TRANSPORT AND INFRASTRUCTURE COUNCIL

Australian Transport Assessment and Planning Guidelines

M1 Public Transport

Supporting Technical Report

Public Transport Parameter Values

September 2018

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Contents

Figures

Tables

Summary

S1 Value of public transport in-vehicle time

The value of in-vehicle time (IVT) is an important parameter in forecasting demand and project appraisal, enabling travel times to be converted into dollars so as to compare travel time savings with project costs.[1] The value of IVT also provides a base against which other travel time components such as access walk time can be valued by applying 'IVT multipliers' (see Section S2 below). In this context, the value of IVT presented here, unless otherwise stated, is for seated onboard time on a bus, train or ferry in the average quality vehicle as perceived by users.

It is important to note that value of IVT plays two distinct 'roles' in transport assessment: a) demand forecasting, and b) in estimation of benefits of initiatives: [2]

- For *demand forecasting*, behavioural values representing willingness-to-pay (WTP) values should be used. WTP values tend to vary between modes and travellers with different income levels. The values presented in this report are behavioural values.
- For the *appraisal of initiatives*, common practice in Australia and around the world (UK Government, 2017, NZ Transport Agency 2017, DAE, 2016) has been to use 'equity' values of time, where the same IVT value is used across all modes and individuals with the aim of according equitable treatment to people with different WTP values arising from differences in income levels.[3] The values of time provided in Part PV2 for car travel should be used as equity values and applied for appraisals of initiatives across all modes.[4] On completion of the current ATAP WTP investigation, further consideration will be given to a suitable equity value based on a weighted average of car and public transport behavioural values will be considered.

The estimates were derived from a regression analysis of 31 Australian and NZ studies, mainly Stated Preference surveys undertaken between 1990 and 2014. Most of the studies (27) were undertaken in Australia (of which 21 were NSW studies with 4 New Zealand studies. Altogether the studies provided 132 observations. In most instances, public transport users were surveyed but a few studies did survey car users about their preferences for travelling by public transport. Analysis did not discern any significant differences in the valuations of car and public transport users. Figure 1 plots the observations and shows how the value of time has trended upwards over the 24 year period.

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[1] Other components, such as access time, are also converted into dollars after they have been expressed in equivalent in-vehicle time minutes (see Section S.2 below).

[2] In four studies reviewed (35, 36, 37 and 38), the valuations were standardised for income allowing the estimated parameters to be adjusted for income.

[3] Average income for travellers varies with mode. The primary example is that public transport users have on average lower incomes than car users. This leads to behavioural values of IVT being lower for public transport than for cars. As a result, using behavioural values of time in an appraisal would create a bias against lower income people using public transport relative to higher income people using cars. To avoid this, the same common value of IVT or 'equity value' is used across modes and individuals for transport appraisal purposes. Douglas and Legaspi (2018) have estimated a weighted average value of time for NSW.

[4] There is a need for care in applying an equity value of time when travel time multipliers have been used in an urban travel demand model. For instance bus or car travel time may be multiplied by a factor of say 1.2 or 1.5 in order to express travel time in equivalent rail time minutes. If the value of time reflects car users, then applying it to a travel time expressed in rail time minutes will over monetise the time saving.

There are a range of approaches to update the value of time. Section 2.2 outlines a selection. An important deciding factor on what index to use is whether the updating is to a new ‘base’ year or whether it is to project the value of time through an evaluation period. To update the value to a base year, the indices used should be in current prices (nominal or prices of the day) whereas for projecting the value through an evaluation period, the indices should be in real (constant or inflation adjusted prices).

Analysis of the Australian and New Zealand studies found that the value of time increased well above consumer price inflation over the 24 year period and so an ‘elasticity’ above one was needed for inflation to track value of time growth. Nominal wage rate and National GDP per capita were closer (and thus needed an elasticity closer to 1). Wage rates have been used to update values of time in some Australia jurisdictions. The UK has used GDP per capita with GDP expressed in current prices (i.e. not the GDP measure commonly reported by the media which is ‘deflated’ for price inflation).

If the value of time is projected to rise in real terms through the evaluation period (rather than remain constant) then either real wages or real GDP per capita could be used.[5]

