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Developing a Suite of Demand Parameters for Inner Sydney Public Transport

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Abstract

Transport Performance and Analytics of Transport for NSW (TfNSW) has developed a public transport project model to forecast patronage from changes in public transport provision. Parameters describing how passengers respond to different aspects of their journey such as frequency, onboard time, vehicle quality, stop quality and fare are an important input into the model.

The paper describes how a suite of parameters was developed through literature review and market research. The literature review identified parameter gaps and benchmark values.

The market research involved three Stated Preference (SP) surveys and one rating survey of vehicle and stop quality. Altogether 6,710 passengers were surveyed by interview using computer tablets or by onboard self completion questionnaire.

1. Introduction

Transport Performance and Analytics of Transport for NSW (TfNSW) has developed a Public Transport Project Model (PTPM) to forecast patronage and user benefit for proposed projects. The model requires parameters that describe the sensitivity of patronage to fare, service level and quality. To help determine appropriate parameter values, a review of the literature was undertaken and a program of market research developed to 'fill in' identified gaps.

This paper describes the market research and compares the estimated parameters with the literature review. Given the wide scope of the study, only brief comments are made regarding the survey methodology and parameter estimation. A detailed description is provided in Douglas Economics (2016).

Section 2 provides an overview of PTPM. Section 3 summarises the literature review. The market research is described in section 4 with descriptors of the survey profile provided in section 5. Sections 6 to 10 present the main results. Some concluding remarks are made in section 11.

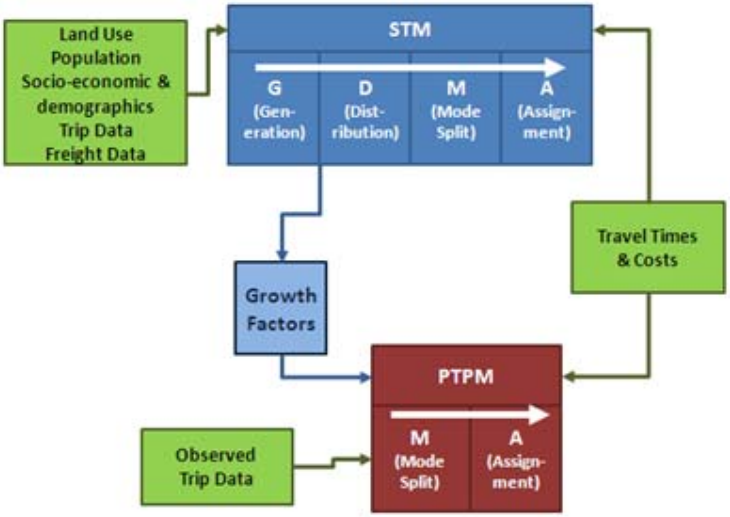
2. Public Transport Project Model

The Public Transport Project Model (PTPM) is a multi-modal model that forecasts patronage and demand related impacts of public transport projects and policies. The model was developed as an incremental model to 'pivot-off observed matrices' and it is this feature which distinguishes it from the Strategic Travel Model (STM). The relationship with the STM is shown in Figure 1.

Essentially, STM provides the exogenous (population/landuse) growth factors for PTPM. Travel times and costs for PT and car are 'inputs' to both models but with PTPM pivoting off the observed trip data.

PTPM forecasts mode choice and assignment based on generalised travel time which is a weighted measure of time and cost. The market research described in the following sections was undertaken as a guide to determining the appropriate weights.

Figure 1: Public Transport Project Model & Strategic Transport Model



There have been a series of versions of PTPM. Version 1 started in 2011 to forecast patronage for the North West Rail Link (NWRL). Version 2 was used to forecast patronage for the CBD and South East Light Rail (CSELR) and was also used in the latter stages of the North West Rail Link 'Business Case'.

PTPM has also been used to assess demand effects of changes to the Epping-Chatswood Rail Link (ECRL); Northern Beaches Bus Rapid Transit (NBBRT); Newcastle Light Rail (NLR) and in strategic planning assessments of the Parramatta Transport Corridor (PTC) and the Parramatta Road Improvement Program.

3. Literature Review

A review of Australasian market research and demand forecasting studies undertaken between 1990 and 2012 was undertaken to guide the development of the market research and to benchmark the estimated parameters.

Nine travel attributes were reviewed with seven included in the market research. The two omitted were access walk time and reliability for which evidence from the literature review was deemed adequate. Table 1 lists the attributes that were considered.

Table 1: Travel Attributes Reviewed and Included in Market Survey

#	Service Attribute	Included in Survey Program?
1	Value of In-Vehicle Time	Yes
2	Access/Egress Walk Time	No - literature review adequate
3	Service Frequency	Yes
4	Travel Time Reliability	No - literature review adequate
5	Crowding	Yes
6	Transfer Penalty and Wait Time	Yes
7	Vehicle Quality	Yes
8	Bus Stop & Train Station Quality	Yes
9	Mode Specific Constants	Yes

A total of 35 Australian and NZ studies were reviewed with all but two being Stated Preference surveys (SP). The two non SP studies were disaggregate choice models that used Household Travel Survey data to estimate the STM; Hague Consulting (2001) and Fox, Daly and Patrolni (2010. These two studies provided the relative value of walking time.

The studies dated from 1990 to 2013 with the bulk undertaken between 1995 and 2005. Most were undertaken as part of demand forecasting studies of major public transport projects in NSW: Travers Morgan (1995), Booz Allen and Hamilton and PCIE (1995), PCIE (1996), PPK (1998) Prosser et al (1997), PPK-PCIE (1998), Halcrow (2000), PCIE & BNR Consulting (2000), Hensher and Rose (2003), Parsons Brinckerhoff (2005) and ITLS Sydney (2011).

Other studies were undertaken as part of building demand models, estimating parameters for economic evaluations or developing business strategies: Booz Allen Hamilton and PCIE (2003) for Sydney ferries; SDG and GHD-Transmark (1992), Pacific Consulting (1996) and Douglas Economics (2008) for Sydney Rail and Douglas and Jones (2013) for PTPM.

Some Queensland and Victoria studies were included such as PCIE (2000) for radial rail services out of Brisbane; Douglas, Frost and Franzman (2003) for the South East Queensland demand model and Halcrow (2005) for Dandenong rail services. One national study of train crowding was included by CRC (2010).

Several NZ studies were reviewed including: SDG (1990), SDG (1991a), SDG (1991b), Beca Carter et al (2002), Vincent, M. (2008) and Douglas (2015).

The studies covered bus, rail, ferry, Light Rail and Busway (the latter modes were usually proposed rather than existing). Most surveys only interviewed users of the travel mode in question but some surveyed car, walk/cycle and other 'non-users'. Respondents were usually presented with a pair-wise journey choices similar to the questionnaires described in this paper. Most compared public transport modes (e.g. bus v bus or bus v rail) but some compared public transport with car and in a few cases train or bus with walk/cycle. In consideration, those studies that presented 'same mode' choices (e.g. bus v bus) tended to produce more accurate parameters than 'different mode' choices (e.g. car v bus). This reflected a tendency for some respondents to always pick their current mode. Car users for example would tend to pick car irrespective of the times and costs shown.

The assessment of stop and vehicle quality borrowed heavily from a 'Pricing Strategies' study undertaken for the NZTA by Douglas (2016).

In assessing modal preferences, reference was also made to the US Federal Transit Administration 'Quality Control' model used to evaluate "New Start" commuter rail, light rail and bus rapid transit projects, Federal Transit Administration (2006).

