Estimating Transfer Penalties and Standardised Income Values of Time by Stated Preference Survey

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Abstract

Changing trains or buses imposes a cost on passengers over and above the connection time involved. Demand models typically represent this cost as a transfer penalty. This paper describes a Stated Preference (SP) survey undertaken in Sydney in 2012 to derive 'pure' transfer penalties that separated out the cost of the penalty from the walk and wait time.

900 passengers were interviewed at stations and bus stops in Sydney using a SP questionnaire on computer tablets. The survey was designed to test the difference between 'same platform' transfers and 'up and down' transfers involving escalators or lifts as well as bus to bus and bus/rail transfers. Different transfer wait times were specified in order to estimate the pure transfer penalty.

The survey was able to isolate the pure transfer penalty and estimate penalties for different types of transfer. As well as estimating transfer penalties, the survey estimated the value of in-vehicle travel time and also assessed how valuations differ by user profile.

A noteworthy feature of the study is the standardisation of valuations for income. The method allowed the values of time and transfer penalties to be estimated at a particular income level and is considered particularly apposite given the recent announcement of Transport to NSW to 'harmonise' values of time in investment evaluations.

The paper also includes a benchmarking exercise in which the values are compared against seventeen other studies.

Keywords: Transfer Penalty, Stated Preference, Values of Time, Equity Values of Time.

1. Introduction

Changing trains or buses imposes cost on passengers over and above the walk and waiting times involved. Demand models typically represent this cost as a transfer penalty.

This study estimates a set of transfer penalties using Stated Preference (SP) market research. As well as estimating a set of transfer penalties, the research attempted to determine whether 'cross-platform transfers' at rail stations had a lower penalty than an 'up/down interchange' requiring a change of platform via escalators, lifts or stairs. The study also compared the penalty of a rail to rail transfer with a bus to rail transfer and also a bus to bus transfer. Finally, the market research also presented the opportunity to estimate the monetary value of onboard bus and rail travel.

A noteworthy feature is a method of standardising the fare and travel time sensitivity parameters for income. This method allows the values of time and service quality to be estimated at a particular income level. The approach is therefore highly relevant given the intent of move to harmonised values of time for purposes of investment evaluations.

The surveys were undertaken in November 2013 during the afternoon peak. 939 rail and bus passengers were interviewed "on train" or at rail stations and bus stops by interviewers using hand held computer tablets. As well as being asked a set of stated preference choice questions, trip purpose, occupation, age group and gender was noted to enable the transfer penalties and values of time to be estimated by market segment.

Section 2 presents a review of previous studies. Section 3 describes the survey design with section 4 summarizes the sample. Section 5 presents the aggregate response to the SP choice questions. Section 6 presents the estimation model and the parameter estimates. Section 7 then presents an innovative method to standardize the parameter estimates for income. Section 8 makes some concluding remarks.

2. A Review of Transfer Penalty Estimates

A literature review was undertaken to understand how other researchers had approached the task of estimating transfer penalties and benchmark the penalties obtained. Seventeen studies were reviewed that provided 35 estimates. Table 1 summarises the studies and the estimated transfer penalties.

The review concentrated on studies undertaken in NSW. Nine of the studies were undertaken in Sydney dating back to a 1992 study of Sydney rail passengers, SDG (1992) and a study of longer distance Sydney to Newcastle rail travel, PCIE (2000). Two Brisbane studies were included; a study of metropolitan travel by Douglas et al (2004), and a study of longer distance rail commuting by PCIE (2000). A study BAH of bus use in Canberra, BAH (2001) was also reviewed.

Most of the transfers concerned transfers between trains. Some estimates were also obtained for other types of transfer: these included a study of bus transfer for the Liverpool - Parramatta Transitway, PPK (1998); a study of Light Rail and bus / rail transfers, BAH (2003) and a study of ferry and bus transfers, Booz (2000).

Most of the estimates were 'gross' penalties that did not separate out the transfer connection time. None of the penalties distinguished between cross-platform and up/down transfers although a study of Glasgow rail did estimate different values for walk connection time, ITS (2001).

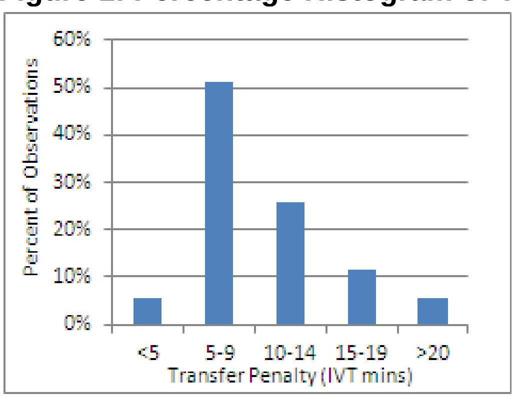
All the Australian studies used Stated Preference market research techniques. Most surveys showed respondents a series (usually 8) of pair-wise travel choices (sometimes three choices) that featured a trade-off between travel time and cost. Transfer was one of usually four or five attributes. The other attributes nearly always included in-vehicle time (IVT) and fare and sometimes included service interval or walk access/egress.

Only three of the Australian studies attempted to estimate the value of time spent at a transfer either walking between platforms or waiting for the next service. Two studies artificially increased the value of transfer time by constraining the coefficient during estimation, BAH (2003) and Douglas (2004).

The estimated transfer penalties ranged from 3 to 31 minutes of IVT with a median value of 9 minutes and an average value of 10 minutes. Figure 1 presents a histogram of the estimated penalties.

The penalty for a same mode transfer e.g. rail to rail or bus to bus tended to be the smaller than a transfer involving a change of mode e.g. bus to rail. Work commuters tended to have a lower penalty than non commuters; a result that may be explained by familiarity and higher train frequencies (which reduce the chance of missed connections).

Figure 1: Percentage Histogram of Transfer Penalties



Of the studies reviewed, the closest to the current study was a 2004 system-wide study of Sydney rail passengers which estimated a transfer penalty of six minutes and valued waiting time at 1.1 times onboard time, Douglas Economics (2004).