Figure 1: Value of time over time $/hr

Values in local currency in current prices and include GST

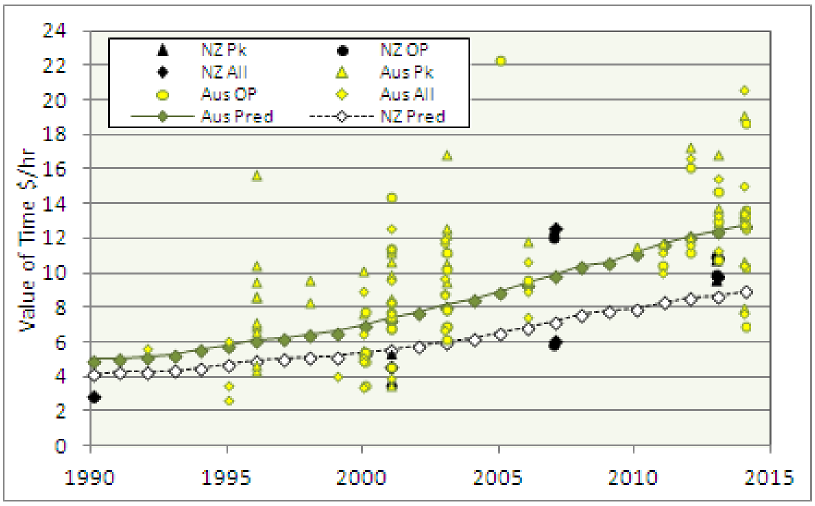


Table 1 provides values of IVT for public transport users in 2014 prices. The values are expressed in 2014 market prices and since they were estimated in studies that compared travel time with fare they include GST levied at 10% in Australia and 15% in NZ on PT fares.[6] The overall value of IVT in national currencies is:

- $12.80/hr for Australia
- $NZ 8.80/hr for NZ.

[5] If values of time are projected to rise in real terms through the evaluation period then for consistency capital and operating costs should also be increased to take account of the proportion of costs that are labour related.

[6] Strictly, values should be discounted at the average rate of indirect taxation in the economy which includes other taxes and duties besides GST.

The values for peak travel are a fifth higher than for off-peak travel. For Australia, the peak VOT was 13.90/hr compared to $11.70/hr in the off-peak.

VOT varied by mode. For Australia, the VOT was $14.40/hr for rail, $13.10/hr for tram/LRT, $11.10/hr for bus and $18.70/hr for ferry.

Table 1: Values of public transport in-vehicle time by mode

Values in local currency in 2014 prices and include GST

Time Period	Australia (Aus $)					New Zealand (NZ$)				
	Rail	Tram	Bus	Ferry	All	Rail	Tram	Bus	Ferry^	All
Peak	15.60	14.20	12.00	20.30	13.90	11.60	na	9.00	15.10	9.70
Off-Peak	13.10	11.90	10.10	17.00	11.70	9.70	na	7.50	12.70	8.10
Overall	14.40	13.10	11.10	18.70	12.80	10.70	na	8.30	13.90	8.90

^ estimate based on Australian surveys since no ferry services were surveyed in NZ
Values include Goods and Service Taxation (GST) levied at 10% for Australia and 15% for NZ.

Table 2 presents guideline factors to calculate the value of IVT by trip purpose for public transport travel. The values have been expressed as a ratio of the average value of IVT (i.e. Table 2). For commuting to/from work, the value of IVT is 115% of the average which for Australia would be $14.70 ($12.80 x 1.15).

Trips to/from school, college and university valued IVT at 76% of the average. Company business trips had the highest value of IVT at 163% of the average but accounted for only 2% of urban public transport trips.

Table 2: Journey purpose values of time and trip shares

Ratio of trip purpose value of IVT (VOT) to average VOT

Statistic	To/From Work	Educ-ation	Personal Business	Company Business	Shop-ping	Visiting Friends/ Relatives	Entertain ment/ Holiday	Other	All
VOT/Av Ratio	115%	74%	95%	163%	93%	83%	89%	88%	100%
Trip Share	47%	17%	9%	2%	7%	8%	8%	2%	100%

Based on studies 22, 37, 38, 39 & 40.

S2 Travel time multipliers for ‘travel convenience’ factors

A set of guideline travel time (IVT) multipliers were derived from a review of 40 Australian and New Zealand studies that covered: walk access/egress, service interval (service frequency), travel time displacement (not travelling at the most desirable time), interchange (transfer penalties and connection time), onboard crowding and reliability.

To calculate a generalised time measure, the weighted components can be added as shown in equation S2. All the components are included in the equation although in practical applications some components may be omitted if they do not change.

$$GT = m_{ae}AE + m_{si}SI + \left(m_{tp}TP + m_{tct}TW\right) + IVT + m_{cwd}IVTCWD + m_{rel}REL + \frac{VOT}{60}FARE$$

…….(S2)

where:

GT = generalised time in minutes

AE = access/egress 'out of vehicle' walk time

SI = service interval (mins between departures)

TP = transfer penalty (number by type)

TW = transfer connection walk and wait time

IVT = in-vehicle time (mins)

IVTCWD= in-vehicle time in crowded conditions (multiplier should be 'net' i.e. minus 1)

REL= reliability measure

FARE = fare in dollars

VOT = value of in-vehicle time ($/hr) in uncrowded seated conditions

m_x = respective multiplier to convert into equivalent IVT minutes.

The generalised time measure can be converted into generalised cost by multiplying by the value of time given in Table 1 or Table 2.[7]. Table 3 presents the guideline travel time multipliers which are expressed relative to seated time in uncrowded conditions on an average quality vehicle.