4. Overview of Surveys

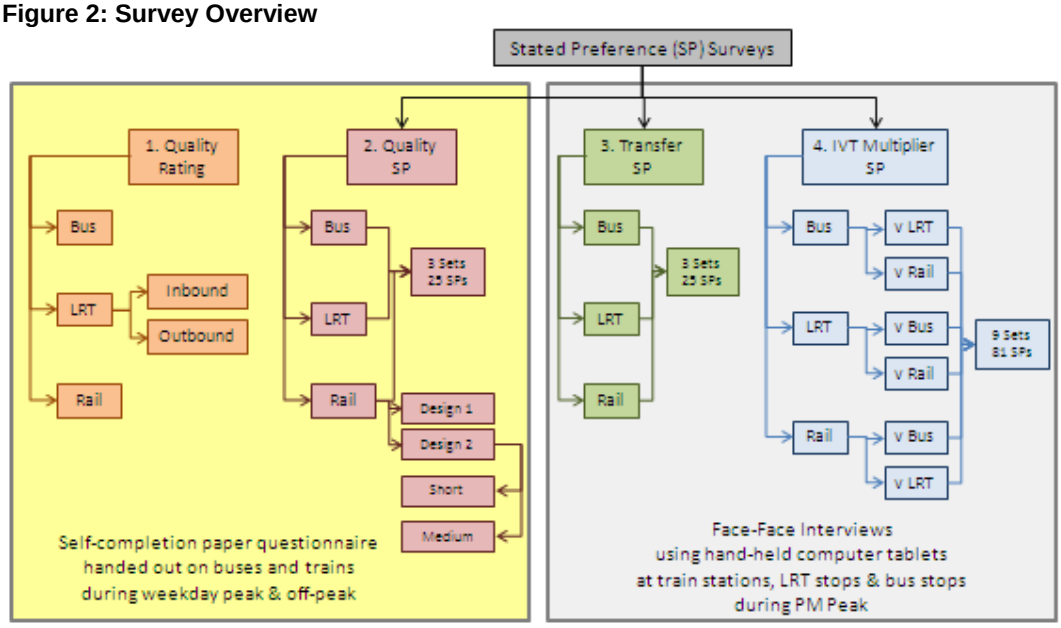
4.0 Types of Survey

Four surveys were undertaken as shown in Figure 2. A Rating survey assessed the quality of stops and stations and bus, light rail and rail vehicles using simple rating questions.

The other three surveys involved Stated Preference (SP) questions in which respondents were presented with a set of pair wise choices. The three SP surveys are referred to Quality, Transfer and In-vehicle Time Multiplier which reflect their principal aim. The Quality SP was linked to the Rating survey. The attributes covered by the surveys are listed in Appendix 1.

The questionnaires were in two parts: (1) the rating and/or Stated Preference (SP) questions and (2) socio- economic, demographic and trip profile questions.

Figure 2: Survey Overview



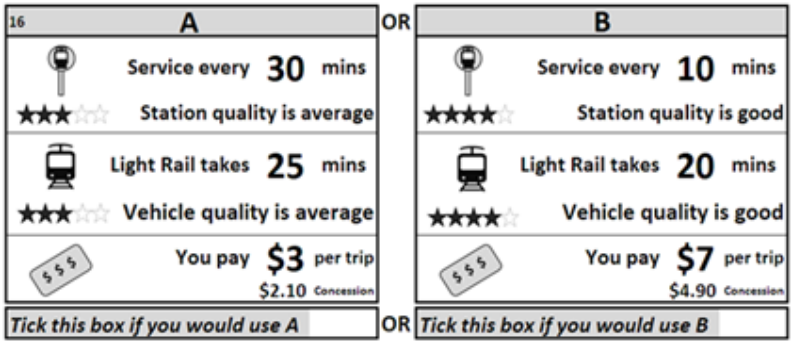
4.1 Quality Stated Preference Survey

The Quality SP survey presented respondents with a series of pair-wise choices in which they 'traded-off' vehicle and stop/station quality, travel time, service frequency and fare. The survey used the same approach as used in New Zealand on bus and train passengers by Douglas (2015).

An example show card is presented in Figure 3. The questionnaire was a four page A5 size booklet handed out and collected on board buses, trains and Light Rail. In handing the questionnaire, the surveyors were asked to give a short description of the survey.

Self-completion was chosen over interviewing principally because the quality of vehicles could be surveyed 'there and then'. Trying to interview onboard trains and especially buses was found to be too difficult when tested in New Zealand.

Figure 3: Example 'Quality' Stated Preference Survey Show Card

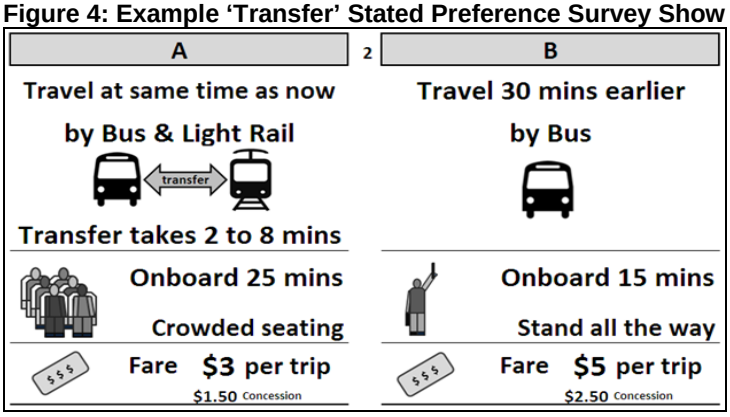


4.2 Transfer Stated Preference Questionnaire

As well as estimating the cost to passengers of changing between services, the 'Transfer' SP estimated the cost of onboard crowding and timetable displacement.

The survey was administered by interviewers using laptop computers and was carried out at bus stops, LRT stations and train stations. The method was chosen because of the need to ask about crowding. Surveying onboard crowded vehicles using self completion or interviews was considered too difficult. The survey featured a series of pair-wise choices. An example show card is presented in Figure 4.

Figure 4: Example 'Transfer' Stated Preference Survey Show Card

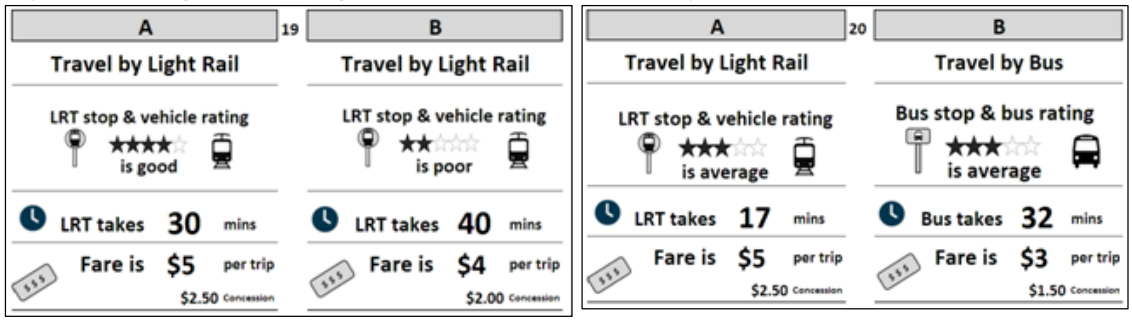


4.3 'IVT Multiplier' Stated Preference Questionnaire

The time multiplier survey was probably the simplest for respondents to complete but the most complex to design and analysis. A full factorial experiment was designed which combined time, cost and quality for bus, LRT and rail. The aim was to estimate travel time multipliers that measure the relative amenity of travelling by bus, LRT and rail for different trip lengths varying from 10 to 40 minutes. The full design required 243 pair-wise journey choices and was administered by interviewers using laptop computers which selected 9 SPs for the respondent to complete. The experimental design was developed by Douglas Economics from first principles.

