $7.50 for the reference trip with a median cost of $5. There were several outliers with the maximum cost of $130 (queried by the interviewer). Commuting trips had a lower fuel cost of $5.70 compared to other trips of $9.30 which reflected trip length).
Toll Payment?	One in five paid a toll for the reference trip. For those that did, the average toll paid was $7.37. Sydney respondents (25%) were more likely to pay a toll than Newcastle and Wollongong (6%) respondents.
Total Trip Cost	The reference trip cost $8.87 comprising $7.50 in fuel (85%) and $1.37 in tolls (15%). Commuting trips had a lower cost ($6.69) than other trips ($11.01).
Cost per Minute	The reference trip cost 22 cents per drive time minute with commuting trips costing less at 20c/min than other trips 24c/min.
Cost Sharing	79% paid all the costs for the reference trip and 21% paid some of the costs. Those that shared were asked the percentage they paid. Over all respondents, the percent of costs paid by the respondent averaged 88%. Cost sharing reduced the cost from $8.87 to $7.81 for the respondent's reference trip.
Cost per Respondent	Taking account of car occupancy produced a cost of $5.35 per trip.
Socio-economic Status	82% of respondents were working, 7% studying, 7% retired 2% were house persons and 2% were unemployed.
Personal Income	93% answered the income question (45 refused). The average income was $62k. 24% had an income <$30k, 27% $30-$60k, 25% $60-$90k, 15% $90-$120k and 9% >$120k. Commuters had highest average $68k with other trips averaging $57k. Across the locations, Wollongong had the lowest income at $57k and Newcastle the highest at $75k.

Variability was greater for Sydney respondents (25% quicker and 50% longer) than N&W (14% quicker and 39% slower) and greater for commuting (24% quicker and 50% longer) than other trips (14% quicker and 39% longer).

The maximum spent on fuel was $130 (an amount queried by the interviewer) with seven trips exceeding $50. The average was $7.50 with a median of $5. Commuting trips averaged $5.70 compared to $9.30 for other trips.

Just less than a fifth paid a toll. The average was $7.37 with toll payers tending to make longer trips (58 mins) than non-toll payers (36 mins). When calculated over all respondents (602), the toll reduced to $1.37 per trip. Sydney respondents (24%) were five times more likely to pay a toll than N&W respondents (6%) although the amount was similar. Commuters were slightly less likely to pay a toll (16%) than other trips (21%) and they paid a lesser amount on average ($6.39 versus $8.01). Over all respondents, tolls worked out at 99c per trip for commuters and $1.71 for other respondents.

The total cost (fuel plus toll) averaged $8.87 comprising $7.50 fuel (85%) and $1.37 tolls (15%).[8] The amount was higher for Sydney ($9.32) than N&W respondents ($7.80) largely due to tolls. Commuters averaged $6.69 and 'other' trips $11.01.

The costs per vehicle shown in the SP were calculated using a cost per minute figure. The amount was based on the Pilot Survey response which gave a figure of 25 Cents per minute. The main survey confirmed the rate for Sydney (24 C/min) but was lower for N&W (19C/min). Commuters at 20C/min had a lower unit cost than 'other trips' at 24C/min.

Cost sharing reduced the cost to $7.81 for the respondent whereas taking account of occupancy reduced the cost per occupant to $5.35 per trip.

Table 4 presents the experimental design which had 16 SP show cards with each respondent completing eight.

On eight show cards, travel time was shown as a 'typical time' and these choices were the simplest for respondents to do and they worked very well. SPD 11 on the left hand side of Figure 2 shows an example. The choice is to pay $5 to save 20 minutes which is a 'threshold' value of time (VOT) of $15/hr.

The other eight choices included travel time variability as requested by the peer reviewer which required a range in travel time to be shown. To do this, five drive times (40% less than the mid-point, 20% less, midpoint, 20% longer and 40% longer) were presented with each time having an equal chance of occurring.

[8] An alternative estimate was to use only those respondents who answered both the fuel and toll questions; this increased the total cost slightly to $8.96 per trip.

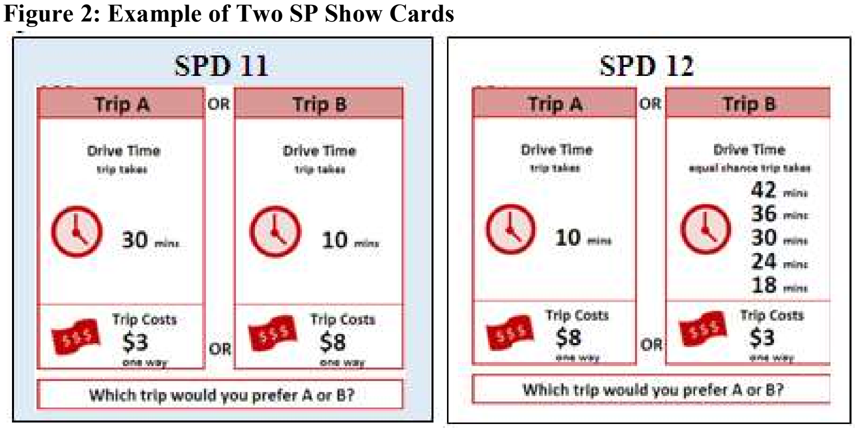
Table 4: Car Stated Preference Experimental Design

SPD	Levels			Differences (Trip A – Trip B)				Design		
	Cost	Time	TTVar	Cost $	IVT	TTVar	VOT	SPC	Rev	Set
1	0	0	0	4	-20	0	12	5	0	1
2	0	0	1	4	-20	0:40%	12	10	1	2
3	0	1	0	4	-10	0	24	14	1	2
4	0	1	1	4	-10	0:40%	24	8	1	1
5	1	1	0	3	-10	0	18	1	0	1
6	1	1	1	3	-10	0:40%	18	12	0	2
7	1	0	0	3	-20	0	9	13	1	2
8	1	0	1	3	-20	0:40%	9	2	0	1
9	2	1	0	5	-10	0	30	3	1	1
10	2	1	1	5	-10	0:40%	30	15	0	2
11	2	0	0	5	-20	0	15	9	1	2
12	2	0	1	5	-20	0:40%	15	4	0	1
13	3	0	0	2	-20	0	6	7	1	1
14	3	0	1	2	-20	0:40%	6	16	1	2
15	3	1	0	2	-10	0	12	11	0	2
16	3	1	1	2	-10	0:40%	12	6	0	1

SPD experimental design; SPC Questionnaire show card number; VOT $/hr; Rev show card reversed
TTVar Travel time variability

SPD 12 on the right hand side of Figure 2 shows an example. The five drive times for option B are 18, 24, 30, 36 and 42 mins. The standard deviation of these five times is 9.49 minutes. Dividing by the average time of 30 minutes gives a Coefficient of Variation (CV) of 0.32. The reliability ratio (RR) which is used in road traffic modelling is the standard deviation of travel time expressed as a ratio of the mean travel time.

Figure 2: Example of Two SP Show Cards



From the feedback the interviewers provided, complicated designs should be avoided (particularly so for self-completion IP surveys). It was travel time variability that caused the most problems with an interviewer remarking: "*the show cards were fine however the concept of 'equal chances of taking 18, 24 30 36 and 42 minutes' was still not intuitive and required explanation at times*".

The effect of travel time variability can be deduced by comparing the response to SPD 11 with SPD 12 since both have the drive time. Despite its simplicity, no similar design could be found in the literature. The tendency over the last decade, at least in Australia, has been to design ever more complicated questionnaires that fill a computer screen with times, costs and attributes for three or more alternatives with the levels selected from an experimental design Alan Turing might have struggled to decipher.

Cost and drive time were specified as differences (option A minus option B). The design specified four levels for travel cost of $2, $3, $4 and $5, two levels for drive time of -10 and -20 minutes and two levels for travel time variability of 0 and 40%. The design was a full factorial (4x2x2). However asking one respondent sixteen questions was too many so the design was split into two sets of eight. The show card order was randomized. Half the show cards were 'reversed' (sometimes the faster choice was shown on the left and sometimes on the right) to make the design less obvious and encourage respondents to consider the questions.

Six trip length sets were developed (short, short-medium, medium, long and very long) by adding travel time (or travel cost) to mid-point values to maintain the time and cost differences. The mid-point costs were based on a 22 cents per minute derived from the Pilot surveys.