Table 1: Review of Studies Valuing Interchange – Part 1

#	Study	Year	Reference	Transfer	Users	Time Period/ Trip Type	Penalty mins	Transfer time weight	Sample	Comment
1	Sydney Rail	2003	Douglas Economics (2004)	Rail	Rail	Peak	6	1.1	1578	Constrained values (Wait = 2xSI value), unconstrained values were higher. Valuation increased with trip length from 4 mins for peak trips < 15 mins to 12 mins for trips > 110 mins
				Rail	Rail	Off-Peak	8	1.0		
2	Sydney LRT	2003	BAH (2003)	Bus	Bus	Peak	8.5	1.7	80	Constrained values (Wait = 2 x Service Interval) unconstrained bus penalties were higher averaging 12 mins and increased with trip length from 6 mins for short trips to 11 mins for medium trips.
				Bus	Bus	Off-Peak	8	1.7	94	
				LRT	LRT	Peak	13	0.6	35	
				LRT	LRT	Off-Peak	16	2.2	41	
				All	All	All	na	1.2	813	Survey of CBD transfer trip provided a value of transfer wait time (values ranged by respondent mode and time period)
3	Sydney Metro	2011	ITS (2011)	Rail	All	Commuter	3	na	524	SP survey to estimate preferences for a NW metro service. The transfer penalties were not reported but calculated from reported WTP figures for onboard time and number of transfers. Transfer time was not specified and the penalties are presumed to be gross. The VOT were $7.68/hr for bus & $8.22/hr for rail/metro.
				Bus	All	Commuter	5	na		
				Metro	All	Commuter	4	na		
4	Sydney Rail	1992	SDG (1992)	Rail	Rail	All	18	na	390	Survey of rail users - values for passengers making medium length rail trips of 21-50 minutes. Transfer time not specified therefore values are gross penalties. Walk access valued at 1.9xonboard time. 1170 interviews over three trip length categories (approx 390 medium).
				R/B	Rail	All	30	na		
5	Par-Chat Sydney	1996	RPPK (1996)	Rail	All	All	14	na	nk	Parramatta-Chatswood rail line market research of rail, bus and car users. Transfer time not estimated so penalties are gross. Walk access was estimated at 1.4 times IVT.
				R/B	All	All	17	na		
6	Liv-Par Sydney	1998	PPK (1998)	B/B	All	All	5	na	nk	Patronage forecasts for Liverpool-Parramatta Transitway in 1998. Bus, rail and car interviews. Transfer time not estimated so penalty is gross. Walk access was estimated at 0.7 to 1.6x onboard time.
7	Syd-New	2000	PCIE (2000)	Rail	Rail	All	9	2.2	255	Survey of longer distance rail travel between Sydney and Newcastle with typical trip of 1.5 hours.
8	Syd Ferries	2000	BAH (2001)	Ferry	Bus/Ferry	Peak	9	na	185	Market research of Sydney Ferry users. Bus/Ferry versus ferry trip. Transfer time was not estimated so gross penalty
						Off-Peak	19	na	190	
9	NWRL Sydney	2004	Hensher (2003)	Rail	All	Non-Work	10.4	na	nk	SP market research by ITS as part of NW demand forecasting. A penalty for non work trips of 10.4 minutes was estimated (presumed to include transfer time) but no estimate for work commuting trips was reported.

Table 1: Review of Studies Valuing Interchange – Part 2

#	Study	Survey Year	Consultant	Transfer	Users	Time Period	Penalty mins	Transfer time weight	Sample	Comment
10	Brisbane	2001	Douglas (2004)	Same Mode	All	All	5	na	3206	SP survey of Brisbane bus, rail, ferry and car users. Suite of SP surveys of 3,206 respondents. Transfer time not estimated so penalties 'gross'. Bus users preferred bus over rail by 11 mins whereas rail users having 5 min preference for rail over bus. Walk time valued at 1.7 for bus and rail and 2.1 for car users.
				Dif Mode	All	All	10	na		
				Rail P&R	All	All	5	na		
				Bus P&R	All	All	11	na		
11	Brisbane Rail	2000	PCIE (2000)	Bus-Rail	Rail&Car	Work	10	na	622	Survey of longer distance Brisbane rail travel with typical trip of 1.5 hours. Transfer penalties estimated for work commuters and non work trips. Survey estimated mode preference for train over bus of 5 mins for commuters & 15 mins for other trips. Walk access valued the same as IVT for commuters & 1.6 for non commuters.
				Bus-Rail	Rail&Car	Non-Work	5	na		
12	Canberra	2001	BAH (2003)	Bus	Bus, car, taxi	Commuting	5	na	586	SP of bus, car & taxi users. Gross penalties estimated. Walk access valued at 1.2xbus IVT for work commuting & other & 1.2-1.9 for educ trips. Wait time valued at 1.1xIVT for car commuters & 1.3 for bus commuters, 1.6 school & 2.4 univ.
						Other	10	na		
13	London Tube	1988	LUL (1988)	Tube	Tube	All	5	2	na	Analysis of O&D data with walk and wait time assumed at 2xIVT
14	UK Rail	2001	ITS (2001)	Rail	Rail	All	8-11	1.7-2.7	nk	Large scale SP study with RP adjustments gave 8 min pure transfer penalty for 20min trip and 11 min for 40 min trip. Cross platform walk time valued at 1.7xIVT and change platform walk time by bridge/subway at 2.7.
15	Glasgow Rail	2001	ITS (2001b)	Rail	Rail	All	8	1.7wt/1.5wlk	nk	SP survey of suburban Glasgow rail users. Pure penalty of 8mins±6mins with wait time valued at 1.7 & walk 1.5xIVT. Pure penalty higher for infrequent rail users.
16	UK Rail	1980-99	ITS (1998)	Rail	Rail	All	31	1.5	na	Meta analysis included 20 mainly SP studies involving rail interchange gave average penalty (presumed gross) of 31 mins. Commuting and SE England had lower penalty attribute to familiarity and reduced chance of missed connections. Walk access was valued at 1.5 and waiting time at 1.6xIVT.
17	UK Rail	na	UKPDFH	Rail	Rail	All	14	na	na	UK Passenger Demand Forecasting Handbook gives a formula to calculate the gross transfer penalty of 10 mins + 0.3xmiles. For a 27 km trip, the penalty would be 14 mins.

2. Survey Design

Based on the findings of the literature review, it was decided to undertake Stated Preference market research of Sydney rail and bus passengers using pair-wise choices presented on computer tablets.

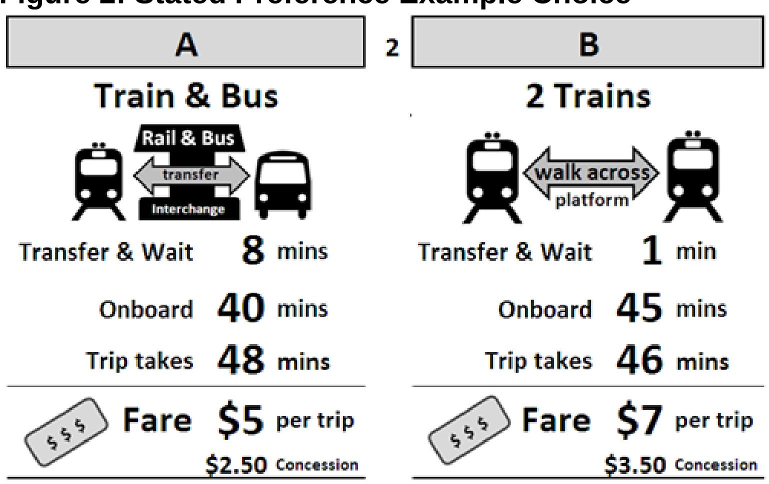
A specific survey aim was to estimate whether a ‘cross-platform transfer’ had a lower penalty to an ‘up/down interchange’ (i.e. involving a change of platform via escalators/lifts) or whether the time spent at the interchange would be a sufficient descriptor. Additional aims were to estimate transfer penalties for bus-to-rail and bus-to-bus.

The market research also presented the opportunity to estimate values of travel time. That is, how much rail and bus passengers are willing to pay to save travel time or avoid a transfer.

The core of the survey was a set of Stated Preference (SP) questions that presented pairs of journeys. The pairs of journeys varied in terms of whether the journey was by train or bus; whether a transfer was required; how long the transfer would take; the onboard time and the fare. For each journey pair, passengers were asked whether they would have used service A or service B for the trip they were making when surveyed.

The choices were developed around a travel convenience versus money ‘trade-off’ that is whether respondents were willing to pay more for a shorter trip / direct trip. Figure 2 provides an example choice. Trip A is by train and bus with the transfer taking 8 minutes, the onboard time takes 40 minutes (giving a total of 48 minutes) and the fare is $5 per trip ($2.50 if eligible for a concession fare). Trip B involves a cross platform rail transfer taking one minute and a rail trip of 45 minutes (total time of 46 minutes) and costs $7 per trip ($3.50 concession).

Figure 2: Stated Preference Example Choice



In summary, the journey choices had four attributes: travel mode for service A; travel mode for service B, the difference in fare for service A minus service B and the difference in onboard time for service A minus service B. Each attribute took 5 levels.