Two example show cards are presented in Figure 5. The show card on the left features the choice of travelling by a good quality light rail service in journey A or poor quality LRT in journey B. In the choice on the right hand side, there is also a difference in mode (LRT v Bus).

Figure 5: Example 'IVT Multiplier Stated Preference Survey Show Cards



4.4 Rating Questions

Three of the four surveys (Rating, Quality SP and IVT Multiplier SP) asked respondents to rate stop and vehicle quality. The Rating and Quality SP asked respondents to rate the stop they boarding and the vehicle they were travelling on. The IVT SP asked respondents to rate an alternative mode as well as the mode they were using. For example, a bus passenger would be asked to rate LRT if they had used the LRT service in Sydney or rail if they had not.

Two rating scales were used. The rating survey used a 9 point scale as shown in Figure 6.

Figure 6: LRT Stop Rating

4. Please rate the station where you got <u>on</u> this light rail service on a 1 to 9 scale where 1 is very poor and 9 is very good. *Please circle your rating or leave blank if you have no opinion.*

	Very Poor			Average			Very Good		
a) Weather protection	1	2	3	4	5	6	7	8	9
b) Seat availability and comfort	1	2	3	4	5	6	7	8	9
c) Cleanliness and graffiti	1	2	3	4	5	6	7	8	9
d) Lighting	1	2	3	4	5	6	7	8	9
e) Timetable information and station announcements	1	2	3	4	5	6	7	8	9
f) Ease of ticket purchase	1	2	3	4	5	6	7	8	9
g) Your overall rating of the station you got on this light rail vehicle	1	2	3	4	5	6	7	8	9

The Quality SP and the IVT Multiplier SP used a 5 point 'star' scale as shown in Figure 7.

Figure 7: Five Point Rating Scale used on LRT Quality SP

7. Please rate the quality of this train in terms of its appearance, information, facilities, cleanliness, comfort and staff on a 1-5 scale where 1 is very poor and 5 is very good.

Please tick one box	1 Very Poor	2 Poor	3 Average	4 Good	5 Very Good
Train Rating					

For analysis purposes, the nine and five point scales were converted to a percentage scale:

Nine Point Scale: $$R\% = 100\left[\frac{R9-1}{8}\right]$$

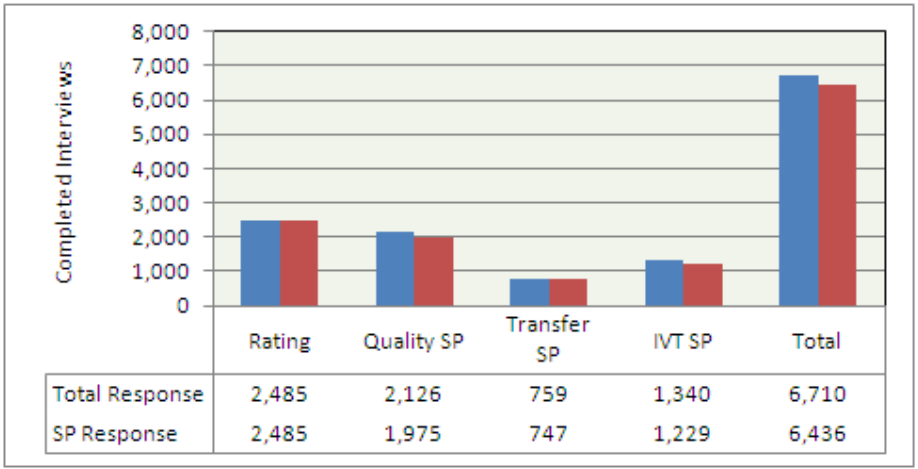
Five Point Scale: $$R\% = 100\left[\frac{R5-1}{4}\right]$$

The conversion of scales allowed the data from all three surveys to be combined.

5. Survey Details and Respondent Profile

6,710 passengers were surveyed in April and May 2013 with 2,485 Rating, 2,126 Quality, 1,430 IVT and 759 Transfer. Similar numbers of bus (33%), LRT (28%) and rail (39%) users were surveyed, Figure 8.

Figure 8: Surveys by Mode



	Rating	Quality SP	Transfer SP	IVT SP	Total
Total Response	2,485	2,126	759	1,340	6,710
SP Response	2,485	1,975	747	1,229	6,436

The surveys focussed on the inner west of Sydney. The Rating and Quality questionnaires were handed out on the 400 series Leichhardt to City bus routes plus the M10 Pre-Pay Metrobus. Around half the rail questionnaires were handed out on Bankstown and Inner West line with the other half distributed on East Hills, Eastern Suburbs, Illawarra, Northern Line and North Shore services. LRT questionnaires were handed on the Central-Lilyfield service. School students were generally 'screened out' by interviewers in accordance with market research protocol. The sample sizes were based around achieving minimum quotas for each travel model by SP response group with response to pilot surveys retained. The IVT and Transfer interviews were undertaken in Sydney CBD at rail stations and at LRT and bus stops. Background questions on journey purpose, gender, age, employment status, occupation and income were used to compare the profile of bus, LRT and rail users and help understand response to the SP and rating questions. Some key profile statistics are given in Table 2.

Table 2: Key Profile Statistics of Inner Sydney Market Research

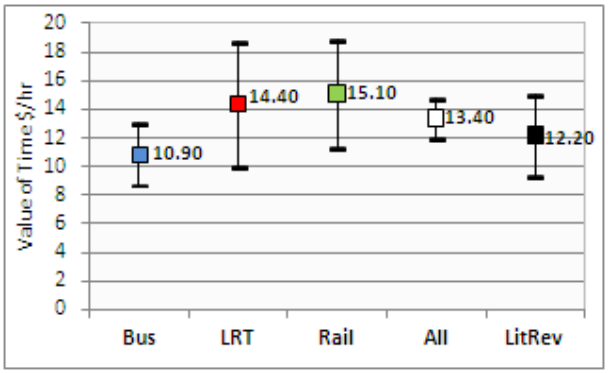
Profile	Statistics	Comment
Trip Purpose	54% to/from work	Varied by time period: 72% Work & 15% Educ in AM Pk compared to 39% Work & 21% Educ in Off-Pk.
	17% to/from education	
	29% other	Rail work share higher (61%) than bus (49%).
Gender	57% Female 42% Male	Bus highest female share 62%, rail 57% & LRT 51%.
Age	Average age of 36	27% were under 24 (note under 12s not surveyed) with 6% over 64. LRT tended to be older with (av age of 40).
Employment	65% Employed	Lower share of bus users employed (54%); 72% for rail.
	24% Student	Higher student share for buses (38%); rail was 21%.
Occupation of Employed	57% Manag/Professional	Consistent shares with little variation by mode or time period.
	37% Clerical	
Income	$51k (gross) p.a.	LRT highest at $57k & bus lowest at $42k.
Trip length	Average of 23 minutes	LRT shorter trips (13 mins) rail longer (29 mins).
Frequency	Service every 12 minutes	Little variation in frequency by mode.
Wait	Wait averaged 6 mins	Wait times tended to be half the service interval.
Fare	Mean $4.67 per trip	Median considered more reliable estimate than mean with bus lowest $2.72, LRT $3.90 and Rail $4.85 per trip.
	Median $3.90 per trip	
Concession	26% used a concession	LRT 16%, rail 23% & bus highest at 39% concession.