As each respondent completed eight SPs, the total number of observations was eight times larger. Including pilot response (where the levels were the same as the Main Survey) gave a total number of SP observations of 4,904 SP from the 613 interviews. The number of respondents completing each SP was around 300 (i.e. half the sample of 613). Response was well-balanced, ranging from 286 for SP2 to 304 for SP7. It was therefore unnecessary to introduce any balancing weights.

Across the six SP trip length categories, 268 (44%) had made a 'last' trip of between 15 and 25 minutes and were allocated the short SP design. 114 (19%) completed the short-medium, 111 (18%) the medium design and 55 (9%) the medium-long design. Only 35 (6%) completed the long design and 30 (5%) the very long design.

The SP aimed to get respondents to vary their choice over the eight questions, sometimes selecting the fast/expensive option and sometimes the slow/cheap option. Over the full sample of 613 respondents, 73% varied their choice, Table 5.

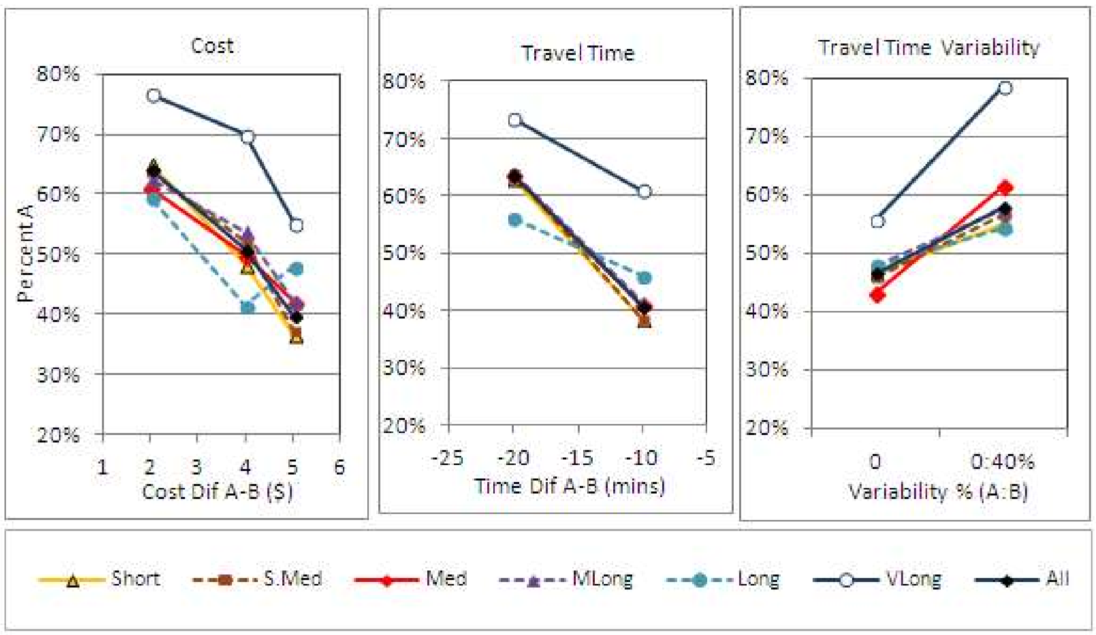
Table 5: Car SP 'Trading Off'

Choice	All	
	N	%
Always A (faster)	80	13%
Always B (cheaper)	85	14%
Varied Choice	448	73%
Total	613	100%

The 27% who did not vary their choice were evenly split between those who always went for the faster/more expensive option (i.e. had a value of time over $30/hr (13%) and those that always went for the slower/cheaper option i.e. had a value of time less than $6/hr (14%).

Graphing aggregate response to the SP questions helps understanding.[9] Figure 3 plots the mean percentage choosing alternative A for each of the cost and time levels in the experimental design. Cost had four levels with the percentage choosing A ranging from 64% when option A cost $2 more than option B to 40% when A cost $5 more than B. Overall response, shown as the black line, was effectively linear.

Figure 3: Percent Choosing A by Time and Cost Level



Travel time had two differences of -10 and -20 minutes. The percentage choosing A declined from 64% when option A was 20 minutes quicker to 41% when it was 10 minutes quicker.

Travel time variability had two levels (zero variability and 0% variability for A and 40% for B). For the total sample, the percentage choosing A declined from 58% when travel time was 40% variable in option B down to 47% when option B had zero variability.

Response for five of the six trip lengths was similar. The exception was for the Very Long segment where a noticeably higher percentage chose A (the faster/more expensive option). The sensitivity to cost reflected in the gradient of the slope was similar however. For travel time, the slope was flatter reflecting a lower sensitivity (as was the responses to the long SP). For travel time variability, sensitivity was similar for all six trip lengths.

A logit model was fitted to the individual response data which took a value of one if option A was chosen and zero if not (i.e. option B was chosen). The variation in choice was explained

[9] Despite enhancing reader understanding, few academics provide any graphs or tables of response by question. The £2 million UK study did not include a single graph in the overview report by Batley et al (2018). Only results derived from complicated statistical models (sometimes constrained and/or adjusted) are given.

in terms of the differences in cost, drive time and travel time variability (Trip A - Trip B). Equation (1) shows the models.

$$P_A = \frac{\exp Z}{1+\exp Z} \textit{where} \qquad \ldots..(1)$$

$$Z = \beta o + \beta_v \Delta V + \beta_t \Delta T + \beta_c \Delta C$$

where: βo = constant; ΔV = difference in travel time variability in minutes (0 or -0.32)

ΔT = difference in travel time in minutes and ΔC = difference in cost in dollars.

The value of time ($/hr) is the ratio of the travel time parameter (mins) over the cost parameter ($) multiplied by 60 (60βt/βc). The reliability ratio is the variability parameter divided by the average travel time of option B divided by the travel time parameter (βv/TB)/βt. The value of the constant (which accounts for any underlying preference for option A or B) is βo/βt. Ideally, the constant should be zero or close to it.[10]

The constant, was worth 4.5 minutes of drive time. For five markets, it was negative implying a preference for the slower/cheaper alternative. Its statistical significance was weak which was desirable with only the medium trip length and the overall model exceeding the 95% confidence level (t>1.96).

Table 6: Disaggregate Time & Cost Attribute Models

		Short	Short Med	Med	Med Long	Long	Very Long	All
Parameter Estimate	Variability (βv)	-1.131	-1.565	-2.434	-1.228	-1.080	-3.432	-1.545
	IVT (βt)	-0.106	-0.110	-0.098	-0.096	-0.045	-0.062	-0.098
	Cost (βc)	-0.392	-0.364	-0.285	-0.259	-0.206	-0.307	-0.337
	Constant (βo)	-0.366	-0.575	-0.744	-0.605	-0.058	0.389	-0.439
t value	*Variability (βv)*	*-4.0*	*-3.3*	*-5.4*	*-2.0*	*-1.3*	*-3.7*	*-8.0*
	IVT (βt)	*-11.7*	*-7.2*	*-6.8*	*-4.8*	*-1.7*	*-2.1*	*-16.3*
	Cost (βc)	*-9.3*	*-5.3*	*-4.4*	*-2.9*	*-1.8*	*-2.3*	*-12.0*
	Constant (βo)	*-1.8*	*-1.7*	*-2.3*	*-1.4*	*-0.1*	*0.6*	*-3.3*
Relative Valuation	VOT 60(βt/βc) $/hr	16.17	18.14	20.63	22.13	12.94	12.14	17.45
	RR (βv/TB)/βt mins	0.43	0.41	0.55	0.23	0.26	0.44	0.37
	CON/IVT (βo/βt)mins	3.5	5.2	7.6	6.3	1.3	-6.3	4.5
t value	*VOT 60(*βt/βc	*7.4*	*4.3*	*3.7*	*2.5*	*1.3*	*1.6*	*9.8*
	RR (βv/TB)/βt	*3.8*	*3.0*	*4.2*	*1.8*	*1.1*	*1.9*	*7.3*
	CON/IVT (βo/βt)	*1.9*	*1.7*	*2.4*	*1.4*	*0.1*	*-0.6*	*3.3*
Average Time B (TB) mins		25	35	45	55	95	125	43
Number of Observations		2,144	786	863	440	249	240	4,722

[10] It is noted that some notable academics refuse to include the constant in their results but this practice should be circumscribed since it deliberately avoids showing whether or not the experimental design 'biased' response i.e. favouring either the fast alternative or the cheap alternative in this study rather than achieve balanced response with a zero constant.