A fractional design of 25 experiments was used. The order of the experiments was randomised and the levels of A and B reversed in half the choices to make the show cards less predictable. The show cards were divided into three sets of 8, 8 and 9 questions. Respondents completing one set chosen at random by the tablet computer.

Table 2 shows the show card levels. There were six transport mode/transfer combinations which were shown using the pictograms in Figure 3. Service A was either (i) a direct rail service, (ii) a direct bus service or (iii) involved a rail cross platform transfer taking 1 minute or (iv) a rail up/down transfer via an escalator or a lift taking 3 minutes. None of the transfers involved waiting for the next train.

Table 2: Attribute Levels in the SP Design

Show	Exp	Service A					Service B					
Card	Design	Mode	Trf Time	Trf Wait	IVT	Fare	Mode	Trf Time	Trf Wait	IVT	Fare	Rev?
1	1	R	0	0	20	4	RCP	1	4	20	3	-
2	13	R_B	4	4	10	3	RCP	1	0	15	5	Yes
3	11	RCP	1	4	30	3	RCP	1	0	20	6	Yes
4	20	RUD	3	0	20	5	R_B	4	0	30	3	-
5	8	B	0	0	15	4	R_B	4	4	20	3	-
6	18	RUD	3	0	20	6	R_B	4	4	20	3	-
7	9	B_B	3	4	10	3	B	0	0	15	6	Yes
8	23	R_B	4	4	35	3	R	0	0	20	6	Yes
9	14	RCP	1	0	20	6	B_B	3	4	20	3	-
10	12	RCP	1	0	15	7	RUD	3	4	20	3	-
11	21	RCP	1	4	10	3	R	0	0	15	7	Yes
12	16	RUD	3	0	15	6	RCP	1	4	20	3	-
13	25	R_B	4	0	20	3	R	0	0	15	6	Yes
14	22	R	0	0	20	5	RUD	3	4	20	3	-
15	19	B_B	3	4	35	3	RUD	3	0	20	7	Yes
16	24	R	0	0	20	4	B_B	3	4	30	3	-
17	17	RUD	3	4	10	3	RUD	3	0	15	4	Yes
18	10	B	0	0	20	7	R_B	4	0	20	3	-
19	15	R_B	4	0	35	3	RCP	1	0	20	4	Yes
20	7	RUD	3	4	30	3	B	0	0	20	6	Yes
21	5	R_B	4	0	10	3	R	0	0	15	6	Yes
22	6	B	0	0	20	5	RCP	1	4	35	3	-
23	2	RUD	3	4	35	3	R	0	0	20	6	Yes
24	4	R	0	0	15	5	B_B	3	4	20	3	-
25	3	R	0	0	20	7	R_B	4	4	30	3	-

R Rail, B Bus, R_B rail and bus, RUD rail up/down transfer, RCP rail cross platform transfer

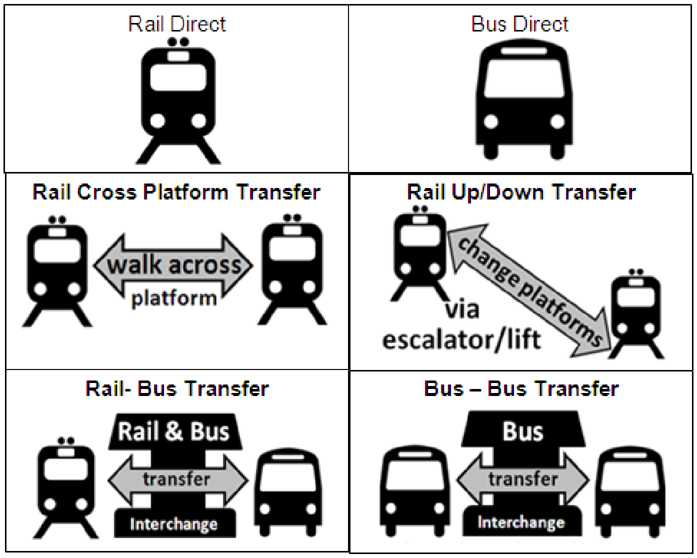
Service B always involved a transfer. Five transfers were specified: (i) a rail cross platform transfer taking 5 minutes, (ii) a rail up/down transfer taking 7 minutes; (iii & iv) a rail - bus transfer taking either 4 or 8 minutes and (v) a bus to bus transfer taking 7 minutes. The transfer times included a wait time of 4 minutes if the transfer was 7 or 8 minutes or zero if the transfer time was less than 7 or 8 minutes. These time components were described to the respondents by the interviewers.

Two sets of fares and travel times were developed to cater for 'short' trips of up to 30 minutes and 'medium' trips taking more than 30 minutes (Table 1 shows the 'short' questionnaire).

Table 1 shows the 'short' questionnaire levels. On the 'medium' questionnaire, the times and costs were increased in a way that kept the time and cost differences between A and B the same. This enabled the 'short' and 'medium' responses to be analysed together without spurious correlations being introduced between the attribute levels.

The combined set of fifty show cards was then loaded onto the tablet computers. The use of tablet computers had the advantage of enabling the order of the show cards to be randomised. It also reduced the amount of paper the fieldworkers had to carry and speeded up data entry. Sweeney Research undertook the fieldwork.

Figure 3: Mode/Transfer Pictograms



3. Sample Size

Three pilot surveys were undertaken to test the design and method. One modification was the addition of an income question onto the survey form. Otherwise, only minor modifications were made to the questionnaire which allowed the pilot data to be included with that of the main survey. The main survey was undertaken in November 2012 on weekdays in the afternoon peak between 3pm and 7pm. Interviews were undertaken on rail station platforms, trains and at bus stops. A total of 1,083 passengers were intercepted of which 939 (84%) completed one or more SP questions. 585 (62%) were rail users and 354 (38%) bus users.

Most respondents (288 bus and 318 rail) were travelling over 30 minutes and completed the ‘medium’ SP. 267 rail and 66 bus respondents completed the ‘short’ SP.

Two thirds were commuting home from work with the share highest at 90% for bus ‘medium’ respondents compared to 57% for rail. For rail, 15% were travelling home from college or university compared to 6% for bus. 10% were making personal business trips, visiting friends and relatives or shopping. Less than 2% were making company business trips.

More females (56%) than males (44%) were surveyed. Nearly 90% were aged 20 to 64 with few young passengers (up to sixteen) or older passengers (65+) interviewed. Around three-quarters were employed with students accounting for a fifth of the sample. Few unemployed, house persons and retired passengers were interviewed. More bus respondents were employed (86%) than rail respondents (65%) and fewer bus respondents were students (11%) than for rail (28%). Bus users had a higher income ($84,000 p.a.) than rail respondents ($52,000 p.a.) reflecting the greater percentage employed.

Sixty percent of ‘medium’ rail trips involved a transfer (41% to/from another train and 19% to/from bus) compared to 18% of ‘short’ trips. For bus, the percentages were much lower at 6% for ‘medium’ and 10% for ‘short’ trips.

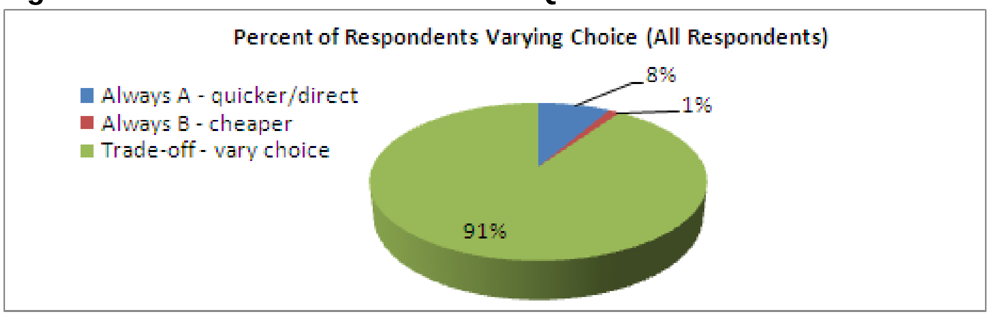
Thirty percent of rail respondents and 13% of bus respondents were entitled to a fare concession which typically gave a 50% discount on the standard fare. On the SP, a 50% discount was shown.