[7] As the generalised time measure is in minutes and the value of time is an hourly figure, to convert to dollars the GT measure should be divided by 60 and then multiplied by the value of time ($/hr).

Table 3: Summary of travel time multipliers

<table>
<tr><th>Attribute</th><th colspan="6">Australian/NZ Review</th><th>OECD Review</th><th>Notes</th></tr>
<tr><td>Service Interval</td><td colspan="6">0.70</td><td>0.5 - 0.8</td><td rowspan="3">The SI/IVT value of 0.7 allowed for a upward trend in valuation over the review period and compares with an average of 0.64 based on 115 obs. A curvilinear function was estimated which declined from 0.93 for a 5 min service to 0.65 for a 20 min service to 0.37 for an hourly service.</td></tr>
<tr><td>SI (mins/depts)</td><td>5</td><td>10</td><td>20</td><td>30</td><td>40</td><td>60</td><td rowspan="2">na</td></tr>
<tr><td>SI/IVT Valuation</td><td>0.93</td><td>0.83</td><td>0.65</td><td>0.52</td><td>0.44</td><td>0.37</td></tr>
<tr><td rowspan="2">Travel Time Displacement</td><td colspan="2">Early</td><td colspan="2">Late</td><td colspan="2">Average</td><td>Average</td><td rowspan="2">The cost of not being able to travel at the desired time. There were only two Sydney studies giving early displacement at 0.5, late displacement at 0.75 and Av Disp at 0.6. Thes recommended values are lower based on analysis of SI function and the OECD review.</td></tr>
<tr><td colspan="2">0.33</td><td colspan="2">0.50</td><td colspan="2">0.42</td><td>0.4 - 0.6</td></tr>
<tr><td>Wait Time</td><td colspan="6">1.40</td><td>1.75 - 2</td><td>Valuation based on decomposition of SI valuation.</td></tr>
<tr><td rowspan="2">Net Transfer Penalty (mins of IVT)</td><td colspan="3">Same Mode Transfer</td><td colspan="3">Different Mode Transfer</td><td>Penalty</td><td rowspan="2">21 studies provided 75 observations from which the average net transfer penalty (excluding time spent at the transfer) averaged 6 minutes for a same mode transfer e.g. bus to bus or train to train. For transfers involving a change of mode e.g. bus to train, the net transfer penalty averaged 10 minutes. For rail, two Sydney studies estimated a cross-platform penalty to be 2 minutes less than a change in platform.</td></tr>
<tr><td colspan="3">6</td><td colspan="3">10</td><td rowspan="2">5 - 15 (Gross included transfer time)</td></tr>
<tr><td>Transfer Connection Time</td><td colspan="6">1.50</td><td>Time at the transfer (largely waiting time) was valued at 1.5 x IVT based on 25 observations. Valuation likely to vary with walk/wait & conditions (seating/shelter & crowding).</td></tr>
<tr><td rowspan="2">Crowding Multipliers</td><td colspan="2">Crowded Seat</td><td colspan="2">Standing</td><td colspan="2">Crush Standing</td><td>Standing</td><td rowspan="2">14 studies (30 obs) estimated crowding multipliers. Crowded seating time was valued a fifth higher than uncrowded seating. Standing multiplied the time cost by 1.65 with crush standing more than doubling the cost (2.11).</td></tr>
<tr><td colspan="2">1.20</td><td colspan="2">1.65</td><td colspan="2">2.10</td><td>1.5 - 2</td></tr>
<tr><td rowspan="2">Reliability (Average Mean Lateness)</td><td colspan="2">At Stop Departure</td><td colspan="2">On-vehicle Arrival</td><td colspan="2">Average</td><td>Lateness</td><td rowspan="2">10 studies (15 obs) measured reliability as Average Mean Lateness (AML) calculated as the proportion of services late multiplied by the number of minutes late. Departure AML at stops was valued higher at 5.9xIVT than vehicle or arrival AML at 2.8. The average AML valuation was 4.1.</td></tr>
<tr><td colspan="2">5.9</td><td colspan="2">2.8</td><td colspan="2">4.1</td><td>3 - 5</td></tr>
<tr><td>Access/Egress: Walk</td><td colspan="6">1.50</td><td>1.75 - 2</td><td>21 studies (19 SP, 2 RP) gave av. multiplier of 1.32 however 2 studies of actual behaviour (Sydney Travel Model calibration) gave higher value of 1.5 and this value is recommended. Valuation will increase where greater effort involved (e.g. 4 for up stairs) or in high crowding (2.3).</td></tr>
</table>

S3 Value of vehicle quality

The values for vehicle quality relate to the provision (or not) of onboard facilities such as passenger information displays and air conditioning and to the level of ‘operational’ quality such as the cleanliness and the friendliness and helpfulness of the bus driver.