The overall value of time was \$17.45/hr. The highest value was for medium-long trips at \$22.13/hr with the lowest values for 'long' and 'very long' trips at \$12.94/hr and \$12.14/hr respectively. The estimates overlapped however in terms of their estimation accuracy.

Travel time variability was measured through the reliability ratio (RR). The average RR was 0.37 and was reasonably constant by trip length. The RR was highest for medium trips at 0.55 and lowest for long-medium trips at 0.23. None of the RR valuations were significantly different from the all observation estimate. The estimates are similar to the UK commuting value (0.33).

It is often the case in SP studies, that the constant is often overlooked or its effects 'covered up'. The preferred set of values is reported depending on whether it was produced with a constant included or excluded. Without the constant, the value of time dropped to \$12.88/hr which was \$5/hr less than the 'with constant' model. Thus, despite the constant being relatively weak, it had a noticeable effect on the value of time.

An innovative feature was to specify the time and cost differences such that a set of 'threshold' values of time ranging from \$6/hr to \$30/hr was included. The seven thresholds were \$6, \$9, \$12, \$15, \$18, \$24 and \$30/hr. Each threshold was included twice, once without travel time variability and once with without design orthogonality (zero correlation between time and cost attributes) being affected.

Figure 4 shows the percentage choosing option A declining as the threshold VOT increases. Just over a quarter had a VOT less than \$6/hr with a fifth \$30/hr or more (black diamonds). Travel time variability for option B increased the percentage choosing option A. With zero travel time variability, 40% had a threshold VOT of \$15/hr (black diamond) but when travel time variability for option B was 40%, the percentage choosing A increased to 60% (red circles).

An estimation model was fitted to the individual response data. In effect, the sixteen proportions shown in Figure 4 were replaced by 4,722 probabilities. Rather than specifying alternative A as the dependent variable, the model fitted the probability of choosing option B. This ensured with the constant omitted that predicted values of time were never negative.

$$P_B = (1 - P_A) = -\beta_{vot} VOT^{0.7} + \beta_{cvv}(CV) VOT^{0.7} \quad .....(2)$$

The threshold VOT had a power function $\left(VOT^{\phi}\right)$ fitted to flatten the steepness of the response curve. The best fit value for ϕ was 0.7. Travel time variability interacted with the threshold value of time so that the median VOT $(P_A = 0.5)$ was equal to $\frac{1}{\beta_{vot}}(0.5)^{(1/0.7)}$ with zero travel time variability. With 40% travel time variability, the median increased to $\frac{1}{\beta_{vot} + \beta_{cvv}}(0.5)^{(1/0.7)}$

Figure 4: Threshold Values of Time With and Without Travel Time Variability

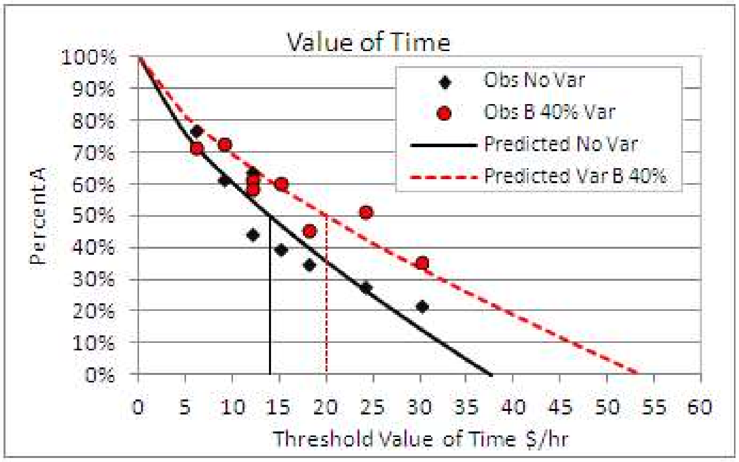


Table 7 presents the fitted models. The median VOT without travel time variability was $13.95/hr and estimated with accuracy (t value of 57.5).

Table 7: Disaggregate Threshold Value of Time Model

Estimate		Short	Short Medium	Medium	Medium Long	Long	Very Long	All
Estimate β	VOT	-0.079	-0.081	-0.082	-0.077	-0.076	-0.066	-0.079
	CV*VOT	0.039	0.057	0.080	0.051	0.049	0.112	0.055
t value	*VOT*	*-38.9*	*-24.5*	*-25.6*	*-16.9*	*-12.1*	*-11.5*	*-57.5*
	*CV*VOT*	*4.4*	*3.8*	*5.6*	*2.5*	*1.8*	*4.4*	*9.0*
Median VOT		13.88	13.44	13.25	14.49	14.71	18.05	13.95
Median VOT 40% Var		17.78	19.32	22.67	20.41	20.51	55.18	19.99
Variability %		28%	44%	71%	41%	39%	206%	43%
Mean VOT		15.41	14.92	14.71	16.09	16.33	20.03	15.48
Observations		2,144	786	863	440	249	240	4,722

Travel time variability (±40%) increased the median VOT by $6/hr to $19.99/hr. The reliability ratio was therefore 0.44 ($6/hr ÷ $13.95/hr).

The mean VOT was the area under the threshold curve and with 0.7 for the power function, it was 11% higher than the median ($15.48/hr compared to $13.95/hr). Compared to the attribute model (Table 6), the threshold mean ($15.48/hr) lay midway between the 'no constant' ($12.88/hr) and 'with constant' estimates ($17.45/hr). The threshold VOT was accurate with a confidence range of ±$1.50/hr (95%CL) and reasonably constant with trip length excepting very long trips ($20.03/hr) although this segment had a wide confidence range.

In terms of market segmentations, commuters had a VOT 14% higher than 'other' trips ($16.58 versus $14.59/hr) with peak trips having a VOT 15% higher than off-peak ($16.58/hr versus $14.41/hr). Females valued travel time variability nearly twice that of males (61% versus 34%).

There was some evidence for drivers travelling with passengers valuing travel time higher ($16.15/hr) than drivers travelling alone ($14.86/hr) but the difference ($1.29/hr) was not statistically significant (t=1.5). Passengers had a higher value of time ($16.15/hr) than drivers ($15.29/hr) but the difference ($1.46/hr) was not statistically significant (t=1.2). There was very little difference between respondents who paid all the costs and those who shared costs.

Table 8: Market Segment Estimates Disaggregate Threshold Model

Segmentation	Segment	Mean Value ($/hr)		% Variability	
		Estimate	*t*	Estimate	*t*
Trip Purpose	JTW	16.58	*38.3*	58%	*6.4*
	Other	14.59	*43.2*	33%	*6.5*
	Difference: JTW - Other	2.00	*2.6*	26%	*1.5*
Location	N&W	16.50	*47.3*	60%	*6.5*
	Sydney	14.96	*32.9*	36%	*6.4*
	Difference: N&W - Sydney	1.54	*1.88*	25%	*1.4*
Peak / Off-Peak	Peak	16.58	*38.0*	46%	*6.2*
	Off-Peak	14.41	*43.4*	41%	*6.6*
	Difference: Peak - Off-Peak	2.18	*2.8*	4%	*0.1*
Driver / Passenger	Driver Alone = 1	14.86	*44.5*	52%	*6.3*
	Driver with Passenger	16.15	*30.5*	35%	*3.0*
	Driver All	15.29	*53.9*	46%	*7.0*
	Passenger	16.75	*20.1*	29%	*1.9*
	Difference: Driver>1 - Driver=1	1.29	*1.5*	-17%	*-1.4*
	Difference: Passenger - Driver	1.46	*1.2*	-16%	*-1.1*
Share Costs	Pay All	15.51	*49.6*	47%	*8.4*
	Share	15.40	*25.0*	32%	*3.1*
	Difference: Pay All - Share	0.11	*0.1*	15%	*0.9*
Income	>120k	25.54	*13.0*	85%	*3.2*
	90-120k	18.16	*20.0*	64%	*4.1*
	60-90k	15.65	*27.7*	44%	*4.4*
	30-60k	14.99	*28.8*	52%	*5.1*
	<30k	12.20	*32.4*	22%	*3.0*
	Refused	16.58	*15.0*	48%	*2.5*
Gender	Male	15.94	*44.5*	34%	*5.9*
	Female	14.77	*36.5*	61%	*7.2*
	Difference: Male - Female	1.16	*1.5*	-26%	*2.1*
ALL		15.48	*57.5*	43%	*9.0*

Two adjustments were made to account for over-sampling of commuter trips and not surveying under 18 year olds. TfNSW Household Travel Survey (HTS) data estimates a fifth of car trips are commuting to/from work and four fifths ‘other’ whereas the survey achieved shares of 47% commuting and 53% ‘other’. With VOT estimates of $16.58/hr and $14.59/hr respectively, the JTS trip weighted average was $14.99/hr.