4. Aggregate Analysis of SP Response

Each respondent was asked either eight or nine SP questions which gave a total of 7,806 SP observations.

Nine out of ten respondents varied their choice; sometimes selecting the more expensive quicker and more direct service A and sometimes the cheaper but slower and less direct service B. Of the 10% who never varied their choice, nearly all chose the quicker more expensive service. Very few always chose the slower but cheaper service.

Figure 4: Choice Variation across SP Questions



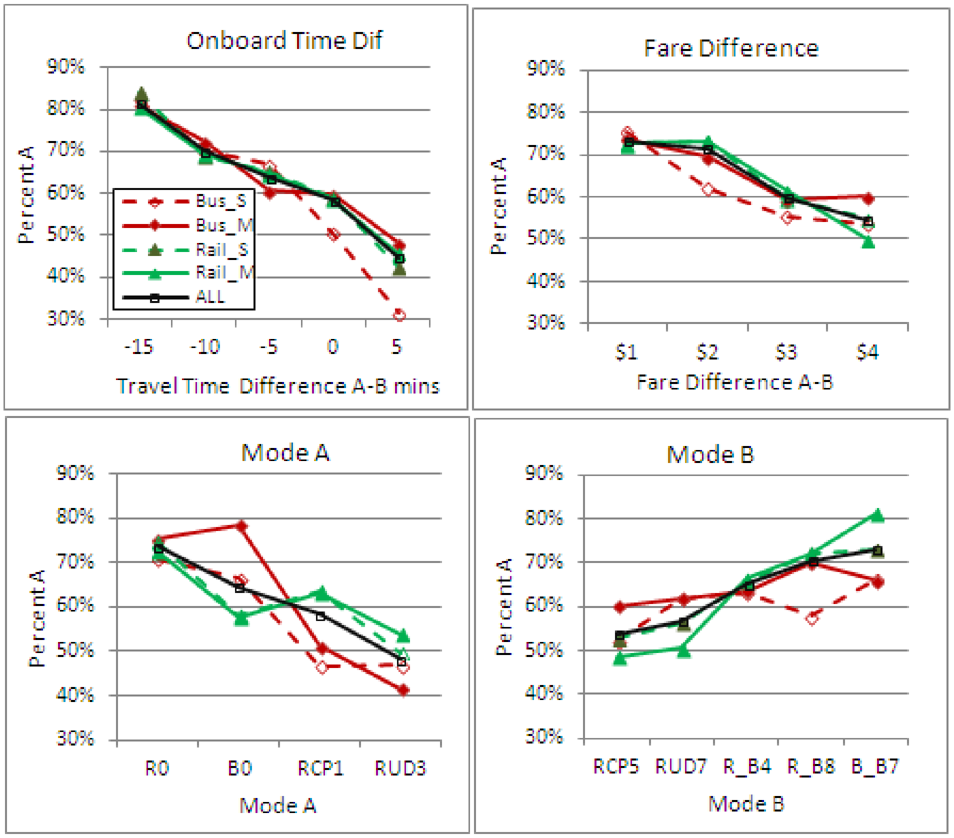
The average percentage choosing service A for each of the four attributes is shown in Figure 5. The graph was approximately linear for IVT with more respondents choosing A, the greater the time saving. For the 15 minute difference, 80% chose A with little difference between the four market segments. When there was no onboard time saving, 60% chose A. When option B was five minutes faster, the percentage choosing A fell to less than 50%.

The sensitivity to fare was also linear but weaker than onboard time. The percentage choosing A was greatest (75%) for the $1 fare difference then fell to 71% at $2, 60% at $3 and 54% at $4. There was little difference between the four market segments.

For transfer/mode, the highest percentage choosing A was for a direct rail service (R0) for three of the market segments. The exception was bus 'medium' where a higher percentage chose the direct bus service (B0). For rail respondents, the percentage fell from over 72% for a direct rail service to 58% for a direct bus service. The percentage then declined again for a rail cross platform transfer taking a minute (RCP1) and was lowest when the service involved a 3 minute 'up/down' rail transfer (RUD3).

The attribute levels for mode B are shown in their preference order and as a result slope upwards to the right. The lowest percentage choosing A was 54% when service B involved a 5 minute rail cross platform minutes (RCP5). The percentage rose to 57% for a seven minute up/down rail transfer. For a four minute rail-bus transfer (R_B4), the percentage increased to 65% and reached 70% for an eight minute transfer. The highest percentage was 73% for a seven minute bus to bus transfer.

Figure 5: Percentage Choosing Train A by Attribute Level



5. Disaggregate Analysis of SP Response

A logit model (equation 1) was fitted using maximum likelihood estimation to the aggregated response data:

$$Pa = \frac{Z}{1+Z} \text{ where:}$$

$$Z = \beta o + \beta_f F + \beta_{fc} Fc + \beta_{OBT} OBT + \beta_{TrfT} TrfT + \beta_{BUS} BUS + \beta_{RCD} RCD + \beta_{RUD} RUD + \beta_{RB} RB + \beta_{BB} BB \quad .....(1)$$

Where:
$\Pr A$ = proportion choosing A
F = fare difference service A- service B
Fc = fare difference service A- service B if passenger is entitled to a concession
OBT = onboard time difference service A- service B
$TrfT$ = transfer time difference service A- service B
BUS = Difference (A-B) in whether service is direct bus (1) else zero
RCD = Difference (A-B) in whether service is a rail cross platform (1) else zero
RUD = Difference (A-B) in whether service is up/down transfer (1) else zero
RB = Difference (A-B) in whether service is rail - bus transfer (1) else zero
BB = Difference (A-B) in whether service is bus - bus transfer (1) else zero
β_i = parameter to be estimated

A study aim was to estimate 'pure' transfer penalties net of any connect or waiting time. Accordingly, a transfer time variable (*TrfT*) was included in equation 1. The type of mode and transfer was described by five dummy variables that took a value of 1 or 0. Direct rail was specified as the base service type. Although a constant is included in equation 1 it should be zero since when there is no difference between A and B, the percentage should be 50%.

There was some imbalance in the sample response by SP question with a greater response to the first set of eight questions than the second and third sets (nine). A set of balancing factors was calculated based on the average number of observations for all 25 questions compared to the respective question.

The estimated models are presented in Table 3. Seven models are presented: one for each segment plus three 'overall' models. The upper part of the table provides samples sizes and 'goodness of fit' statistics. Two sample sizes are given: the number of SP observations and the number of interviews (approximately 3/25 of the number of SP observations). The 'goodness of fit' statistic is the percentage of observations correctly predicted by the model. In the middle of the table are the parameter estimates. In the lower part of the table are the parameter |t| values which measure the accuracy of the estimates and which were calculated as the ratio of the parameter estimate over the standard error.