Analysis of the response to the rating and SP questions was by mode and trip purpose although other segmentations were made. In accordance with the specification of PTPM, three trip purposes were defined: commuting to/from work, education and 'other'. The few number of company business responses were included with commuting.

6. Value of In-vehicle Time (IVT)

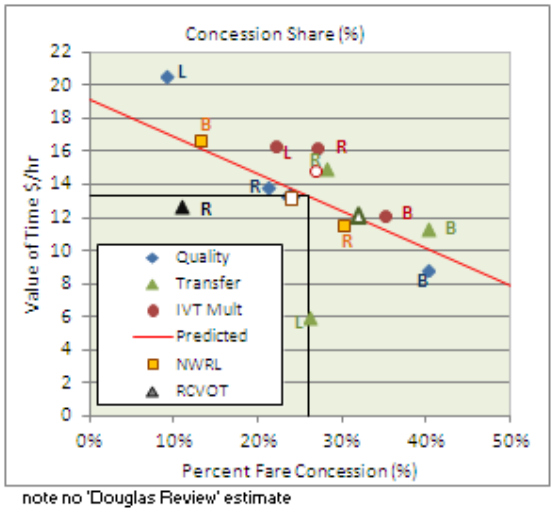
All three SP surveys included a time versus money trade-off. The mean value of in-vehicle time (IVT) in April/May 2013 was $13.40/hr with a 95% confidence range of ±$1.40/hr (. Rail had the highest value ($15.10/hr) with LRT slightly lower ($14.40/hr) and bus lowest ($10.90/hr). The values compare with a figure of $12.20/hr estimated by the Literature Review which collated 81 values of time between 1992 and 2012.

Figure 9: Estimated Value of Time (with 95% Confidence Interval) April/May 2013

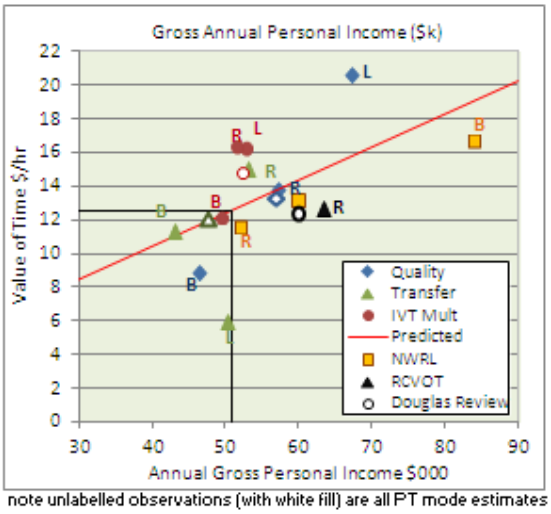


The values reflected concession use (which typically halved the values) and personal income which increased willingness to pay. Figure 10 plots the estimated mean values including the NWRL estimates by Douglas and Jones (2013) and a RailCorp (RCVOT) estimate (updated) by Douglas Economics (2010). At a concession share of 24% and average income of $56k, the predicted VOT was $13.70 per hour which was a little higher than the Inner Sydney estimate of $13.40/hr. The income relationship was quite strong which was reflected in an elasticity of 0.8.[1]

Figure 10: Estimated Value of Time with Concession Entitlement and Income April/May 2013



note no 'Douglas Review' estimate



note unlabelled observations (with white fill) are all PT mode estimates

[1] $e = \frac{\delta VOT}{\delta Y} . \frac{Y}{VOT} = 0.196 . \frac{55.6}{13.80} = 0.81$

7. Travel Time Multipliers

Travel time can be broken down into components such as walking to the bus stop, waiting for the bus and travelling on the bus. The disutility of the the various components varies according to comfort, convenience, anxiety etc. A set of travel time multipliers were estimated that expressed each component relative to in-vehicle time (uncrowded seat). Table 3 presents a summary of the estimated values and compares them with the literature review. As well as the central estimate, the 95% confidence range is presented for the survey estimates and the interquartile range (25%-75%) for the literature review estimates.

Table 3: Relative Value of Different Components of Travel Time

Attribute	Valuation in IVT Mins				Comments
	Survey			Review	
Service Interval	**0.75** ± 0.07			**0.64** (0.46-0.78)	Most services high frequency. Valuation decreased with service interval. Little difference by mode.
Displacement	**0.45** ± 0.2			**0.8** (one study)	Value of not being able to travel at desired time. Early displacement (0.4) less than late (0.5). Values less than 2010 RailCorp study of 0.6 early & 1.0 late.
Waiting Time	**1.5** ± 0.15			**1.38** (0.92-1.56)	Value implied from SI valuation assuming random arrivals (half headway).
Transfer Penalty to/from Rail or LRT	**5** ± 4.8 mins			Same mode: **8** (5-12) mins Dif mode: **13** (9-18) mins	Review estimated a 'same mode' transfer penalty (i.e. excluding connection time)of 8 mins (4 pk & 12.5 off-pk) and a different mode penalty of 13 mins (9 pk & 17 off-pk).
Transfer Penalty to/from Bus	**8** ± 4.75 mins				
Wait Time at Transfer	**1.5** ± 0.15			**1.25** (1.05-1.44)	Waiting time constained to 1.5 in estimating transfer penalties (SI value).
Crowding	Bus	Rail	LRT/All	Review	Additional time factor for crowding relative to comfortably seated IVT. The LRT/All value was similar to literature review but rail & bus values higher.
Crush Standing^	**1.11**	**1.53**	**1.03**	**1.0** (0.86-1.25)	
Standing^	**0.81**	**0.84**	**0.60**	**0.58** (0.39-0.78)	
Crowded Seating^	**0.34**	**0.25**	**0.23**	**0.23** (0.86-1.25)	
Reliability	not surveyed			**3.2** (1.9-4.5)	10 studies measured reliability (expected lateness: Prop late x mins late) at 3.2 x
Access Walk	not surveyed			**RP:1.5** SP&RP:1.3 (1.0-1.4)	Two Revealed Preference Sydney studies valued walking time at 1.5xIVT which compared with 1.3 from 48 mostly SP obs.

± is 95% confidence range. Figures in brackets for review are interquartile range (25%-75%)

^ indicative 95% confidence ranges: crowded seating ± 0.15; standing ± 0.2; crush standing ± 0.75.

Service Interval (the number of minutes betweeen departures) effectively combines waiting time and 'displacement' (the inconvenience of not being able to travel when you want). The Inner Sydney SP valued service interval (SI) less than invehicle time (IVT) with a minute of SI worth 0.75 minutes of IVT. The value compared with the review estimate of 0.64.

Inner Sydney services were frequent averaging five per hour (SI of 12 minutes). As a consequence, the SI valuation mostly reflected the disutility of waiting. For less frequent services, the relative valuation declined reflecting timetable displacement as can be seen from Figure 11.

The Inner Sydney function was similar to that estimated to that estimated for Sydney trains by Douglas Economics (2008) and rail and bus for NZ by Douglas (2015). The function was be positioned noticeably higher than the National Guidelines for Transport System Management (ATC 2006) function for higher frequency services.