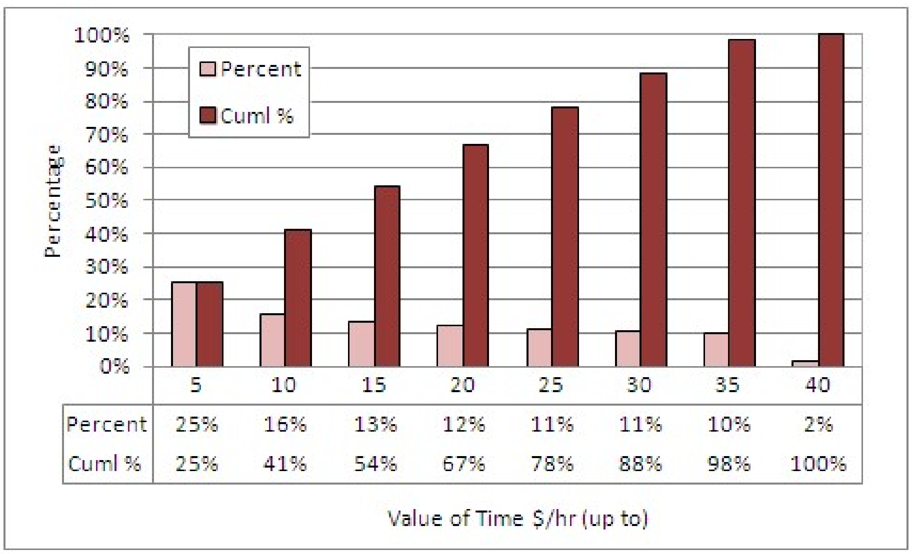
In accordance with market research protocol, under 18 year olds were not surveyed. Their share of the NSW population is 22%. If it is assumed under 18s travel are car passengers (and not drivers) and that passenger trips are in proportion to age then under 18s would make up 7% of car trips (based on a 32% passenger share) Assuming under 18s olds have zero personal income, (VOT of $10.04/hr) and make ‘other’ trips rather than commuting trips gives a VOT of $9.46/hr.

Together the two adjustments reduced the average VOT to $14.63/hr which was a little lower than the 40% wage rate value of $15.14/hr. The 95% confidence range ($13.13/hr to $16.13/hr) straddled the 40% estimate however. For the UK, Arup (2015) estimated a VOT of around A$14/hr.

The threshold approach automatically provides a VOT distribution since it gives the percentage of respondents who have a VOT of at least $X/hr. Figure 5 plots the distribution for a mean VOT of $14.63/hr (the overall adjusted average). At 25%, the largest category is 'up to $5/hr' followed by 16% in the $5-$10 category. The percentages then gradually decline to a predicted maximum VOT of $35.80/hr.

Knowing the VOT distribution has applications for toll road forecasting. If for example, a toll road saved 15 minutes and charged a toll of $5, the required value of time would be $20/hr. From Figure 5, the percentage of drivers with a value of time of up to $20/hr is 67%. Thus by subtraction, 33% of drivers would use the toll road.[11]

Figure 5: Percentage Distribution of Values of Time



5. Public Transport 'Quality' Stated Preference Survey

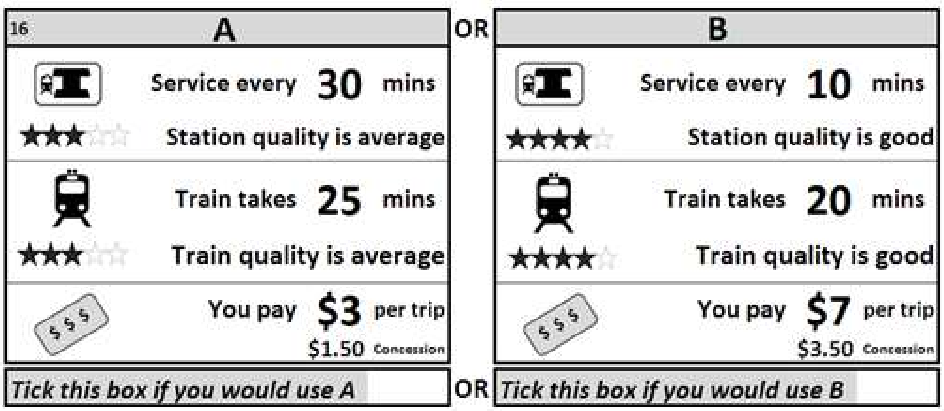
Four PT surveys were undertaken as part of estimating a suite of parameters for demand forecasting and evaluation purposes. The main survey is referred to as the 'Quality' SP because it included vehicle and stop quality. It was also the largest in sample size and coverage. The three other surveys estimated values of time as well as valuing other service attributes. They were interviewer led surveys and had smaller sample sizes. Section 6 combines the results of all four PT surveys.

[11] The percentage excludes commercial and company business trips. The vehicle VOT should not be factored for occupancy since there was no significant response difference. It could also be argued that the driver value should be used as the mean (i.e. not adjusted for under 18s etc) which would be $14.99/hr.

The Quality SP built on a suite of surveys undertaken for Inner Sydney by the Bureau of Transport Statistics (BTS) in 2013, see Douglas and Jones (2016) and surveys by Sydney Trains in 2014. The 'Value of Time' study 'filled in the gaps' by extending the coverage of the bus surveys to the wider Sydney area including Newcastle and Wollongong and by surveying ferry users in Sydney and Newcastle. The additional VOT surveys were undertaken in 2014. More detail on the PT surveys is provided in Legaspi and Douglas (2016) with the ferry survey described by Douglas (2017) and greater description of the ratings in Douglas (2016). In total, 5,112 SP questionnaires were completed: 1,817 rail, 1,710 bus, 1,114 ferry and 471 LRT. In terms of efficiency, the cost including design, analysis and reporting was around $10 per questionnaire a figure which compares with $1,000 per respondent for a recent Australian VOT survey.

The surveys used the same SP design which featured five attributes and required 25 experiments (a fractional design). The design was split into three sets with each respondent completing a set of 8 or 9 SPs. An example show card is provided in Figure 6.

Figure 6: Example Stated Preference Show Card for Rail



A time versus cost trade-off underpinned the SP whereby respondents could choose a quicker but more expensive option or a slower but cheaper option. The time/cost trade-off was confounded by vehicle quality, station quality and frequency.

Vehicle and station quality was shown using a five 'star' scale with 5 stars being very good, 4 good, 3 average, 2 poor and 1 very poor. Higher vehicle quality was associated with the more faster/expensive service but was varied so that it was not correlated with time or fare. Station quality (and service frequency) varied so that higher quality (or more frequent services) appeared with the faster service and sometimes with the slower service.

The time, fare, frequency and quality differences were kept exactly the same for the different modes and trip lengths so that response could be pooled without affecting the orthogonality of the design. Section 9 looks at this aspect of the survey.

The times and fares were customized to a respondent's trip. Short, medium and long versions were developed for bus and rail. Another design was developed for Newcastle buses to take account of the different fare structure. LRT had a separate design to take account of trip length and a lower fare concession (75% of the standard fare rather than 50%). Five designs were developed for ferry to cover Inner Harbour, Manly Standard Ferry, Manly Fast Ferry, Parramatta and the short Newcastle-Stockton ferry.

5,112 SP questionnaires were obtained and with each respondent answering eight or nine SPs, the total number of SP observations was 40,175 (7.9 SP observations per questionnaire). The response to the 25 SP questions was well balanced.