Table 3: Market Segment Parameter Estimates

	Bus			Rail			
	Short	Med	All	Short	Med	All	ALL
Observations	553	2,403	2,956	2,220	2,661	4,881	7,837
Interviews	66	288	354	267	318	585	939
% Correct	73%	72%	72%	70%	72%	71%	70%
Parameter Est							
IVT	-0.116	-0.083	-0.089	-0.096	-0.087	-0.091	-0.087
Fare	-0.37	-0.277	-0.291	-0.359	-0.404	-0.384	-0.337
Fare_C	-0.572	-0.693	-0.657	-0.467	-0.691	-0.6	-0.576
TrfT	0.023	-0.14	-0.113	-0.091	-0.058	-0.074	-0.092
Bus	-0.225	0.192	0.105	-0.929	-0.929	-0.921	-0.566
RCP	-1.042	-1.139	-1.115	-0.65	-0.624	-0.628	-0.807
RUD	-1.316	-1.125	-1.146	-0.912	-0.809	-0.843	-0.943
B_R	-1.286	-1.376	-1.347	-1.519	-1.682	-1.596	-1.501
B_B	-1.711	-1.215	-1.293	-1.738	-2.491	-2.123	-1.784
Const	0.266	-0.482	-0.356	-0.051	0.191	0.082	-0.128
|t| value							
IVT	7.7	11.9	14.8	13.7	12.4	18.2	21.8
Fare	3.6	5.7	6.6	6.9	8.1	10.7	12.5
Fare_C	2.9	6.7	7.3	5.5	9.6	10.9	12.8
TrfT	0.3	3.7	3.3	2.2	1.6	2.7	4.4
Bus	0.8	1.3	0.8	6.8	7.4	10.0	7.8
RCP	4.0	9.5	10.3	5.2	5.3	7.3	12.0
RUD	3.9	7.1	8.0	5.5	5.3	7.5	10.8
B_R	3.8	8.5	9.3	8.9	10.6	13.9	16.9
B_B	3.9	6.0	7.0	8.0	11.8	14.0	15.4
Const	0.6	2.1	1.8	0.2	0.9	0.5	1.0

Precise estimates were obtained for three of the market segments. The exception was 'short' bus where some parameters were insignificant reflecting the smaller sample (66 interviews). In terms of 'goodness of fit', over 70% of the observed choices were correctly predicted with little difference across the market segments.

In terms of the estimated parameters, the fare and onboard travel time parameters had correct negative sign and were estimated with precision. Parameter size (ignoring sign) reflects the sensitivity of passengers to changes in time or cost. The higher the value, the more sensitive passengers are to a difference of a minute or a dollar.

There were statistically significant differences in the value of the 'bus' constant. Rail users preferred rail and thus the bus parameter was negative whereas bus respondents making medium trips preferred bus and thus the parameter was positive (although not significantly different from zero at the 95% confidence level).

All the transfer penalties were negative and statistically significant indicating a preference for direct travel. The smallest parameters (ignoring sign) and hence the smallest penalties were for a rail cross platform followed by a rail up/down transfer. The largest parameters were for a bus to bus transfer and a rail to bus transfer. Again, for rail users, the preference against a bus to bus transfer was higher than for bus respondents.

Table 4, Figure 5 and Figure 6 present the relative valuations calculated from the parameter values. The top half of the table presents the central estimates and the lower part presents the standard error of the estimate. The graphs present the 95% confidence range of the estimates as well as the central estimate.

Table 4: Market Segment Relative Valuations

	Bus			Rail			
Mean Estimate	Short	Med	All	Short	Med	All	ALL
VOT NonConc $/hr	18.81	17.98	18.35	16.04	12.92	14.22	15.49
VOT_Conc $/hr	7.39	5.13	5.63	6.97	4.77	5.55	5.72
VOT_Av $/hr	16.87	16.31	16.70	13.78	10.15	11.62	13.14
TrfT/OnBT mins	-0.2	1.7	1.3	0.9	0.7	0.8	1.1
Bus/OnBT mins	1.9	-2.3	-1.2	9.7	10.7	10.1	6.5
RCP/onBT mins	9.0	13.7	12.5	6.8	7.2	6.9	9.3
RUD/OnBT mins	11.3	13.6	12.9	9.5	9.3	9.3	10.8
B_R/OnBT mins	11.1	16.6	15.1	15.8	19.3	17.5	17.3
B_B/OnBT mins	14.8	14.6	14.5	18.1	28.6	23.3	20.5
Const/OnBT mins	-2.3	5.8	4.0	0.5	-2.2	-0.9	1.5
Standard Error of Estimate							
VOT NonConc $/hr	5.59	3.47	2.99	2.54	1.81	1.48	1.38
VOT_Conc $/hr	3.40	1.05	1.04	1.82	0.82	0.78	0.67
VOT_Av $/hr	4.67	3.02	2.61	1.95	1.23	1.06	1.06
TrfT/OnBT mins	0.7	0.5	0.4	0.4	0.4	0.3	0.2
Bus/OnBT mins	2.4	1.8	1.4	1.5	1.6	1.1	0.9
RCP/onBT mins	2.4	1.8	1.4	1.4	1.5	1.0	0.9
RUD/OnBT mins	3.1	2.2	1.8	1.8	1.9	1.3	1.1
B_R/OnBT mins	3.1	2.3	1.9	2.0	2.2	1.5	1.2
B_B/OnBT mins	4.1	2.7	2.3	2.5	3.1	2.0	1.6
Const/OnBT mins	4.1	2.7	2.2	2.6	2.6	1.8	1.4
% Concession	17%	13%	13%	25%	34%	30%	24%

All the relative valuations involve the onboard time parameter. The value of time uses the onboard time parameter as the numerator and multiplies by 60 to get a dollar value per hour whereas the mode/transfer valuations use the onboard time parameter as a denominator to express the penalties in equivalent IVT minutes.

The overall value of IVT was $13.14/hr. Bus respondents had a higher value than rail respondents at $16.70/hr versus $11.62/hr (|t|= 1.81). It should be stressed that the difference reflects user preferences and not modal characteristics since both rail and bus users completed the same questionnaire featuring travel by bus and train. The value of $11.62/hr for rail compares with $12.17/hr estimated by similar SP surveys in 2010-2011 of Sydney rail passengers travelling in the peak, Douglas & Karpouzis (2012).

Figure 5: Estimated Value of Time by Market Segment
Central and 95% Confidence Range in the Value of Onboard Train Time in Fare Dollars