Figure 11: Inner Sydney SI Function

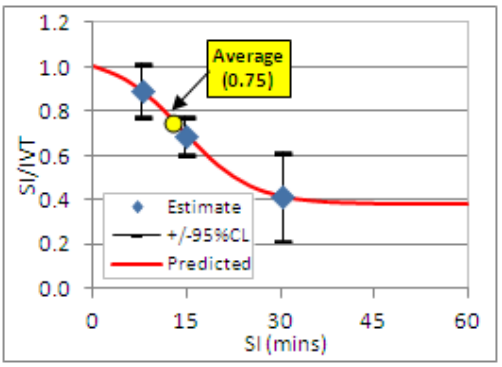
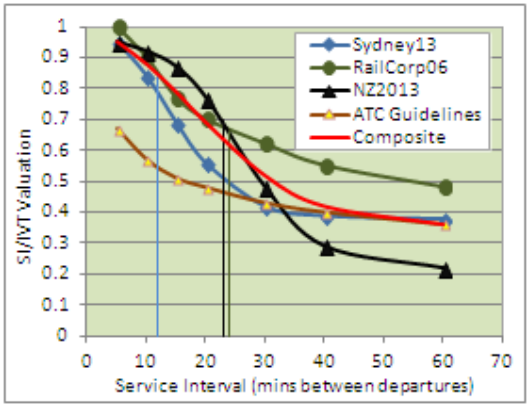
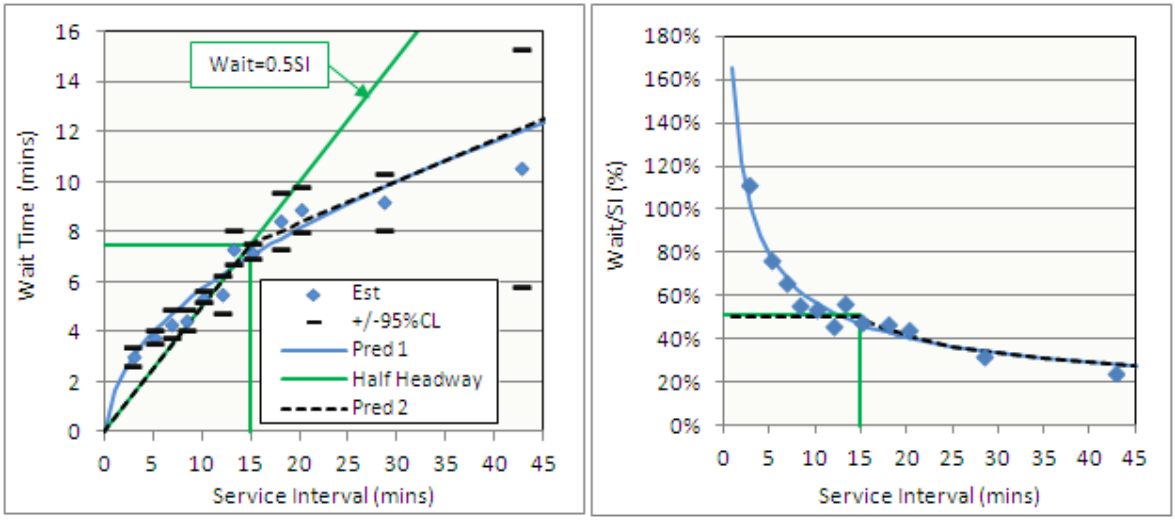


Figure 12: Comparison of SI Functions



The IVT multiplier for waiting time was 1.5 which was derived from the waiting and service frequencies given by respondents (see Figure 13). For a 15 service interval, the average wait was close to 7.5 minutes. Thus the value of waiting time would be twice the SI value of 0.75.

Figure 13: Waiting Time & Service Interval as Perceived by Respondents



The cost of displacement time was less than in-vehicle time. Travelling earlier than desired was valued at 0.4 and travelling later at 0.5 times IVT. The only comparable Sydney study was an AM Peak Sydney rail users by Douglas, Henn and Sloan (2010) which estimated early and late displacement values of 0.6 and 1.0 respectively (average 0.8). The lower Inner Sydney value may have resulted from surveying the PM rather than AM peak.

Transfers impose a 'penalty' additional to the time spent at the interchange (walking plus waiting) that reflects the anxiety and inconvenience of changing vehicles. Transfers to (or from) bus had a higher penalty of around 8 mins than transfers to rail/LRT which averaged 5 mins. The peak penalties were similar to the Literature Review but the 'all day' values were lower.

Onboard crowding increases the cost of travel especially in crush conditions. The survey estimated the cost of crowded seating, standing and crush standing. Lower crowding costs were estimated for LRT than for bus or rail. Crowded seating added 23% to 34% to the onboard time, standing 60% to 84% and crush standing 103% to 153%. The LRT crowding costs were similar to the literature review estimates but the bus and rail costs were higher. The survey estimates were developed into a set of crowding functions as shown in Figure 14.

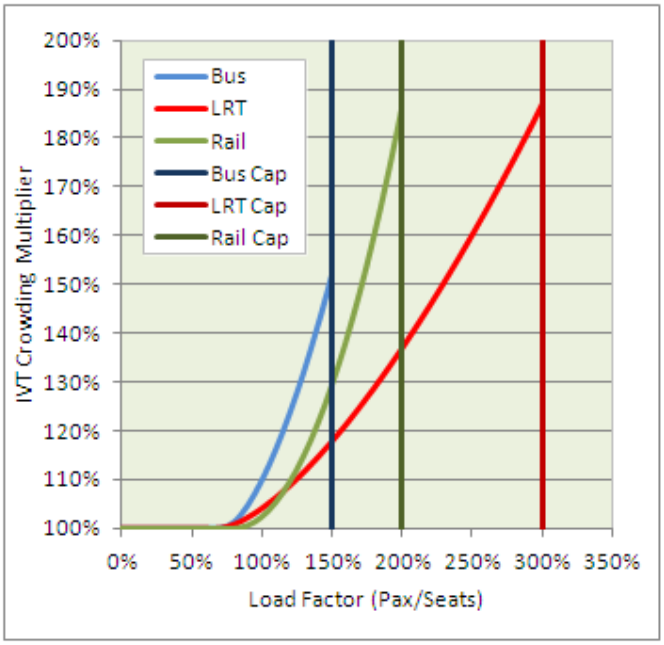
Reliability and access walk time were reviewed but not surveyed. A minute of expected lateness (probability of a service being late times the number of minutes expected to be late) was valued at 3.2 times IVT.

Walking time was valued at 1.5 times IVT based on the two RP studies (as mentioned in section 3).