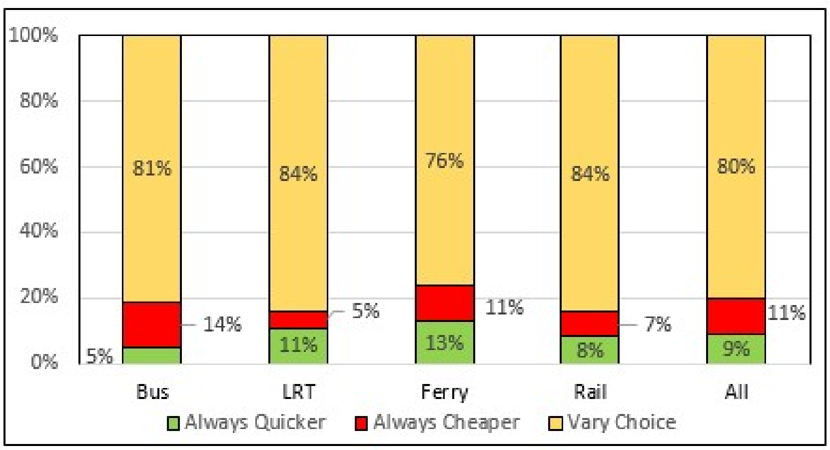
Table 9: SP Observations and Completed Questionnaires

Response	Bus	LRT	Rail	Ferry	All
1) SP Observations	13,285	3,598	14,462	8,830	40,175
2) SP Questionnaires	1,710	471	1,817	1,114	5,112
3) Total Questionnaires+	1,847	516	1,910	1,223	5,496
Obs / SP Questionnaire (1÷2)	7.8	7.6	8.0	7.9	7.9

+ returned SP questionnaires with no answer to any SP question

Eight out of ten respondents varied their choice over their set of SP questions, sometimes selecting the quicker /expensive option and sometimes the slower/cheaper option.

Figure 7: PT SP 'Trading Off'

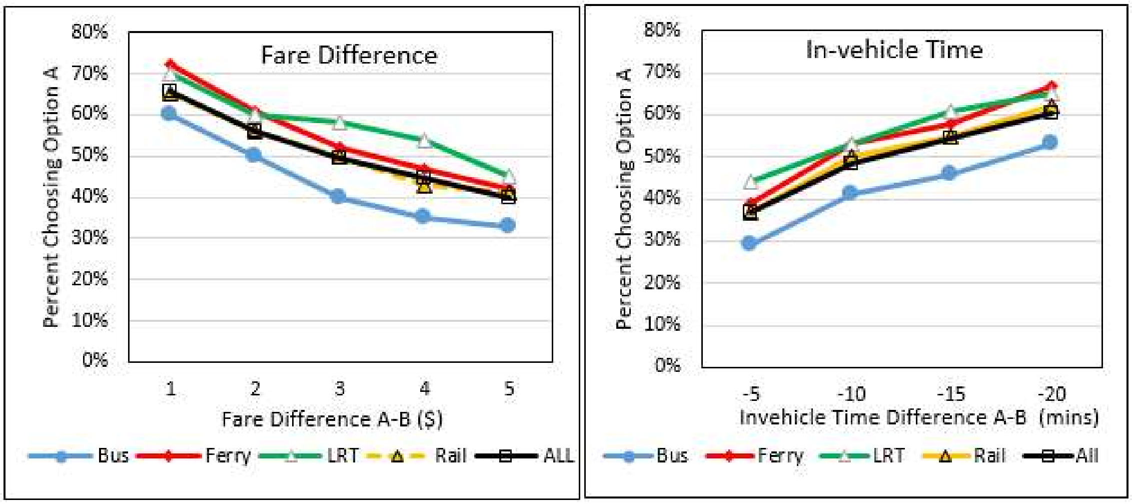


Ferry users traded off the least (76%) and rail and LRT users the most (84%). Those that did not trade-off were reasonably split between those that always went for the quicker option (9%) and those that always went for the cheaper option (11%).

Figure 8 plots the mean percentage choosing alternative A for each of the fare and time levels. Fare had five levels and the percentage choosing A ranged from 65% when option A cost \$1 more than option B to 40% when A cost \$5 more.[12] Response was reasonably linear.
In-vehicle time had four levels with the percentage choosing A increasing from 38% when option A was 5 minutes quicker to 60% when it was 20 minutes quicker. Response was reasonably linear.

[12] The graph does not take fare concessions into account. Hence the VOT calculated by dividing time sensitivity by fare sensitivity over-estimates the VOT. For overall response VOT =60 x (0.38-0.6)/(-5 - -20) ÷ (0.65-0.4)/(\$3-\$5) = \$14.08/hr.

Figure 8: Sensitivity to PT Fare and IVT



The individual SP question response was analysed by fitting the logistic equation in equation 3 by maximum likelihood.

$$Pa = \frac{\exp Z}{1 + \exp Z}$$

where:

$$Z = \left\{ \begin{array}{l} \alpha + \beta_f \Delta F + \beta_{fc} \Delta F.C + \beta_t \Delta T + \beta_{si} \Delta SI + \beta_{vq} \left\{ (1 - VQ_A^{\phi}) - (1 - VQ_B^{\phi}) \right\} \\ + \beta_{sq} \left\{ (1 - SQ_A^{\phi}) - (1 - SQ_B^{\phi}) \right\} \end{array} \right\} \quad \ldots\ldots(3)$$

$F =$ fare difference A-B in dollars (taking account fare concession (½ΔF) where appropriate)

$C =$ concession entitlement taking a value of 1 if entitled to a concession else zero

$T =$ Difference in travel time A-B in minutes

$SI =$ Difference in service interval A-B in minutes

$VQ =$ Difference in vehicle quality rating A-B 'transformed' by quality power function of ϕ

$SQ =$ Difference in stop/station quality rating A-B (same as vehicle quality)

$\alpha, \beta =$ parameters to be estimated.

The quality '5 star' ratings were converted to a 0-1 scale so that a very good 5 star converted to 1.0, an average 3 star rating to 0.5 and a poor 2 star rating to 0.25.[13] A power function was then applied to allow for a non-linear response. With a value less than 1, the sensitivity to quality is heightened at poor quality ratings and suppressed at good ratings. A value of 0.7 was found to provide a good fit for both vehicle and stop/station/wharf quality. With this value, an average rating 50% rating transformed to 62%.

[13] The conversion is {Star Rating – 1}/4. In the regression model, the converted rating was subtracted from 1 to make it negative (the same as the cost and time attributes).

Figure 9 shows the effect of the quality transformation. Table 10 presents the estimated models. The 'all' model estimates have been weighted to reflect the actual patronage by market segment and time period.[14]

The overall weighted average VOT for PT was \$10.45/hr. LRT at \$20.69/hr was the highest and bus the lowest on \$8.36/hr. Ferry at \$14.19/hr and rail at \$12.33/hr were in the middle. Standard fare payers had a VOT of \$12.37/hr with those entitled to a concession (50% discount for bus, rail and ferry and 25% for LRT) had a VOT of \$5.98/hr.

Figure 9: Quality Rating Transformation Parameter

The value of service interval (the number of minutes between departures) expressed in equivalent in-vehicle time was 0.64. The valuations were conditioned by frequency so that respondents with frequent services viewed the attribute as waiting time (half the service interval) and respondents with less frequent services saw it as timetable inconvenience of not being able to travel exactly when you want. The estimated valuations showed LRT to have the highest valuation (0.75) reflecting the high frequency (6 per hour for respondents). Ferry had the lowest valuation (0.36) reflecting the lower frequency (2 sailings per hour on average) and the ability to 'wait on board' at Circular Quay, Manly and other terminal stops. Bus and rail had similar valuations averaging of 0.62 and 0.68 respectively (with respondents having a service interval of 18 minutes).

Stop quality from very poor to very good (0-100%) was valued at 12.2 minutes. This is an extreme valuation however since the chances of all users rating a change in stop quality from 0% to 100% is almost impossible. Based on the observed ratings a realistic range is from 40% to 80% which with the power transformation would be worth a third of the theoretical maximum which is 4 minutes. The valuation was reasonably constant across the four modes with the lowest valuation for ferry wharfs and the highest for rail stations.

[14] The estimated models are without a constant. Models were run with a constant. The bus constant was worth 5.9 minutes and was significant (t=5.7). The ferry constant was small at 0.3 minutes and insignificant (t=0.3). The LRT constant was negative and worth 4.7 minutes and was significant (t= 2.2). The rail constant was worth 1.7 minutes and was not significant (t=1.8).

Vehicle quality was valued 11.9 minutes. As with stop quality, this is a theoretical maximum for a 0% to 100% range in rating. Limited to 40%-80% reduces the valuation to 3.9 minutes. Bus, ferry and rail had similar valuations. The exception was LRT which had a lower valuation reflecting a shorter average trip (13 minutes versus the 23 for bus and ferry and 34 for rail).