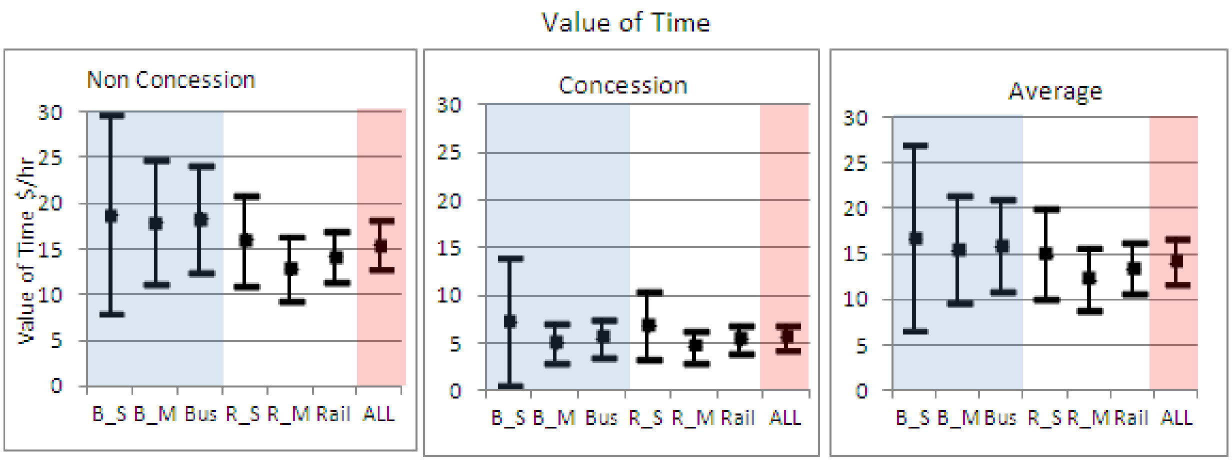
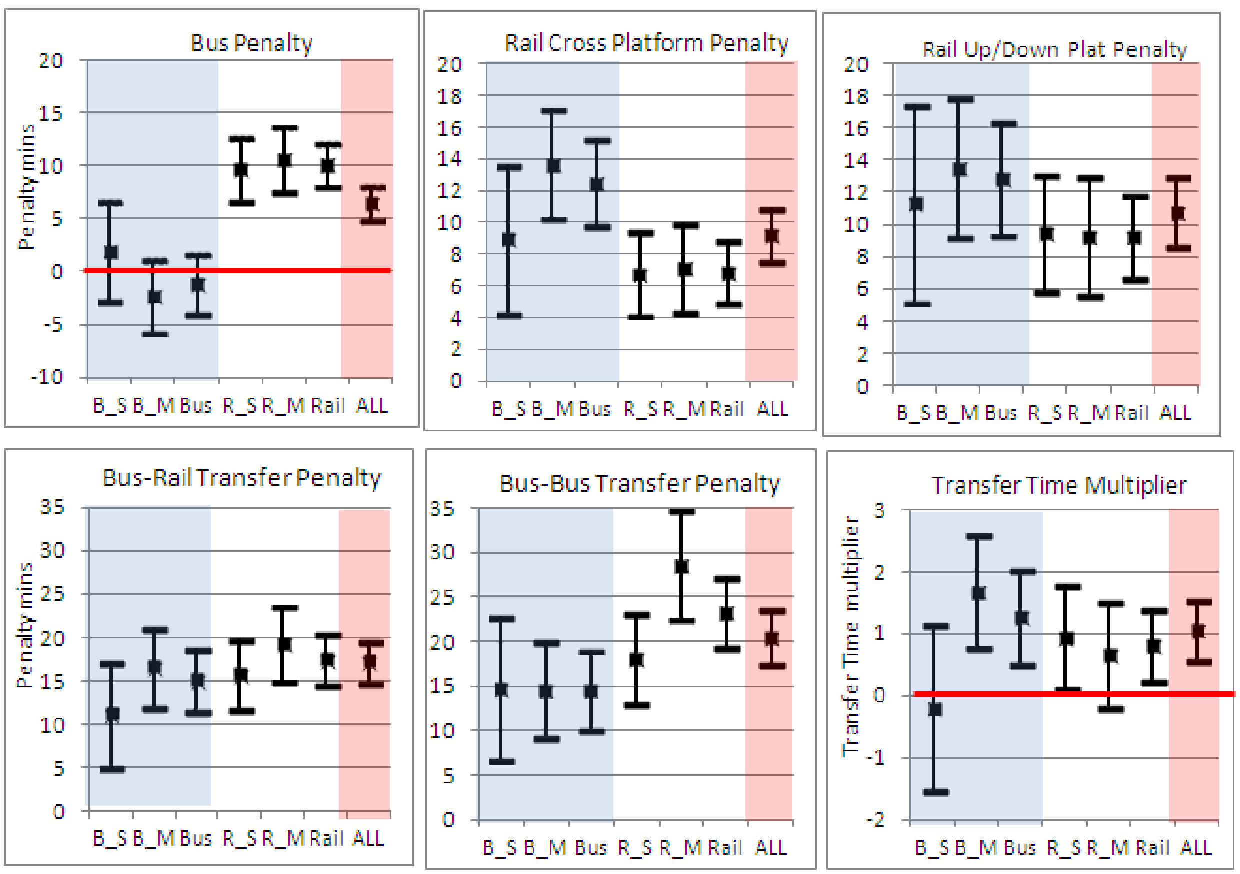


Figure 6: Estimated Transfer Penalties by Market Segment
Central and 95% Confidence Range in the Estimated Transfer Penalties



One contributing factor to the higher bus value was a lower concession share. For bus respondents, 13% were concession users whereas for rail, the percentage was more than double at 30%. The standard fare (non concession) value of time was also higher for bus at $18.35/hr than for rail at $14.22/hr reflecting higher incomes (see section 7) amongst bus respondents and a greater commuting percentage.

There were significant differences between bus and rail respondents in terms of their mode and transfer penalties. One of the most noteworthy was the modal preference for rail and bus. Rail respondents had a 10 minute penalty against travelling by direct bus whereas bus medium respondents had a 2 minute penalty against travelling by direct rail.

Bus respondents also had a significantly higher transfer penalty than rail respondents. For a cross-platform rail transfer, the penalty was 12.5 minutes for bus respondents compared to 7 minutes for rail respondents.

Bus users did not distinguish a cross-platform from an up/down transfer whereas rail respondents, more familiar with station layouts, valued a rail up/down transfer 2.4 minutes worse than a cross platform transfer although the difference was not statistically significant at the 95% level ($|t| = 1.4$).

Like the bus penalty, a bus-bus transfer was valued significantly higher by rail respondents at 23 minutes than bus respondents at 14.5 minutes. Subtracting the bus penalty to get the net cost of a bus to bus transfer (versus a direct bus trip), brought the valuations closer to 16 and 13 minutes for rail and bus respondents respectively.

Bus and rail users valued the penalty of a rail-bus transfer similarly. For bus respondents the penalty was valued at 15 minutes compared to 17.5 minutes by rail respondents. It is worth noting that for this mixed mode journey involving both bus and rail any ‘own’ mode bias is neutralised.

The value of transfer time, an amalgam of the time to get from one platform to another plus the waiting time was valued 10% higher than IVT. The valuation differed by segment. Bus ‘medium’ respondents valued transfer time at 1.7 times IVT whereas rail respondents valued transfer time less than IVT. For the ‘short’ bus segment, the wait parameter was very weak and had a positive instead of negative sign.

The transfer valuation is lower than the ‘conventional’ wait time valuation of twice IVT. This is important if the pure penalties presented in this paper are used to calculate ‘gross’ transfer penalties in combination with a ‘conventional’ (or other) wait time valuation. If such an amalgam is used, the gross penalty will be overstated. Instead it would be better to calculate a gross penalty using the wait time in this study and then subtract the ‘conventional’ wait time from it.

The passenger and trip profile information was used to estimate market segment models and see how valuations were affected by purpose, gender, occupation etc. Figure 7 summarises the results by denoting the values of time and transfer penalties that were statistically significant at the 90% (light shading) and 95% (dark shading) confidence level. Where the group listed first had a higher valuation, a positive sign is used and red shading. Where the first group had a lower valuation, a negative sign and blue shading is used.

Figure 7: Effect of profile on the estimated relative valuations

Profile	Group	Average VOT $/hr	TrfT/ IVT	Penalty/IVT Bus	RCP	RUD	B_R	B_B
Market Segment	Bus S/Bus M		--			-		
	Rail S/Rail M	+						--
	Bus / Rail	+	+	--	+			--
Purpose	Educ/Work	--		+				
	PB&CB/Work				-			
	Other/Work	--		++				
Gender	Female/Male	++		--				-
Occupation	Student/Emp	--	--					
	Not Emp/Emp	--		++				
Transfer	Rail Trfr/Direct			++	-			++
	Bus Trfr/Direct			-				
Ticket Type	Single/Multi Use	--		++				++

Key:

++	Higher valuation for 1st group / 2nd group statistical significant at 95% CL
+	Higher valuation for 1st group / 2nd group statistical significant at 90% CL
--	Lower valuation for 1st group / 2nd group statistical significant at 95% CL
-	Lower valuation for 1st group / 2nd group statistical significant at 90% CL

In terms of market segmentation, bus passengers making short trips valued transfer time less than bus passengers making medium length trips.