The values for bus, LRT/tram and rail rely heavily on the results of three large-scale market research studies undertaken in NZ (Auckland, Christchurch and Wellington) in 2012/13, Sydney in 2013 and Melbourne in 2014. The three studies used a passenger rating approach that valued quality on a scale from ‘very poor’ to ‘very good’. The scale was converted to a percentage scale that allowed for the ‘willingness to pay’ to diminish as quality improved and for individual attribute improvements to be valued consistently with improvement ‘packages’.

Table 4 presents the value of improving the rating of an individual attribute from a rating of 40% to 80% which is considered the practical range of low to high quality. Benefit is presented for a 25-minute trip and for a 50-minute rail trip.

Table 4: Value of improving vehicle attribute ratings from 40% to 80%

Attribute	Value (mins) by mode & trip length (mins)			
	Bus	LRT	Rail	
	25	25	25	50
Vehicle's Outside Appearance	0.72	0.75	0.88	1.76
Ease of Getting On & Off	0.35	0.37	0.43	0.86
Seat Availability & Comfort	0.57	0.59	0.70	1.40
Space for Personal Belongings	0.19	0.20	0.24	0.47
Smoothness & Quietness of ride	0.51	0.53	0.62	1.25
Heating & Air-conditioning	0.50	0.52	0.61	1.23
Lighting	0.36	0.38	0.44	0.88
Inside Cleanliness & Graffiti	0.57	0.59	0.70	1.39
Onboard Information & announcements	0.38	0.40	0.47	0.94
Bus/Tram Driver, Onboard Staff	0.60	0.62	0.74	1.47
Ability to use computer/internet connectivity	0.09	0.09	0.11	0.21
Environmental Impact (emissions, noise)	0.54	0.56	0.66	1.33
Toilet Availability & Cleanliness * IVT>40mins	na	na	na	0.29
Sum of Individual Attributes *	5.38	5.60	6.60	13.48
Modelled Package	4.33	4.66	5.57	11.30
40%-80% Change in all attributes	4.33	4.66	5.58	11.16

The sum of the individual attribute improvements deliberately exceeds the modelled package due to the functional specification of the model. For packages of improvements, the model (as presented in the main report) should be used which will ensure consistent valuations. The values in Table 4 exclude halo effects whereby improving one attribute improves the ratings of other attributes and hence the overall rating. Analysis of Sydney passenger ratings has shown that halo effects could be significant, doubling the overall impact of individual attribute improvements.

Table 5 presents the value of a selection of vehicle features. Two values are tabulated: the value per trip in minutes; and the valuation expressed as a ratio of onboard trip length (which enables the values to be applied to other trip lengths). A commentary on the results is provided in the main report.

Also presented in the main report are values for ferry attributes, although these are based on an older 2001 study of Sydney Ferries.

Table 5: Value of vehicle attributes and features

Mode	Comparison	Attribute Rating	IVT Valuation mins per trip	IVT Valuation Percent of IVT	Comment
Rail	Old v New Train	Overall	4.18	8.0%	Sydney CK sets vs Waratah; V set vs Oscar; WTN Ganz Mavag vs Matangi
	Old v Refurb Train	Overall	2.00	5.4%	Sydney Tangara refurbishment.
	Diesel v Electric	Overall	1.78	5.9%	AUC DMUs vs WTN EMUs
	Diesel v Electric	Environ Rating	0.26	0.9%	AUC DMUs vs WTN EMUs
	Onboard Elect. Info Displays	Onboard Info. & announcements	0.40	0.8%	SYD CK Sets vs Waratah, V set vs OSCAR; MEL Comeng vs Xtra; WTN G.Mav vs Matangi
	Air-Conditioning	Heating and air conditioning	0.35	1.0%	Sydney S vs CK set; WTN Ganz Mavag vs Matangi.
	Security CCTVs	Feeling of Personal Security	0.43	1.2%	Sydney Tangara,C, K & S sets vs Waratah (uses Study #25 Personal Security estimate).
	Onboard Staff	Staff availability & helpfulness	0.70	2.3%	Auckland & Wellington Onboard Staff with ticketing duties (vs guards on train).
	Toilets	Toilet availability & cleanliness	0.43	0.5%	Sydney intercity OSCAR & V sets; WTN Wairarapa Line.
Tram	Old v New Tram	Overall	0.89	4.5%	MEL Z class versus E class
	Onboard Elect. Info Displays	Onboard Info. & announcements	0.12	0.6%	MEL A,B vs C,D,E class tram
	Onboard Staff	Staff availability & helpfulness	0.11	0.6%	MEL driver only trams versus SYD LRT with onboard staff
	Low Floor	Ease of On/Off	0.09	0.5%	MEL Z class vs CDE
Bus	29 year old v New	Overall	3.90	17.0%	NZ: 29 year old vs 1.5 year old bus
	20 year old v New	Overall	1.36	5.9%	NZ: Pred rating for 45 seater for 20 year old v brand new (0 years)
	10 year old v New	Overall	0.62	2.7%	NZ: Pred rating for 45 seater for 10 year old v brand new (0 years)
	Premium Routes	Overall	0.91	4.0%	NZ: Std routes vs AUC Inner/Outer Loop & WTN Airport Flyer
	Premium Routes	Onboard Info. & announcements	0.15	0.7%	NZ: Std routes vs AUC Inner/Outer Loop & WTN Airport Flyer
	Diesel vs Trolley	Overall	0.35	1.5%	NZ: WTN Trolley bus vs Diesel bus
	Diesel vs Euro 5	Overall	0.70	3.0%	NZ: Non Euro 5 Diesel vs Euro 5 Diesel bus
	Pre Euro vs Trolley	Environ Rating	0.11	0.5%	NZ: Pre Euro vs WTN trolley
	Pre Euro vs Euro 5	Environ Rating	0.10	0.4%	NZ Pre Euro vs Euro 5 rated bus
	Midi vs Std Bus	Seat Avail & Comfort	0.08	0.3%	NZ: Midi 20 seat vs Std 45 seat
	Std vs Artic Bus	Seat Avail & Comfort	0.09	0.3%	NZ Std 75 seat vs 45 seat, Syd Std vs Artic
	Std vs Low Floor	Ease of On/Off	0.06	0.3%	NZ: Std bus vs low floor bus