Table 10: Estimated Value of Times & Service Quality

Parameter	Bus		Ferry		LRT		Rail		All	
	β	*t*	β	*t*	β	*t*	β	*t*	β	*t*
SI	-0.041	*47.0*	-0.032	*-16.0*	-0.061	*-20.3*	-0.047	*-47.0*	-0.043	*-55.0*
IVT	-0.066	*23.7*	-0.088	*-22.0*	-0.081	*-13.5*	-0.069	*-23.0*	-0.068	*-41.3*
Fare	-0.392	*32.2*	-0.321	*-21.4*	-0.225	*-9.8*	-0.289	*-22.2*	-0.332	*-44.5*
Fare Conc	-0.360	*14.5*	-0.706	*-19.6*	-0.208	*-3.9*	-0.307	*-12.3*	-0.355	*-25.1*
Stop Quality	-0.687	*12.1*	-0.900	*-12.9*	-0.954	*-8.5*	-0.965	*-17.9*	-0.836	*-26.1*
Vehicle Quality	-0.747	*7.5*	-1.119	*-10.7*	-0.328	*-2.0*	-0.845	*-10.4*	-0.811	*-17.0*
VOT - Std $/hr	10.10	*19.0*	16.45	*15.3*	21.60	*7.9*	14.33	*16.0*	12.37	*30.0*
VOT - Conc $/hr	5.27	*14.3*	5.14	*14.8*	11.22	*4.9*	6.95	*12.5*	5.98	*24.3*
VOT - Av $/hr	8.36	*22.9*	14.19	*18.2*	20.69	*8.3*	12.33	*18.4*	10.45	*35.0*
SI/IVT	0.62	*19.8*	0.36	*12.9*	0.75	*11.2*	0.68	*20.7*	0.64	*32.9*
Stop Quality/IVT	10.4	*11.5*	10.2	*11.1*	11.8	*7.2*	14.0	*14.1*	12.2	*21.9*
Vehicle Quality/IVT	11.3	*9.1*	12.7	*9.6*	4.0	*1.9*	12.2	*9.5*	11.9	*15.7*
Concession %	36%		20%		9%		27%		30%	
Income $kpa	44		73		65		51		49	
IVT mins	23		23		13		34		29	
SI mins	18		31		12		18		18	
Wait mins	7		7		6		7		7	
Observations	13,285		8,825		3,598		14,462		40,147	
Patronage Weight	43%		3%		1%		53%		100%	

Models weighted by patronage data

7. Including Other TfNSW Public Transport SPs

Three other SP surveys of PT users were carried out by TfNSW between 2012 and 2014 to estimate parameters for the Public Transport Project Model (PTPM). All three surveys estimated values of time which were combined with the Quality SP survey to provide a total sample of 8,264.

In November 2012, an SP survey was undertaken to estimate transfer penalties for bus and rail passengers as part of forecasting the demand for the North West Rail Link. 384 bus passengers and 585 rail passengers were surveyed by interviewers with computer tablets. Values of time of $16.70/hr for bus (reflecting the high annual income of respondents of $84,000) and $11.62/hr for rail were obtained. More details of this survey are provided in Douglas and Jones (2013).

In 2013, a SP survey using interviewers with computer tablets was undertaken of bus, LRT and rail users in inner west Sydney to estimate transfer penalties, on-board crowding time multipliers and travel displacement (not being able to travel when you want). Values of time of \$15.11/hr for rail, \$11.40/hr for bus and \$6.01/hr for LRT were estimated from the 954 interviews. More details on this survey are given in Douglas and Jones (2016).

Also in 2013, an SP survey was undertaken of 1,229 bus, LRT and rail users using interviewers with computers tablets to estimate travel time multipliers and alternative specific constants taking account vehicle and stop quality. The survey estimated values of time of \$12.24/hr for bus, \$16.41/hr for LRT and \$16.30/hr for rail. More details on this survey are given in Douglas and Jones (2016).

Table 11: Values of Time by Mode and Survey

Survey	Year	Mode	VOT \$/hr	|t|	Concession Percent	Income \$000	Sample Size
Quality	2013-14	Bus	8.36	23	36%	44	1710
	2013	LRT	20.69	8	9%	65	471
	2013-14	Rail	12.33	18	27%	51	1817
	2014	Ferry	14.19	18	20%	73	1114
Inner Sydney Transfer	2013	Bus	11.40	5	40%	43	417
	2013	LRT	6.01	3	26%	50	320
	2013	Rail	15.11	5	28%	53	217
Inner Sydney IVT Multiplier	2013	Bus	12.24	12	35%	49	417
	2013	LRT	16.41	10	22%	51	320
	2013	Rail	16.30	8	27%	53	492
NWRL Transfer	2012	Bus	16.70	6	13%	84	384
	2012	Rail	11.62	11	30%	52	585
Car	2014	Car	14.63	58	na	58	613

Figure 10 plots the VOT estimates against the average income of the respondents.[15] Superimposed on the graph is the predicted VOT for each mode from fitting the model in equation 4.[16]

$$\begin{array}{l} VOT\ \$/hr = -.597 + .225 INCOME + 4.4 LRT + 2.143 RAIL - 1.64 FERRY + 2.25 CAR \\ \qquad\qquad\qquad (.126)\quad (2.509) \qquad\quad (1.880) \quad (1.148) \qquad (0.532) \qquad (1.212) \end{array}$$

VOT increased with income at \$0.225/hr per thousand dollars of annual income (11.25C/hr per dollar of hourly income).[17] The mode variables effectively 'position' the predicted VOTs vertically (with bus the base mode). Also plotted is the predicted VOT for bus, LRT and rail where there was more than one SP survey.[18] For bus there were 4 surveys and, after taking their relative precision into account (t values), the predicted VOT was \$9.30/hr at the average income of \$44k. This was a dollar higher than the Quality SP estimate of \$8.36/hr.

[15] The standard error is shown for each estimate as a vertical bar above and below the mean (the 95% confidence range would be twice as wide).

[16] The observations were weighted according to the t values in Table 11 and calculated for each mode.

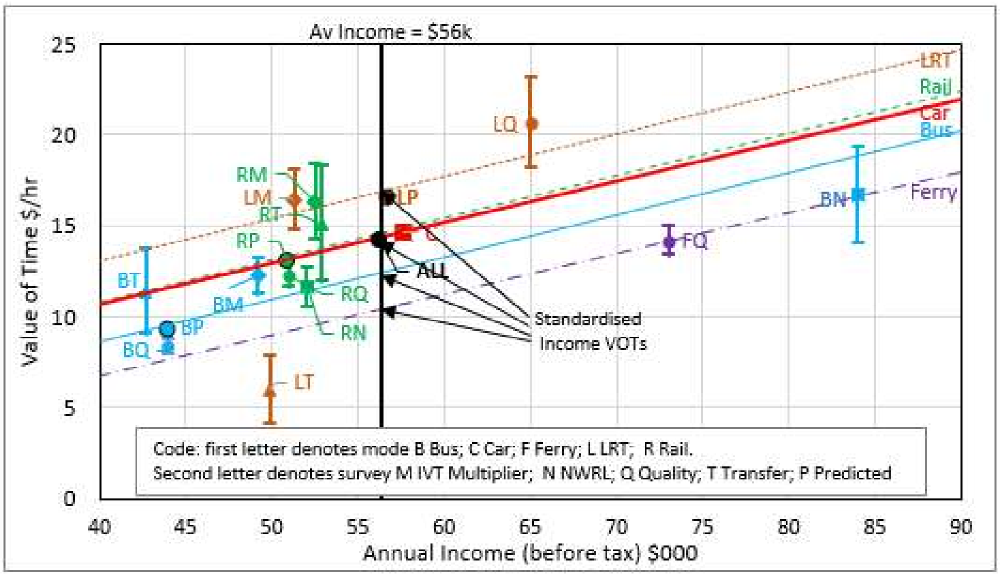
[17] Hourly income calculated on the basis of 2,000 hours work per year.

[18] As there was only one survey estimate for ferry and car, there are no predicted values on the graph.

For LRT (3 estimates), the predicted VOT was $16.56/hr at an average income of $56,700 ($4/hr lower than the Quality estimate of $20.69/hr).[19]

There were four rail estimates with a predicted value of $13.02/hr at $51k (70 cents higher than the Quality SP estimate of $12.33/hr). The standardised VOTs are where the prediction lines cross the vertical black income demarking the average income of $56k.

Figure 10: Values of Time by Mode and Survey



The estimates are summarised in Table 12 as three sets of values. Set 1 is the PT 'Quality SP' estimates; set 2 includes all the PT SP survey estimates and set 3 standardises the values at the average income of $56,300.