Rail passengers making short trips had a lower bus to bus transfer penalty than rail passengers making medium trips. Bus users had a lower bus penalty and a lower bus-bus transfer penalty than rail respondents.

Education ($7.50/hr) and 'other' (shopping / leisure) trips ($8.70/hr) had a lower value of time than work commuting trips ($15.70/hr) and company/personal business trips ($12.80/hr).

Females ($15.80/hr) had a higher value of time than males ($10.90/hr); they also had a lower preference for rail over bus than males worth 9 minutes compared to 5 minutes for females.

Students ($8.30/hr) and passengers 'not employed' ($10.90/hr) had a lower value of time than work commuters ($15.10/hr). Students valued transfer time less than work commuters whilst commuters had a lower penalty (6 minutes) than passengers making 'other' trips travelling (14 mins).

7. Income Standardised Valuations

In March 2013, TfNSW released *"Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives"* (PGEATII), TfNSW in which the adoption of a common value of time for bus, rail and car is recommended for equity reasons, TfNSW (2013). The SP survey offered the opportunity to investigate a method of standardising parameters for income whilst retaining preference differences between bus and rail users and also by trip purpose.

Income Standardisation involved a six step procedure: step 1 'in-filled' non-response to the income question; step 2 undertook choice regressions by income category; step 3 regressed the fare and IVT parameters on the mid-point income; step 4 standardised the regression parameters for the average income of the sample; step 5 multiplied the fare and IVT income adjustments against the IVT and fare differences and step 6 re-estimated the choice model.

Step 1 'in-filled' for non response to the income question. 505 out of the 939 (54%) SP respondents answered the income question which involved 'ticking' which annual gross personal income band they were in: <$30k, $30-60k, $60-90k, $90k-120k, >$120k. The 'response rate' was artificially reduced by not including the income question on the pilot questionnaire. When limited to those asked the question, the response rate increased to 80%. Income categories were assigned probabilistically using of random numbers (0-1) referenced to the cumulative income percentage by occupation (employed, student, house-person, retired and unemployed) and controlled for concession entitlement.

Step 2 fitted the choice model (equation 1) to the five income bands, Table 5. The standard value of time increased from $13.10/hr for the <$30k income band to $16.90/hr for the $90-120k band. By contrast, the concession value remained around $5.50/hr with too few observations in the highest two income bands to estimate a value. The average value of time (weighted by the concession proportion) increased from $9/hr to $16.90/hr ($90-120k) then declined to $15.50/hr in the >$120k band.

Table 5: Effect of Income on parameter & relative values

	Parameter Estimate					Parameter |t| value				
	1	2	3	4	5	6	7	8	9	10
Parameter	<$30k	$30-60k	$60-90k	$90-120k	<120k	<$30k	$30-60k	$60-90k	$90-120k	<120k
IVT	-0.081	-0.094	-0.088	-0.085	-0.096	11.6	11.8	11.0	7.1	8.0
Fare	-0.371	-0.359	-0.321	-0.301	-0.371	7.3	6.3	5.6	3.5	4.6
Fare_C	-0.484	-0.668	-0.636	ne	ne	7.4	6.3	4.4	na	na
TrfT	-0.064	-0.116	-0.127	-0.065	-0.097	2.4	2.6	2.9	1.0	1.6
Bus	-0.779	-0.513	-0.435	-0.323	-0.577	6.1	3.4	2.8	1.4	2.6
RCP	-0.652	-0.923	-0.908	-0.726	-0.934	5.6	6.6	6.5	3.5	37.4
RUD	-0.898	-1.059	-1.027	-0.692	-0.897	5.8	5.8	5.6	2.5	3.4
B_R	1.399	1.757	1.695	1.169	1.212	9.0	9.4	8.9	4.1	4.5
B_B	1.833	1.958	1.716	1.626	1.494	9.0	8.1	7.2	4.5	4.2
Constant	-0.03	-0.244	-0.427	-0.022	0.185	0.1	0.9	1.6	0.1	0.5
VOT Std $/hr	13.1	15.7	16.4	16.9	15.5	12.6	6.6	5.4	3.2	4.2
VOT Conc $/hr	5.7	5.5	5.5	ne	ne	1.8	6.0	12.4	na	na
VOT AV $/hr	9.0	14.0	15.6	16.9	15.5	3.7	7.0	5.5	3.2	4.2
TrfT/IVT	0.79	1.23	1.44	0.76	1.01	2.3	2.6	2.8	1.0	1.6
Bus/IVT	10	5	5	4	6	5.4	3.3	2.7	1.3	2.5
RCP/IVT	8	10	10	9	10	5.0	5.8	5.6	3.1	7.8
RUD/IVT	11	11	12	8	9	5.2	5.2	5.0	2.4	3.1
B_R/IVT	-17	-19	-19	-14	-13	7.1	7.3	6.9	3.6	3.9
B_B/IVT	-23	-21	-20	-19	-16	7.1	6.6	6.0	3.8	3.7
Prop Concession	55%	17%	8%	1%	6%					
SP Obs	2429	1914	1852	762	880					
Interviews	291	230	222	91	106					

ne not estimated due to too few observations

Step 3 developed income adjustment factors for the IVT and standard fare attributes by fitting the parameter value for each income band to the mid-point income using weighted Ordinary Least Squares (OLS) regression with weights proportional to the relative t value $5.\{t_y / \sum t_y\}$).

Figure 8 shows the relationship for standard fare respondents between income and the fare parameter, the IVT parameter and the resultant value of time. The relationship is presented for standard fare payers and as well as the mean value, the range in the estimated is presented (± the standard error). Superimposed is the regression line.

Figure 8: Effect of Income on IVT, Fare & Value of Time

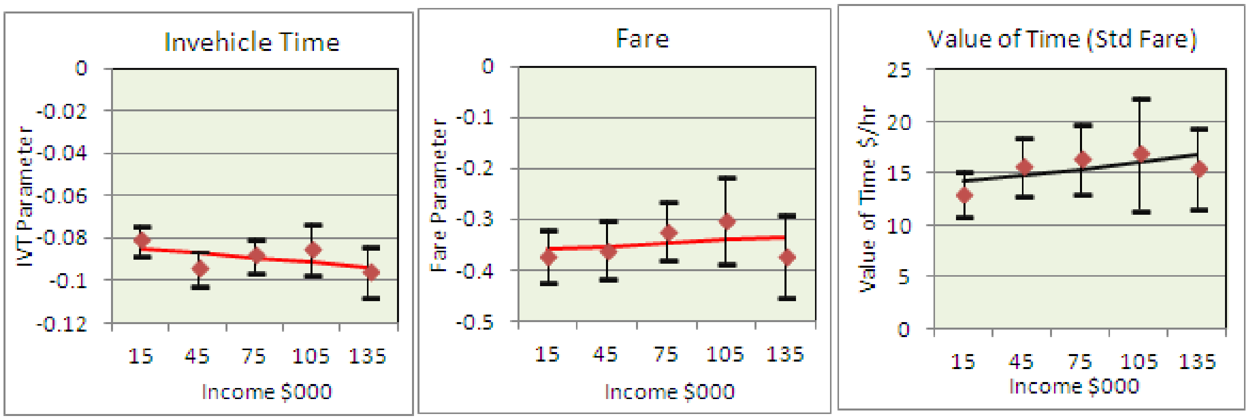


Table 6 presents the regression parameters. For IVT, increasing income made the parameter more negative thereby increasing the sensitivity to travel time whereas for fare the converse was true. The strength of relationships was not strong however partly resulting from the incomplete income data. A stronger relationship has been estimated in a contemporary study of Inner Sydney public transport, Douglas Economics (2013).