Figure 14: Estimated Crowding Cost Functions for Inner Sydney

Load Factor(1)	Bus	LRT	Rail
80%	101%	101%	100%
90%	105%	102%	101%
100%	110%	104%	102%
110%	116%	106%	105%
120%	124%	109%	109%
130%	132%	112%	115%
140%	141%	115%	121%
150%	152%	118%	129%
160%	na	121%	138%
170%	na	125%	148%
180%	na	129%	160%
190%	na	133%	172%
200%	na	137%	186%
220%	na	146%	na
240%	na	155%	na
260%	na	165%	na
280%	na	176%	na
300%	na	187%	na

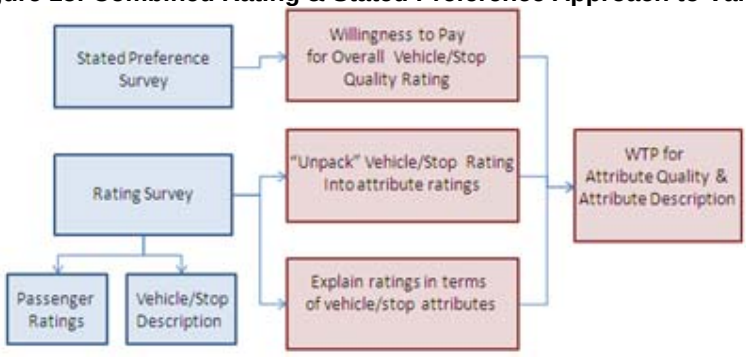
(1) Passengers / Seats



8. Vehicle Quality

Vehicle quality (and stop quality) was estimated via passenger ratings as section 4.4 described. Changes in rating were converted into IVT minutes (or fare) by applying the SP quality and IVT multiplier survey parameter estimates. Figure 15 presents an overview.

Figure 15: Combined Rating & Stated Preference Approach to Value Quality



The approach was developed by Douglas (2015) in a study of bus and rail users in Auckland, Christchurch and Wellington.

Figure 16 presents the average and the range in vehicle ratings for bus, rail and LRT. The LRT Variotram (averaging 15 years in service) was the highest rated vehicle scoring an overall rating of 80%. Buses averaged 68% with a narrow range by 'bus type' from 64% to 75%. Trains rated the lowest on average scoring 64% with a ranged from 43% for the 40 year old non air-conditioned C/K sets to 74% for the two year old Waratahs.

The overall rating was 71% and ranged from 43% to 80% across the vehicle types.

Figure 16: Range in Vehicle Ratings for Inner Sydney Survey

Mode	Average Rating	Lowest Rated Type	Highest Rated Type	Rating Range
LRT	80%	Variotram 	Only one LRT type	
Bus	68%	'Other' 64% Rating 	M10 Artic. 75% Rating 	64% - 75%
Train	64%	C/K Sets 43% Rating 	Waratah 74% Rating 	43% - 74%
All *	71%	43% C/K Train	80% LRT Variotram	43% - 80%

The Quality SP was designed to value vehicle and stop quality from very poor (0%) through to very good (100%). The response found respondents more sensitive to changes in rating from very poor to poor than from good to very good. To model the non proportional response, a 'power function' was introduced, see Douglas (2015). The optimal value for the power parameter was 0.7 (for vehicles and stop/station quality). This meant that a 40%-80% change in rating was worth 33% of the maximum (0%-100%) rather than 40%.

The value of a 40% to 80% difference in vehicle quality (close to the observed 43%-80% range for Inner Sydney vehicle types) based on the results of the Inner Sydney Quality SP survey was equivalent to 2.9 minutes of IVT or 16% of the average fare (21 minute trip).

As can be seen from Table 4, the estimates were lower than those estimated for NZ using the same rating/SP approach (Douglas (2015) and by an earlier Sydney Rail study, Douglas Economics (2008). Contributing to the lower estimate were the shorter trips and a focus on the peak period. The Literature Review estimated a median value of 4.3 minutes for improved vehicle quality.

Table 4: Estimated Value of Vehicle Quality

Maximum Valuation of Vehicle Quality: Very Poor (0%) to Very Good (100%)												
	Per Minute of IVT				Per Trip (Minutes)				Percent of Fare			
	Bus	LRT	Rail	All	Bus	LRT	Rail	All	Bus	LRT	Rail	All
Inner Sydney^	0.28	0.31	0.50	0.41	6.2	4.0	12.5	8.7	41%	25%	65%	50%
RailCorp 06*	na	na	0.68	na	na	na	16.9	na	na	na	94%	na
NZ+	0.72	na	0.88	0.80	18	na	22	20	68%	na	84%	76%
Valuation of Improvement from 40% to 80% Vehicle Quality												
	Per Minute of IVT				Per Trip (Minutes)				Percent of Fare			
	Bus	LRT	Rail	All	Bus	LRT	Rail	All	Bus	LRT	Rail	All
Sydney^	0.09	0.10	0.16	0.14	2.0	1.3	4.1	2.9	14%	8%	21%	16%
RailCorp 06*	na	na	0.25	na	na	na	6.3	na	na	na	35%	na
NZ+	0.23	na	0.28	0.25	5.6	na	6.9	6.3	21%	na	26%	24%
Review#	0.17				4.3				27%			

^Sydney VoT B$10.90, L$14.40, R$15.10, All$13.40/hr; Median Fares: B$2.72, L$3.90, R$4.85, All$3.90

Average Trip length: Bus 22 mins, LRT 13 mins, Rail 25 mins, All 21 mins. Power function 0.7

* VoT $8.76, Av Fare $2.62, value for 25 minute trip. Douglas Economics (2008)

+ NZ: $4 fare, 25 minute trip (power function 0.65). Douglas (2015)

Median values from Literature Review (/min IVT calculated for trip of 25 mins)

The Rating survey also asked respondents to rate a list of vehicle attributes. Table 5 presents the ratings. LRT scored the highest for every attribute rating particularly highly for inside cleanliness/graffiti (84%) ease of on/off (83%) and staff (82%).

Bus rated lower and scored its highest ratings for 'ease of on-off' (74%), lighting (72%) and driver (72%) but scored low ratings for information (51%) and 'ability to use computer and internet' (47%).

Rail achieved its highest ratings for ease of on-off (71%) and lighting (70%) and scored low ratings for environment (56%) and 'ability to use computer and internet' (42%).

Table 5: Vehicle Attribute Ratings for Inner Sydney - Percentage Score by Attribute

Vehicle Attribute	Sydney 2013			
	Bus	LRT	Rail	Av
Outside Appearance	70%	79%	61%	70%
Ease of On/Off	74%	83%	71%	76%
Seat Availability & Comfort	70%	75%	68%	71%
Space for Personal Belongings	59%	62%	60%	61%
Smoothness & Quietness or Ride	63%	77%	64%	68%
Heating & Air Conditioning	67%	78%	60%	69%
Lighting	72%	81%	70%	74%
Inside Cleanliness & Graffiti	71%	84%	65%	73%
Onboard Info. & Announcements	51%	71%	67%	63%
Ability to Use Computer & Internet	47%	62%	42%	50%
Bus Driver / Onboard Train Staff	72%	82%	*	77%
Environment: Noise & Emissions	59%	77%	56%	64%
Overall	68%	80%	64%	71%

* not included on rail questionnaire

Regression analysis was undertaken to 'unpack' the overall rating and enable individual attributes such as lighting to be valued. The variation in the overall rating was regressed with the variation in the individual attributes. The resultant parameter estimates indicated the relative importance of the individual attributes. Table 6 presents the estimates. For bus, the inside cleanliness/graffiti was most important attribute explaining 15% of the overall rating with driver second on 14%.