Table 12: Values of Time by Mode and Survey

	Trip	1. Quality SP		2. ALL SPs		3. Income Standardised	
Mode	Share	Income $kpa	VOT $/hr	Income $kpa	VOT $/hr	Income $kpa	VOT $/hr
Bus	43%	44.0	8.36	44.0	9.30	56.3	12.07
LRT	1%	65.0	20.69	56.7	16.56	56.3	16.47
Rail	53%	51.0	12.33	51.0	13.02	56.3	14.22
Ferry	3%	73.0	14.19	73.0	14.19	56.3	10.44
PT	15%	48.8	10.76	48.7	11.49	56.3	13.20
Car	85%	57.7	14.63	57.7	14.63	56.3	14.33
All	100%	56.3	14.05	56.3	14.16	56.3	14.16

Including all four PT SPs narrowed the range in VOT. The bus VOT increased from $8.36/hr to $9.30/hr and the LRT VOT reduced from $20.69/hr to $16.56/hr. The average VOT for PT increased slightly from $10.76/hr to $11.49/hr. Given car's dominant share (85%) the effect on the overall average was negligible; an increase from $14.05/hr to $14.16/hr.

[19] Given all three SPs were carried out on the Central-Lilyfield LRT service, average income was calculated as a weighted estimate of all three surveys rather than just the Quality survey.

Standardising VOT at the average income of $56,300 increased the bus and rail values and reduced the LRT, ferry and car values. The biggest impact was on ferry users with VOT reducing from $14.19/hr to $10.40/hr reflecting their higher incomes ($73k). The second biggest impact was on bus users with VOT increasing from $9.30/hr to $12.07/hr reflecting their lower incomes of $44k. The overall VOT at $14.16/hr was unaffected (as it should be). The weighted average VOT of $14.16/hr was 37% of the hourly wage rate used by TfNSW ($37.85) and a dollar lower than the $15.14/hr which would be required for a 40% valuation.

Car had an overall value of $14.63/hr which was 39% of the wage rate. Commuting time was valued at $16.58/hr (44% of the wage rate) and other travel at $14.14/hr (37%). The PT values were lower, averaging $10.32/hr (27%) with a commuter value of $12.38/hr (33%) and an 'other' trip value of $8.66/hr (23%) which reflected lower incomes and greater use of fare concessions.[20]

8. Value of Time by Trip Purpose

Company business trips had a value of time of $16.62/hr and commuters (JTW) a VOT of $14.98/hr. Both were higher than the trip weighted average of $11.49/hr. For the remaining trip purposes, the VOT ranged from $7.78/hr for education to $10.66/hr for entertainment/holiday.[21]

Table 13: PT Values of Travel by Trip Purpose (2013-14)

Estimate	JTW	Educ	PBsn	CBsn	Shop	VFR	EntHol	Other	All
VOT $/hr	14.98	7.78	9.39	16.61	7.92	8.94	10.66	8.93	11.49
STE $/hr	0.72	0.48	0.87	3.08	1.14	0.89	1.02	1.25	0.34
Ratio of Av VOT	1.30	0.68	0.82	1.45	0.69	0.78	0.93	0.78	1.00
Income $000 p.a.	63.5	21.5	43.0	75.2	38.1	42.0	50.8	40.1	48.7
Std VOT $/hr^	11.65	13.90	10.67	10.65	10.31	10.45	10.19	10.87	11.49
Ratio of Av	1.01	1.21	0.93	0.93	0.90	0.91	0.89	0.95	1.00
Response	1,969	868	478	118	379	445	679	208	5,112
Response %	39%	17%	9%	2%	7%	9%	13%	4%	100%

^ standardised at average PT VOT of $11.49/hr using $0.225/hr per $1,000 of annual income.

The parameters were estimated with accuracy as can be seen from Figure 11. Differences in income help explain the range in VOT. 'Standardising' the values using the income parameter in section 7 reduced the range in estimate by reducing the JTW VOT to $11.65/hr (just 1% above the average). For education trips, standardisation increased the VOT from 32% below the average to 21% above the average.

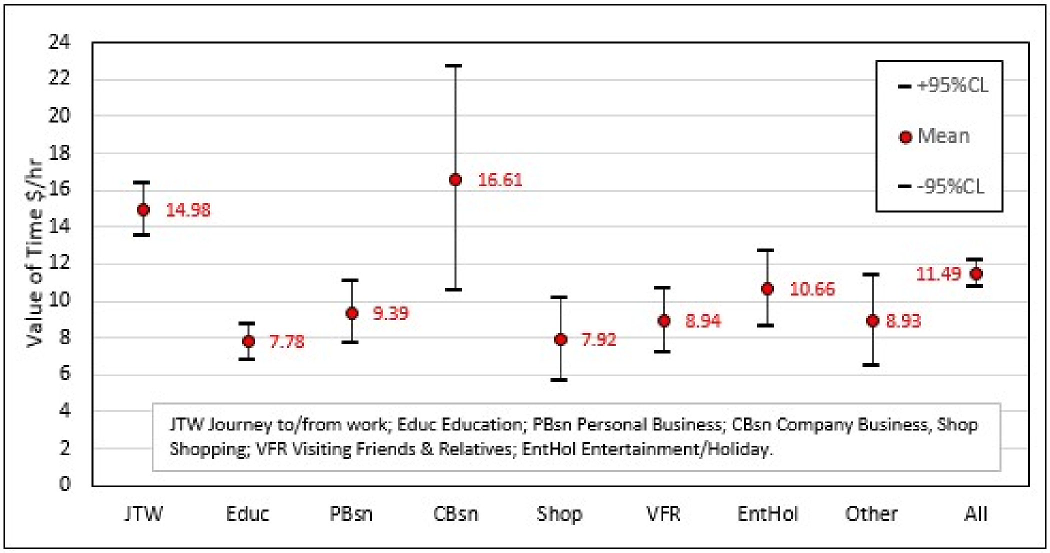
The highest VOT was for company business trips at $16.61/hr which compares with $48.45/hr (2013/14 prices) used in economic appraisals (see section 1). Unlike car, company business trips time were not 'screened out' of the survey. Consequently, the average VOT for PT is not

[20] The much higher use of concession fares (49%) amongst PT users reduced the value of time for other trips (49%) compared to commuting (9%) because time savings could be bought at half the price.

[21] The estimates were adjusted to take account of the other four PT SP surveys and thereby match the overall PT average in Table 12.

a pure private travel time value but includes 2% company business trips (118 responses out of 5,112). Excluding them reduced the overall PT value of time from \$11.49/hr to \$11.32/hr and the non-commuting value from \$9.31/hr to \$8.94/hr.

Figure 11: Public Transport Values of Time by Trip Purpose



The difference in VOT for commuting versus other trips was greater for PT than for car.[22] For commuting by car, the VOT was 43% of the wage rate (\$37.85/hr) and for PT, it was slightly lower than the 40% valuation.

Table 14: Car, PT & Overall Values of Private Travel Time by Trip Purpose

Trip	Value of Time $/hr			Percentage of Wage Rate^			Av. Income $000 p.a.		
Purpose	Car	PT	ALL	Car	PT	ALL	Car	PT	ALL
Commuting	16.58	14.98	16.13	44%	40%	43%	68	64	67
Other Trips#	14.14	8.94	13.57	37%	24%	36%	52	38	50
All	14.63	11.32	14.13	39%	30%	37%	55	48	54

^ Calculated as percentage of \$37.85/hr. Car shares 72% commuting, 89% other and 85% overall.
\# Excludes trips travelling on company business

For other trips, the VOT for PT was only 24% of the wage rate. The car VOT at 37% was reasonably close and given its dominant trip share (89%) raised the overall average for 'other' trips to 36% of the wage rate.

At \$14.13/hr, the overall private travel VOT was 37% of the wage rate. Car had a value of \$14.63/hr (39% of the wage rate) and PT a value of \$11.32/hr (30% of the wage rate).

[22] PT respondents completed the questionnaire during their trip whereas car users recalled a recent trip to an interviewer. For some car respondents (especially those recalling an 'other' trip) memories might have faded (was the respondent in a hurry, were the kids in the back of the car behaving themselves) and replaced by a general mush about car travel.