S4 Value of stop/station quality

The same approach as for vehicles was used to value bus and tram stops and rail stations. Table 6 presents the valuations if improving the rating of individual stop/station attributes from 40% to 80%.[8]

As with vehicle quality, the sum of the individual attribute valuations exceeded the package value. A longer list of attributes was valued for rail stations. There was also a slight difference between bus and tram stops due to the inclusion of ticket purchase facilities for tram stops, which lowered the importance of the other attributes. Again halo effects are excluded which could double the impact of individual attribute improvements.

Table 6: Value of improving stop attribute ratings from 40% to 80%

Attribute	Value mins/boarding		
	Bus Stop	Tram/ LRT Stop	Rail Stat
Platform Weather Protection	1.18	1.14	0.79
Platform Seating	1.00	0.97	0.77
Timetable Information & Announcements	1.01	0.99	0.67
Station Lighting	0.57	0.56	0.53
Cleanliness & Graffiti	0.89	0.86	0.90
Ease of Ticket Purchase	na	0.30	0.58
Platform Surface	na	na	0.68
Ease of getting to & from the plaform e.g. stairs, lifts, escalators	na	na	0.59
Toilet Availability & Cleanliness	na	na	0.16
Availability & Helpfulness of Staff	na	na	0.23
"Retail" - Ability to buy food, drinks and newspapers etc	na	na	0.18
Car Parking and Car Passenger Pick Up and Set Down Facilities	na	na	0.27
Ease of Transferring to & from Bus	na	na	0.11
Sum of Individual Attributes	4.65	4.82	5.70
Modelled Package	3.79	3.88	5.19
Change in all attributes	3.81	3.90	5.21

The rating data was combined with the availability of bus stop facilities (as perceived by users) to estimate the value of providing a timetable (T), RTI (R), weather protection (W), seating (S) at bus stops and of a raised platform and providing ticket purchase facilities at tram stops. Figure 2 graphs the value of difference facility combinations.

The benefit from providing RTI at a stop with shelter, seating and a timetable can be determined by subtracting T-SW (2.68) from TRSW (3.23) which is 0.55 minutes. By contrast, if RTI was provided at a stop with no other facilities, the benefit would be 0.79 minutes.

For rail stations, the value of providing different facilities was based on a cross-sectional comparison of passenger ratings ‘with and without’ provision. Unlike bus and trams, facility provision was based on ‘actual’ data provided by operators and territorial authorities rather

[8] Stop/station facilities will mostly benefit passengers who board at the stop but passengers who alight and who transfer at a stop/station may also derive some benefit. The main text presents some guideline factors to apply to the attribute valuations to value the benefit.

than passenger perceptions. Table 7 presents the valuations.