Table 6: Value of Vehicle Attribute Quality for Inner Sydney
Value of 40%-80% Rating Improvement in IVT minutes

	Attribute Importance in Explaining Overall Rating				Value of 40%-80% Attribute Rating Improvement (IVT mins)			
Attribute	Bus	LRT	Rail	All	Bus	LRT	Rail	All
Outside Appearance	6%	14%	19%	13%	0.13	0.18	0.80	0.37
Ease of On/Off	7%	11%	5%	7%	0.14	0.15	0.20	0.21
Seat Availability & Comfort	12%	9%	15%	10%	0.24	0.11	0.60	0.29
Space for Personal Belongings	0%	4%	2%	1%	0.01	0.05	0.09	0.03
Smoothness & Quietness or Ride	12%	12%	7%	11%	0.25	0.16	0.27	0.30
Heating & Air Conditioning	10%	9%	15%	11%	0.21	0.11	0.61	0.30
Lighting	5%	7%	7%	6%	0.10	0.10	0.28	0.16
Inside Cleanliness & Graffiti	16%	5%	10%	10%	0.32	0.07	0.39	0.29
Onboard Info. & Announcements	5%	3%	10%	6%	0.10	0.04	0.42	0.17
Ability to Use Computer & Internet	1%	0%	3%	1%	0.02	0.00	0.11	0.03
Bus Driver / Onboard Train Staff	15%	14%	-	14%	0.31	0.18	na	0.40
Environment: Noise & Emissions	10%	12%	8%	10%	0.20	0.15	0.33	0.29
Total	100%	100%	100%	100%	2.0	1.3	4.1	2.9

By mulitplying the percentage importance by the overall rating valuation (Table 4) the value of improving individual attributes can be predicted. For a 40%-80% change in cleanlines/grafitti for buses, the value was worth 0.32 minutes.

9. Stop/Station Quality

As with vehicle quality, the value users placed on bus stop and rail station quality was determined by combining the results of the Rating and Quality SP results.

As with the vehicle ratings, LRT rated the highest in terms of the board stop scoring 74%. Rail stations averaged 66% and bus stops 62%. The range in stop/station rating was between 56% and 81% as summarised in Figure 17.[2]

Figure 17: Range in Bus Stop & Train Station Ratings from Inner Sydney Survey

Mode	Average Rating	Lowest Rated Stop/Station	Highest Rated Stop/Station	Rating Range
LRT	74%	John St Sq 63% 	Rozelle 81% 	63%-81%
Bus	62%	Town Hall 56% 	Central 70% 	56%-70%
Rail	66%	Town Hall 61% 	Illawarra 76% 	61%-76%
ALL *	67%	Town Hall (Bus) 56%	Rozelle LRT 81%	56%-81%

A 40%-80% range in stop quality was worth 4.1 minutes of in-vehicle time (25% of fare). The value ranged from 3.2 minutes for bus to 4.7 minutes for rail. By comparison, the NZ study estimated values of 4.9 minutes for bus and 5.9 minutes for rail (Douglas 2015). The 2008 RailCorp study estimated a value of 5.3 minutes, Douglas Economics (2008). The Literature Review estimated a median value of 5.7 minutes.

Table 7: Value of Stop/Station Quality for Inner Sydney
40%-80% Overall Rating Difference

Valuation of Improvement from 40% to 80% Stop/Station Rating								
	Minutes of IVT				Percent of Average Fare			
	Bus	LRT	Rail	ALL	Bus	LRT	Rail	ALL
Sydney^	3.2	3.9	4.7	4.1	21%	24%	25%	23%
RailCorp 06*	na	na	5.3	na	na	na	30%	na
NZ+	4.9	na	5.9	5.3	25%	na	20%	22%
Review#	5.7				25%			

^ VOT B$10.90, L$14.40, R$15.10, All $13.40/hr
^ median fares of B$2.72, L$3.90 R$4.85 ALL$3.90 (Table 3.12.2 All time period estimates)
* Value of time of $8.76 and an average fare of $2.62, Douglas Economic (2008)
+ NZ VOT B$9.80/hr, R$10.90, ALL $9.84/hr, av fares B$3.20, R$5.40, $4ALL. Douglas (2015)
# median values from Literature Review

[2] For rail, stations on the Illawarra line were grouped because there were too few individually. For bus stops, the stop details usually street names given by respondents were coded up into aggregated stops.

As with vehicles, respondents were also asked to rate a list of 'stop' attributes. LRT (see Figure 6) and bus users were given a shorter list of attributes than rail users. Table 8 presents the response.

LRT rated highest in all atttributes except for information where it scored the lowest (58%). For bus, information at bus stops was the highest rated attribute (65%) with seating the lowest (52%). For rail, weather protection rated the highest (71%) with car access facilities (52%) and toilet availability/cleanliness (47%) rated the lowest.

Table 8: Stop/Station Ratings for Inner Sydney

Stop/Station Attribute	Bus	LRT	Rail	All
Weather Protection	54%	74%	71%	66%
Seating	52%	67%	53%	57%
Information	65%	58%	66%	63%
Lighting	60%	73%	69%	67%
Cleanliness & Graffiti	64%	76%	66%	69%
Ticket Purchase	53%	74%	65%	64%
Platform Surface	*	*	65%	65%
Platform On/Off	*	*	65%	65%
Toilet Avail & Cleanliness	*	*	47%	47%
Staff	*	*	61%	61%
Retail Facilities	*	*	56%	56%
Car Access Facilities	*	*	52%	52%
Bus Access Facilities	*	*	62%	62%
Overall Rating	62%	74%	66%	67%

Table 9 presents the percentage importance of individual stop attributes which, as for the vehicle ratings, was determined by regression. For bus stops, the most important attribute was weather protection which explained 26% of the overall rating. For LRT stops, the most important attribute was cleanliness/graffiti (31%). The longer list of rail attributes meant that the importance of individual attributes was less. Cleanliness/graffiti and ticket purchase were the most important with each explaining 14%. It should be noted here that the surveys were undertaken before the electronic OPAL travel card was introduced. The introduction of OPAL will probably have reduced the importance of ease of ticket purchase at stops and stations.

Table 9: Value of Stop Attribute Quality for Inner Sydney
Value of 40%-80% Rating Improvement in IVT minutes

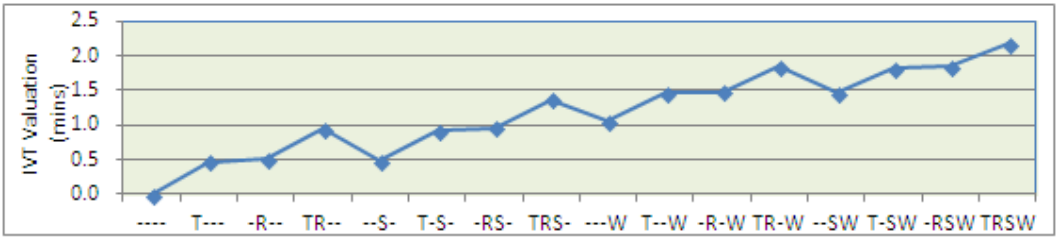
Attribute	Attribute Importance in Explaining Overall Rating			Value of 40%-80% Attribute Rating Improvement (IVT mins)		
	Bus	LRT	Rail	Bus	LRT	Rail
Weather Protection	26%	12%	8%	0.83	0.48	0.38
Seating	19%	14%	11%	0.60	0.54	0.50
Information	23%	17%	8%	0.75	0.65	0.40
Lighting	11%	12%	8%	0.34	0.48	0.40
Cleanliness & Graffiti	15%	31%	14%	0.47	1.21	0.67
Ticket Purchase	6%	13%	14%	0.20	0.51	0.66
Platform Surface	*	*	13%	*	*	0.63
Platform On/Off	*	*	9%	*	*	0.44
Toilet Avail & Cleanliness	*	*	6%	*	*	0.26
Staff	*	*	2%	*	*	0.12
Retail Facilities	*	*	2%	*	*	0.12
Car Access Facilities	*	*	2%	*	*	0.08
Bus Access Facilities	*	*	2%	*	*	0.07
All	100%	100%	100%	3.2	3.9	4.7

The value of individual attribute improvements can be determined by multiplying attribute importance by the overall value. For LRT stops and train stations, the biggest benefit was improved cleanliness/graffiti at 1.21 minutes and 0.67 minutes for rail stations.