9. Effect of Trip Length on Values of Time

Some urban transport demand models dampen demand sensitivity as trip length increases. Some models dampen generalised cost response and some dampen the response to either cost or time.[23] An example is the Sydney Strategic Travel Model (STM) estimated by Fox et al (2015) which dampens cost sensitivity but keeps travel time sensitivity fixed. This means that VOT increases with cost.[24]

Some VOT survey designs increase the differences in travel time and cost with distance. Figure 12 presents the example show-card given in the UK VOT overview paper, Batley et al (2018). The choices are set around a 4 hour trip costing around £34 ($A62). Option B is 53 minutes quicker but costs £2 ($A3.64) more than option A. The VOT threshold for a respondent would only have to be at £2.26/hr ($A4.12/hr) for the respondent to choose option B. This is a low threshold and most people should choose option B.

Figure 12: Value of Time Showcard used in the UK Car Stated Preference Survey

	Option A	Option B
One way fuel cost	£33.30	£35.00
One way travel time by car	4 hours 23 minutes	3 hours 30 minutes

Option A Option B

The percentage differences for option A versus option B are +6% for cost and -20% for time. Had the reference trip been 20 minutes, the differences would have been 4 minutes and 15 pence. Thus the problem for estimation is that combining response over varying trip length introduces a correlation between time and cost. This could have been avoided if the cost differences had been kept constant which was deliberately done in the TfNSW car SP allowing six sets of questionnaires varying in trip length to be analysed together.

In the PT Quality SP, there were four time differences (5, 10, 15 and 20 minutes) which were kept the same across thirteen questionnaires covering trips from 5 minutes (Newcastle-Stockton ferry) to over 90 minutes (long distance rail).[25] Keeping the differences constant meant that no correlation was introduced between time and cost when the response to all thirteen designs was pooled.

[23] The Lincolnshire travel demand model dampens cost sensitivity, Lincolnshire County Council (2011). Generalized cost comprises time t and cost c (expressed in minutes via the value of time v) and is specified as $g'' = \mu(t + \frac{c}{v})^{\beta}$ where parameters μ and β are positive coefficients determined by experimentation with β calibrated to 0.8 with μ set to give the mean generalised cost (for each trip purpose).

[24] The Sydney Strategic Transport Model is estimated on Household Travel Survey data. The values of time are therefore model results and not model inputs. The cost function includes linear and logarithmic components that increase sensitivity as cost increases. The same function is applied to all mechanized modes which means a dollar spent on bus fares is valued the same as a dollar spent on taxi fares or on petrol, car running costs, tolls and parking (with different parameter values for each trip purpose). Travel time sensitivity is defined by a constant parameter for each mode and for each purpose.

[25] A fractional rather than full factorial design of 25 choice comparisons was used. The correlation between the levels of the five attributes was zero.

Figure 13 plots the estimated sensitivity parameters for in-vehicle time and cost.[26] Travel time sensitivity declined with trip length (particularly for car trips over 90 minutes). At short distances (15 mins), sensitivity was a fifth higher than at long distances (90 mins). However for bus, the decline was slight and for ferry it increased (with fast ferry a noticeably high outlier).

The right hand graph shows cost sensitivity. Only car users had a declining sensitivity with trip length. For standard fare paying PT respondents (concessions users are not shown) a slight decline was evident for rail and ferry users but for bus users, sensitivity increased.

Figure 13: In-vehicle Time Parameter & Trip Length

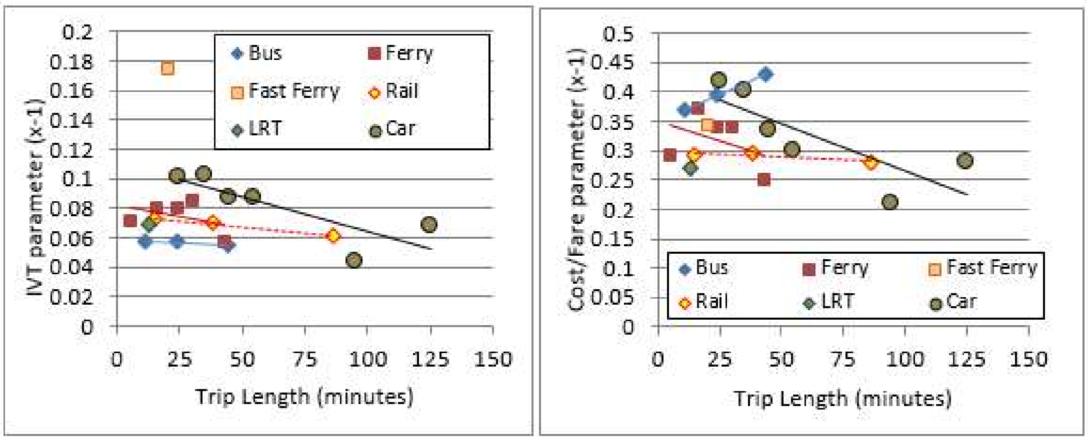
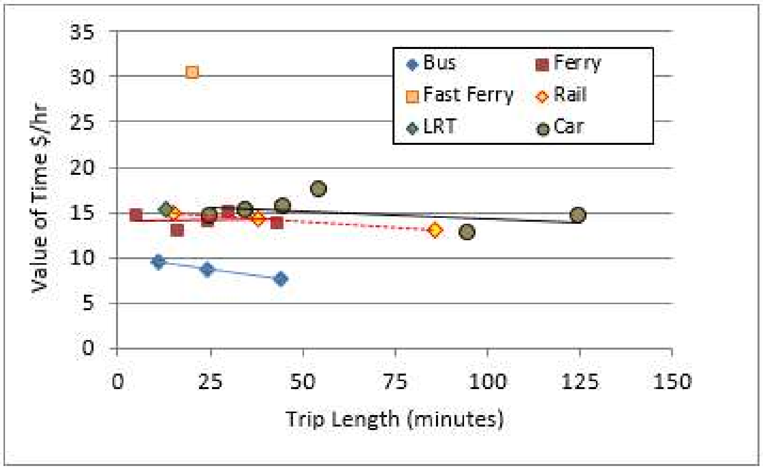


Figure 14 plots the value of time which is the ratio of time sensitivity over cost sensitivity multiplied by 60 (expressing it in dollars per hour).
For car, standard ferry, rail and LRT, VOT was around $15/hr and was invariant with trip length. Fast ferry at $30/hr had a much higher value reflecting 'self-selection'. Bus VOTs were lower and were the only mode where VOT noticeably declined with trip length; reducing from $9.50 at 10 minutes to $7.70 at 44 minutes.

Thus overall, there was no evidence to support an increasing VOT for longer trips as purported by the UK study or an increase in VOT from increased cost sensitivity as per the Sydney Strategic Travel Model.

[26] It is worth recalling that response to the differences in time and cost on the show cards was approximately linear (Figure 3 for car and Figure 8 for PT).

Figure 14: Value of Time & Trip Length.



9. Conclusions

It has become the norm to use a single 'equity' value of time for valuing private travel time in economic appraisals. In Australia, the recommended value for all private travel including walking and waiting time since 1997 has been 40% of the wage rate. In practice this single value has not been applied as intended. Instead travel time multipliers (e.g. for waiting time) have been applied to a base 40% wage value for in-vehicle time.

In NSW, the 40% value has been used for private car travel whereas for rail, until TfNSW was created, Stated Preference surveys were used which gave lower VOTs.

In 2012, TfNSW began a program of market research to test the 40% assumption. An Internet Panel survey was tested but produced poor quality responses from overly price sensitive respondents and was therefore discontinued. Instead, car users were interviewed at activity centres about a recent trip. Four surveys public transport surveys were undertaken. The largest used self-completion questionnaires handed out and collected by surveyors on-board buses, trains and ferries. The other three PT surveys used interviewers with handheld computer tablets. The surveys were kept short and simple which enabled a large sample of 8,877 respondents and 71,000 choice observations to be achieved.

A conventional 'ratio of slopes' approach was used to estimate VOT for public transport. The car survey was designed to include a 'threshold' approach which outperformed the attributes approach and also provided a statistical distribution for the VOT.

Response supported a 40% wage rate assumption for private travel time by car and for commuting trips by public transport. However a lower valuation of around a quarter the wage rate was estimated for non-commuting private travel trips by public transport.

Part of the reason for the lower VOT for other trips was lower personal income. Standardising for income was able to reduce some of the observed differences by mode and trip purpose.

The SP surveys were deliberately designed to test how VOT changed with trip length. It was found that although time and cost sensitivity declined as trip length increased, they both declined at a similar rate which left VOT largely unaffected.

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