Figure 2: Value of bus and tram stop facilities in IVT minutes

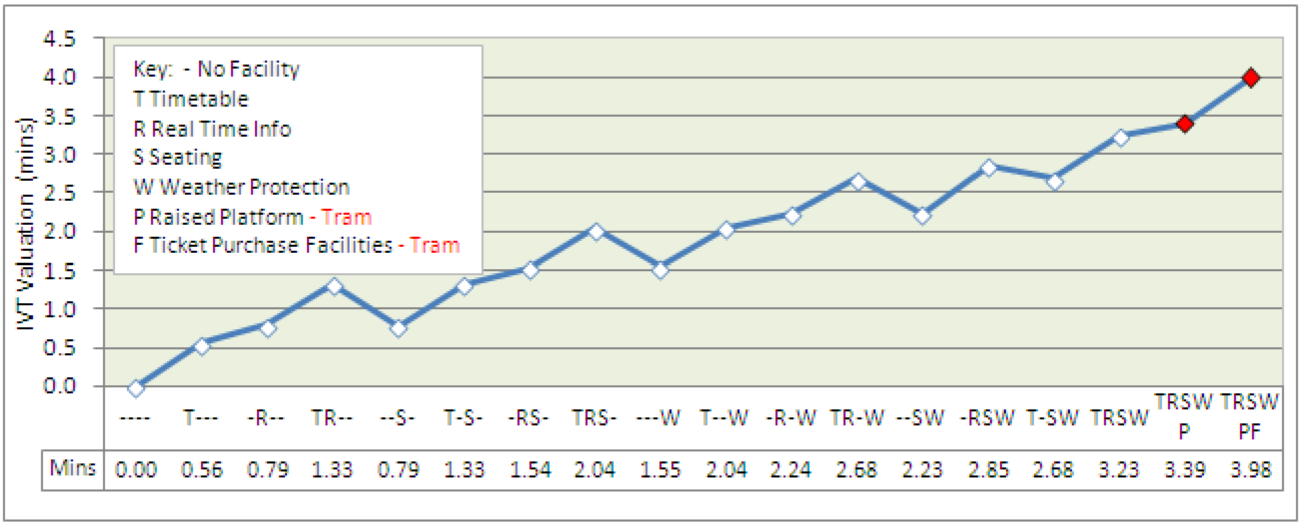


Table 7: Value of rail station facility provision in IVT minutes

Attribute	Value Mins	Comment
Passenger Information Displays (PIDs)	0.28	Mel: Comparison of stations with/without PIDs (adjusted for more facilities at PIDs stations) for suburban trains.
Ticket Purchase Facilities	0.18	NZ: Based on difference in ticket rating at stations with/without ticket purchase facilities.
Staff Presence	0.15	NZ & SYD: Based on staff rating at stations with/without staff.
Retail Facilities	0.13	NZ: Based on retail rating for stations with/without.
Toilets	0.06	NZ & SYD: Based on toilet avail/cleanliness rating for stations with/ without.
Ease of Bus Access	0.03	NZ & SYD: Difference in whether bus transfer available or not
Car Park / Drop Off	0.06	NZ & SYD: Based on car access rating with/without car park.
Bike Racks/Lockers	0.03	SYD: Based on bike rating with/without bike rack/locker (pivoted on Sydney rating model).
Taxi Rank	0.02	SYD: Based on rating of taxi rating (pivoted on Sydney model).
Provision of Lifts/Escalators	0.08	NZ: Based on platform on/off rating with/without lifts/escalators at stations with overbridge.
Provision of Lifts	0.08	SYD: Based on platform on/off rating at stations with/without lifts. The value increased to 0.1 after taking account the increase in use by mobility challenged users.^
Flat versus Overbridge	0.05	NZ: Based on plt on/off rating for stats with o'bridge vs flat.
Newly Upgraded/Built	2.33	NZ: Major upgrade/0-5 five years old.
Recently Upgraded/Built	1.32	NZ: Major upgrade/built 5-10 years old.

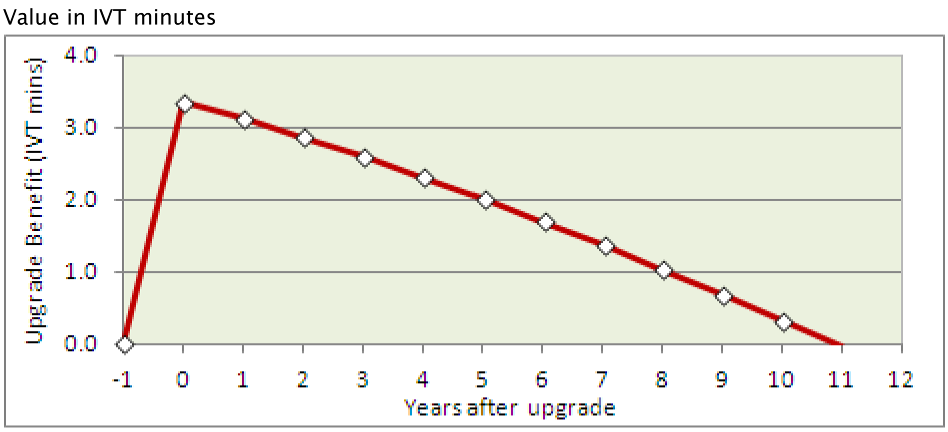
^ average station user - Lifts mainly benefit to 'Mobility Challenged' (MC) users (eg wheelchair, infirm, pax with heavy luggage, strollers etc). Taking account trip generation, the benefit was 0.1 mins per trip.