Table 6: In-vehicle time & fare parameter model with income

Parameter	δo	|t|	δy*1000	|t|	Obs
IVT	-0.084	16.1	-0.073	1.1	5
Fare	-0.362	13.3	0.202	3.1	5

Step 4 applied the parameters (δo) and (δy) to each income category and then standardised the values to the mean income of $59k using equation 2. The result was the income adjustment factors in Table 7.

$$Yc = \frac{\delta o + \delta y Yc}{\delta o + \delta y(59)} \text{........(2)}$$

Table 7: Income adjustment factors

Parameter	Income Category <\$30k	\$30-60k	\$60-90k	\$90-120k	<120k
IVT	1.025	1.008	0.991	0.973	0.956
Fare	0.964	0.988	1.013	1.038	1.063

Step 5 multiplied the fare (F) and IVT (OBT) variables (equation 1) by the respective income adjustment factor. The choice model (equation 1) was then re-estimated with the resultant parameters and relative values now standardised at the mean income level ($59k) of the sample. Table 8 presents the market segment models. The parameter estimates can be compared with the income un-standardised values in Table 3.

Table 8: Income Standardised Parameters

	Parmeter Value							t value						
	Bus			Rail				Bus			Rail			
Parameter	Shrt	Med	All	Shrt	Med	All	All	Shrt	Med	All	Shrt	Med	All	All
IVT * PY	-0.116	-0.082	-0.088	-0.097	-0.088	-0.092	-0.087	7.7	11.7	14.7	13.9	12.6	18.4	21.8
Fare * PY	-0.356	-0.281	-0.292	-0.367	-0.410	-0.391	-0.342	3.5	5.7	6.6	7.1	8.2	10.9	12.2
Fare_C	-0.546	-0.679	-0.641	-0.459	-0.679	-0.590	-0.563	2.8	6.7	7.1	5.4	9.4	10.9	12.5
TrfT (Transfer Time)	0.022	-0.141	-0.113	-0.093	-0.058	-0.074	-0.092	0.3	3.7	3.3	2.3	1.6	2.7	4.2
Bus	-0.232	0.193	0.104	-0.930	-0.931	-0.922	-0.566	0.8	1.3	0.8	6.8	7.4	10.0	7.8
RCP (cross plat)	-1.040	-1.140	-1.115	-0.652	-0.625	-0.622	-0.808	4.0	9.5	10.3	5.2	5.3	7.2	12.1
RUD (up/down)	-1.310	-1.123	-1.145	-0.917	-0.811	-0.850	-0.944	3.9	7.1	8.0	5.6	5.3	7.6	10.9
B_R^ (Bus&Rail)	-1.280	-1.377	-1.347	-1.523	-1.684	-1.600	-1.600	3.8	8.6	9.3	9.0	10.7	13.9	18.0
B_B^ (Bus&Bus)	-1.700	-1.213	-1.300	-1.746	-2.499	-2.130	-1.787	3.9	5.9	7.1	8.0	11.7	14.0	15.4
Constant	0.229	-0.483	-0.363	-0.033	0.198	0.090	-0.124	0.5	2.1	1.8	0.1	0.9	0.5	1.0
VOT Std $/hr	19.55	17.51	18.08	15.91	12.88	14.12	15.30	3.7	7.7	8.5	7.3	7.7	10.6	13.9
VOT Conc $/hr	7.72	5.13	5.66	7.07	4.85	5.63	5.78	5.6	2.9	3.8	7.1	7.9	9.5	5.5
VOT Wghtd Av $/hr	17.66	13.30	14.36	13.70	10.15	11.57	13.05	4.0	7.3	8.5	7.4	6.9	9.8	13.3
TrfT/IVT	-0.19	1.72	1.28	0.96	0.66	0.80	1.06	0.3	3.5	3.2	2.2	1.6	2.7	4.1
Bus/IVT	2.0	-2.4	-1.2	9.6	10.6	10.0	6.5	0.8	1.3	0.8	6.1	6.4	8.8	7.3
RCP/IVT	9.0	13.9	12.7	6.7	7.1	6.8	9.3	3.6	7.4	8.4	4.8	4.9	6.7	10.6
RUD/IVT	11.3	13.7	13.0	9.4	9.2	9.2	10.8	3.4	6.0	7.0	5.2	4.9	7.0	9.7
B_R/IVT	11.0	16.8	15.3	15.7	19.1	17.4	18.3	3.4	6.9	7.8	7.5	8.1	11.1	13.9
B_B/IVT	14.7	14.8	14.8	17.9	28.4	23.2	20.5	3.5	5.3	6.4	6.9	8.6	11.1	12.6
Prop Conc	16%	13%	13%	25%	34%	30%	24%							
Av Income $k p.a.	63	72	70	51	53	52	59							
SP Obs	553	2,403	2,956	2,220	2,661	4,881	7,837							
Interviews	66	288	355	266	319	586	940							

notes: PY = Personal Income ^ sign reversed on B R & B B parameters

The standard fare value of time was left virtually unchanged at $15.30/hr (as it should be) as was weighted average value at $13.05/hr. Where there was a noticeable effect was in the value of time for medium bus which declined by $3/hr from $16.31/hr to $13.30/hr due to the higher average income ($72k). The effect on the transfer penalties from standardising the IVT parameter for income was negligible with only a slight decrease in the bus medium values.

8. Conclusions

The survey was able to estimate the 'pure' transfer penalty that people associate with changing trains or buses in contrast to most of the studies reviewed that reported 'gross' penalties including the time spent at a transfer station. In this survey, the pure penalty was isolated by showing a range of connection times.

The survey found rail respondents to have a strong preference for travelling by direct rail rather than direct bus which converted into a bus 'penalty' of 10 minutes of onboard time. However amongst bus users there was no strong preference for rail. Indeed the survey estimated a preference albeit weak for bus over rail of one minute. The weighted average penalty of 7 minutes reflected the relative number of rail and bus interviews in the sample.

Four types of transfer penalty were estimated. The smallest penalty was for a rail cross platform followed by a rail 'up/down' transfer. Amongst rail users, most of whom were frequent users and therefore familiar with station layouts, the advantage of a cross platform transfer was worth 2.4 minutes. However amongst bus users, who were less familiar with station layouts, there was virtually no difference in the two penalties.

The penalty for a bus-rail transfer was nearly twice as great as a rail-rail transfer at 18.3 minutes. Bus users making short trips had the lowest bus-rail transfer penalty of 11 minutes and rail users making medium trips had the greatest penalty of 19 minutes.

The fourth type of penalty was a bus to bus transfer and this penalty was perceived the most onerous with a time cost of 20.5 minutes. For rail, the 'penalty' was 23 minutes and includes a general mode preference against bus. After the bus penalty of 10 minutes was subtracted, the bus to bus transfer penalty reduced to 13 minutes which is reasonably close to the penalty of 15 minutes perceived by bus respondents.

The study was also able to estimate the value of in-vehicle time for bus and rail users. In March 2013, Transport for NSW signalled a move towards a 'harmonised' for private travel with the same value used for bus, light rail, rail, ferry and car irrespective of the quality of the service. An alternative approach has been developed in this study that standardised parameter values for income.

The study found that bus respondents, who had incomes a third higher than rail respondents, had a value of time 44% higher. Adjusting for their higher income reduced the difference to 24%. At the average income of $59,000 per year, the average value of time (taking into account concession use) was $13.05/hr. For the transfer penalties, the effect of standardising the IVT parameter for income was negligible.

Income standardisation offers a way forward in allowing income effects to be removed from economic evaluations whilst retaining residual modal preferences and perceived quality differences.

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