Bus passengers were asked whether weather protection, seating, a timetable and electronic timetable information was provided at their stop. By relating availability to the overall bus stop rating, it was possible to value the benefit of facility provision.

Figure 18 presents the valuations. Compared to 'no' facilities, providing shelter (---W) was worth 1.1 minutes. Seating (--S-) was worth 0.5 minutes. Electronic timetables (-R--) and standard timetables (T---) were worth 0.5 minutes each. Providing all four bus stop facilities was worth 2.2 minutes. For a bus stop with shelter, seating and timetable (TS-W), the added value from providing electronic timtables (WSRT) was worth 0.4 minutes.

Figure 18: Value of Bus Stop Facilities for Boarding Passengers



Codes: T Timetable; R Real Time Information; S Seating; W Weather Protection

Finally it should be noted that the survey was undertaken in terms of boarding. Alighting and transfer passengers should also benefit from improvements at stops and stations albeit by a lower amount than boarders. Based on a set of assumed attribute factors, the value for alighting bus and LRT passengers was calculated to be a fifth that of boarding passengers. For rail, the overall value of station improvements to alighters was half that of boarders whereas for transferring passengers it was approximately the same.

10. Gross Modal Preference

A study aim was to estimate the modal preference for LRT relative to bus. To do this, two 'types' of preference were estimated: quality and 'intrinsic'. The link between the two was that the intrinsic preference was the residual preference after subtracting stop/station and vehicle 'quality' differences.

To address a concern that 'independent' modal ratings may be 'mode specific' and therefore invalid as a basis to compare modes, the IVT Multiplier SP asked passengers to rate an 'alternative' mode as well as their 'current' mode. Thus bus users were asked rate Light Rail (if they had used the Sydney service) and rail if they had not (some bus were asked to rate rail without asking about LRT).

Table 10 compares the IVT and Quality survey ratings. Although all the ratings dropped when the alternative mode ratings were included the difference between the modes stayed roughly the same. LRT remained the highest rated mode at 70% with bus and rail 12-13% points lower on 58% and 57% respectively.

Table 10: Comparison of Overall Mode Ratings Estimated for Inner Sydney

Survey	Basis of Rating	Mode		
		Bus	LRT	Rail
Quality	Mode Used	65%	77%	65%
IVT SP	Mode Used	61%	77%	60%
IVT SP	Mode Used & Alternative	58%	70%	57%

Given there was little difference in the bus and rail ratings, quality modal preference was close to zero but for LRT, the higher rating was worth 1.3 minutes.

Table 11: Gross Modal Preferences for LRT & Rail versus Bus for Inner Sydney
Estimated for a 25 minute trip

Survey	IVT Mins		IVT Multiplier	
	LRT	Rail	LRT	Rail
Quality Modal Preference	2.1	0.1	0.92	1.00
Intrinsic Modal Preference	2.8	2.5	0.89	0.90
Gross Modal Preference	4.9	2.6	0.81	0.90

The intrinsic preference was estimated by the IVT multiplier survey and was found to be larger than the rating quality difference. The intrinsic preference for travelling by LRT versus bus was worth around 10% per minute. Thus for a 25 minute trip (the average of the trip times featured in the IVT Multiplier Survey) the preference was worth 2.8 minutes in favour of LRT. The underlying preference for travelling by rail compared to bus was worth similar at 2.6 minutes.

The literature review estimated a preference for rail and LRT compared to bus at 6.1 minutes for a 25 minute trip (an IVT multiplier of 0.75). The 2006 ATC Guidelines report an IVT multiplier of 0.63 for new rail, 0.86 for old rail and 0.77 for LRT. The US Federal Transit Administration recommends an IVT multiplier of 0.8 for commuter rail compared to bus.

This inconsideration, the gross modal preferences estimated for Inner Sydney were reasonably close to the literature review for LRT but were only around half the size for rail.

11. Concluding Remarks

The literature review and market research developed a reference set of demand parameters to describe the sensitivity of public transport users to changes in travel time, service level, modal quality and fare. The parameters were developed as part of a Public Transport Project Model to forecast patronage from changes in public transport provision.

The review considered Australasian market research and demand forecasting studies undertaken over a 25 year period. A program of market research was then developed to estimate a suite of demand parameters tailored to peak period travel in Inner Sydney. Four surveys were designed and 6,710 bus, rail and LRT users surveyed in April/May 2013.

Subsequently, the geographic scope of the surveys has been extended to cover bus and rail services in the wider Sydney area, Newcastle and Wollongong and a modified questionnaire has been used for ferry services in Sydney and Newcastle. A survey has also been undertaken of car drivers and passengers in Sydney, Wollongong and Newcastle to estimate values of travel time and reliability.

At the time of writing, an off-peak sub-model for PTPM is under-development as part of forecasting demand for a proposed Parramatta Light Rail service and it is intended to revisit the market research results and literature review findings to develop a suite of off-peak parameters.

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Appendix 1

The attributes covered by the four surveys are listed in Table A. The rating attributes, listed at the top of the table, covered stop/station and vehicle. The in-vehicle time survey included an overall service rating and asked respondents to rate alternative modes.

Attribute	1. Rating Q'aire	2. Quality SP	3. Transfer	4. IVT Multiplier SP
Stop/Station Rating	✓	✓		✓
Stop/Station Attribute Ratings	✓			
Stop/Station Rating - Alternative Mode				✓
Vehicle Rating	✓	✓		✓
Vehicle Attribute Ratings	✓			
Vehicle Rating - Alternative Mode				✓
Overall Rating				✓
Overall Rating - Alternative Mode				✓
SP - Onboard Travel Time		✓	✓	✓
SP - Fare		✓	✓	✓
SP - Service Interval		✓		
SP - Station/Stop Quality		✓		
SP - Vehicle Quality		✓		
SP - Overall Quality				✓
SP - Interchange			✓	
SP - Travel Time Displacement			✓	
SP - Onboard Crowding			✓	
SP - Travel Mode				✓
Ticket Type		✓	✓	
Fare Concession Entitlement		✓	✓	✓
Fare Paid		✓	✓•	✓
How often use service	✓			
Board Stop/Station	✓	✓	✓•	✓•
Alight Stop/Station	✓	✓		
Access mode to board station	✓+			
Egress mode from alight station	✓++			
Wait time at station/stop	✓	✓		
Service frequency	✓	✓		
Onboard travel time	✓	✓	✓	✓
Travel time flexibility			✓	
Transfer between modes			✓	
Onboard Crowding			✓	
Trip purpose	✓	✓	✓	✓
Age group	✓	✓	✓	✓
Gender	✓	✓	✓	✓
Employment Status	✓	✓	✓	✓
Occupation (verbatim)	✓	✓		✓
Personal Income group		✓	✓	✓
Comments	✓			
Email address for further survey	✓			

*fare range category; • station where interview was undertaken; + only asked on Light Rail and Rail questionnaires; ++ only asked on outbound (LRT) questionnaire (ReportTables.xls)