The NZ study was able to estimate the value of minor and major upgrades to stations to passengers by combining the results of two near identical passenger station rating surveys undertaken 10 years apart. The value of a major station upgrade which typically would involve rebuilding the main station building was worth 3.35 minutes per boarding trip. This is the 'brand new' value (i.e. the day after completion). The value then gradually decreased such that after 5 years, it was worth 2 minutes, 0.32 minutes after 10 years and was close to zero after 11 years as Figure 3 shows.

Table 8: Value of minor and major rail station upgrades in IVT minutes

Upgrade	Attribute Rating Affected	Valuation Minor Upgrade	Valuation Major Upgrade	Comment
Platform Shelter	Shelter	0.09	0.36	Based on predicted effect on weather protection rating
Seating	Seating	0.16	0.41	
Platform Surface	Platform Surface	0.19	0.44	Major upgrade included rebuilding platforms with access paths to 'street'
" " "	Platform On/off	0.24	0.41	
Information	Information	na	0.30	
Lighting	Lighting	0.11	0.21	
Cleaning/Graffiti	Cleanliness/Graffiti	0.25	0.62	
Toilets	Toilet	na	0.09	
Retail	Retail	na	0.18	Opening of café/small shop on platform or near platform.
" " "	Staff	na	0.04	'Staff' presence from retail facility
" " "	Ticket Purchase	na	0.46	Ability to sell rail tickets from retail outlet.
Car Park	Car Access	na	0.17	Major upgrade of car parking area including resurfacing,lighting, signing and walkways.
Bus Facilities	Bus Access	na	0.03	Improvement of bus waiting area including shelter and signage.
Overall Station	Sum of Attributes	1.04	3.73	Sum of individual valuations
Station Upgrade	Overall Rating	0.94	3.35	Valuation of major upgrade on opening day, on year 5 and on year 10.
After 5 years	" " "	na	2.01	
After 10 years	" " "	na	0.32	

Figure 3: Value of station upgrading by year



S5 Mode Specific Constants

Mode Specific Constants (MSCs) measure the residual difference in modal quality after differences in travel convenience notably access/egress time, in-vehicle time, service frequency, transfer, crowding, reliability and fare have been deducted. They are often used in multi-modal studies such as forecasting the patronage for new services.

Four MSCs were estimated from a review of 15 Australian and NZ studies. Table 9 presents the MSC estimates which measure the additional cost in IVT minutes of travelling by bus versus the comparison mode.

Table 9: Mode Specific Constants in IVT minutes

	Bus - Rail	Bus - LRT	Bus-(Rail/LRT)+	Bus - TW	Bus - Ferry
MSC mins	10	12	7	5	16
Bus IVT mins	33	28	30	40	40
MSC Multiplier	0.31	0.43	0.24	0.12	0.40

+ based on logistic regression

In the third column, a combined Bus-(Rail/LRT) MSC was estimated based on a regression analysis of the 31 observations taking account the trip length. The predicted MSC for different trip lengths is presented in Table 10.

Table 10: Bus – (LRT/Rail) gross Mode Specific Constant by trip length

Bus IVT mins	5	10	15	20	25	30	35	40	45	50	55	60
MSC (mins)	0.6	1.1	1.8	3.0	4.7	7.1	10.0	13.1	16.2	18.8	20.8	22.2
IVT multiplier	0.12	0.11	0.12	0.15	0.19	0.24	0.28	0.33	0.36	0.38	0.38	0.37

A Sydney 2013 study estimated the 'intrinsic' Mode Specific Constant for Rail/LRT versus bus after standardising for quality difference between the modes. For a 25-minute trip, the intrinsic modal preference was worth 2.7-minute advantage for LRT/rail over bus (with negligible difference between rail and LRT). Having established the intrinsic difference, the value from differences in stop/station and vehicle quality can then be added. Table 11 presents the combined value of vehicle and stop quality.

Table 11: Value of vehicle and stop/station quality differences in IVT mins

Attribute	Valuation of Quality Rating (mins) for a 25 minute trip								
	40%	45%	50%	55%	60%	65%	70%	75%	80%
Vehicle	8.0	8.7	9.4	10.0	10.6	11.2	11.8	12.3	12.9
Stop/Station	8.0	8.7	9.2	9.8	10.3	10.9	11.4	11.9	12.4
Total	16.1	17.4	18.6	19.8	20.9	22.1	23.2	24.2	25.3

To illustrate the approach, a proposed LRT system is assessed where the vehicle rating is expected to increase from 70% to 80% and the stop/station rating from 65% to 75%. The vehicle improvement (70% to 80%) would be worth 1.1 minute per trip (12.9 to 11.8) and the stop/station improvement (65% to 75%) 1 minute (11.9 to 10.9). Therefore, the combined quality improvement from the proposed LRT system compared with the existing bus service would be worth 2.1 minutes. The intrinsic MSC of 2.7 minutes is then added to get a gross MSC worth 4.8 minutes.

1. Introduction

This is a technical report on public transport parameter values and supports ATAP Part M1 Public Transport Guidance. The parameter values (values of in-vehicle time and travel time multipliers) are based on a review of 40 market research studies and model estimation studies undertaken in Australia and New Zealand between 1990 and 2013.[9] Reference is also made to an OECD review of convenience factors that was undertaken by Wardman in 2013. Table 12 lists the attributes covered by the review.

Table 12: Attributes reviewed

#	Service attribute	Section
1	Value of in-vehicle time in dollars	2
2	Access walk time	3
3	Service Frequency (Wait Time & Displacement)	4
4	Travel Time Reliability	5
5	Crowding	6
6	Transfer Penalty and Wait Time	7
7	Vehicle Quality	8
8	Bus Stop & Train Station Quality	9
9	Mode Specific Constants	10

Thirty-three of the studies were undertaken in Australia and seven in NZ. Most (25) of the Australian studies were undertaken in NSW (all except one in metropolitan Sydney). Eight of the Australian studies were undertaken outside NSW. Of these, two were undertaken in Brisbane/SE Queensland, three in Victoria, one in Perth, one in Canberra and one ‘capital cities’ study.

All but two studies were Stated Preferences (SP) market research surveys about *‘what people say they would do’.* Only two studies were based on Revealed Preferences (RP) (i.e. *‘what people actually do’).* The two RP studies were calibration analyses for the Sydney Travel Model which used Household Travel Survey data.

Many of the SP studies were undertaken as part of forecasting the demand for a new service such as a light rail or a bus rapid transit. Other surveys were part of building demand models or estimating parameters for economic evaluations.

While the studies cover, bus, rail, ferry, light rail and busway (the latter only as a forecast mode), rail studies were predominant. Most surveys only interviewed users of the mode ‘in question’ but some surveys did interview car users and walkers/cyclists.

Typically, respondents were presented with a series of pair-wise choices that varied the times and costs. Usually, two public transport modes were compared such as bus versus bus or train versus bus. A few studies compared public transport with car or walk/cycle. Generally, those studies that presented ‘same mode’ choices (e.g. bus v bus) produced

[9] Appendix Table A1 provides summaries.

more precise estimates.[10]

For some attributes, the observations were weighted to reflect the relative accuracy of the study estimates.[11]

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[10] Respondents in 'same mode' SPs were more likely to trade-off time with cost, varying their response across the choice situations whereas in 'between mode' SPs, respondents were more likely to stick to their current mode.

[11] The weights were based on the 't' statistic of the relative valuation. The t value is the ratio of the mean estimate to the standard error. Many studies reported t values for individual parameters such as fare or in-vehicle time but not for the relative valuation (the ratio of the estimates). Where possible, the t value for the relative value was calculated (assuming zero covariance between estimators). Where it was not possible to calculate, a value of 2 was assumed. To produce the weighting index, the t values were allocated to three categories and given a score of 1 for t values between 0 and 2, 2 for t values between 2 and 4 and 3 for t values exceeding 4. An average weight was then calculated whilst maintaining the number of observations. In general, the t statistic increased with the size of the sample but also reflected the design of the questionnaire, the composition of the samples and the survey method (self-completion, mail-back, interviewer led or internet survey).

2. Value of travel time

2.1 Introduction

The value of in-vehicle time (VOT) is an important parameter in computing generalised cost measures for patronage forecasts and project appraisal. The VOT enables travel times savings to be converted into dollars in order to compare travel time savings with project costs.[12] The value of in-vehicle time (IVT) also provides a base on which other travel time components such as access walk time can be monetised after applying 'IVT multipliers'. In this context the value of IVT time presented in this section, unless otherwise stated, is for seated onboard time on a bus, train or ferry for an average quality vehicle as perceived by users.

Thirty of the studies reviewed provided VOT estimates. Some studies provided estimates by time period (peak, off-peak and all) and some by travel mode (bus, LRT/tram, train and ferry). Altogether a total of 110 VOT estimates were provided.[13] The values were in market prices (i.e. inclusive of GST levied at the time).[14] Twenty-six of the studies were Australian (94 observations) and four were NZ (16 observations). Most of the Australian studies were undertaken in Sydney or NSW (20 studies and 69 observations).

The estimates covered a 24-year period from 1990 to 2014 and a key task was to take account of the year in which the studies were undertaken. As well as estimating a value of time for 2014, the review assessed the ability of three economic indicators to track the value of time and thereby provide a basis for updating the values from year to year and projecting the estimate through an appraisal period. The three indicators are: Consumer Price Index (CPI), Average Hourly Earnings (AHE)[15] and Gross Domestic Product.[16]

2.2 Trend in the value of time

Over the 25 years, the VOT for Australia increased from $4.75/hr in 1990 to $12.80/hr in 2014 as can be seen in Figure 4.

State as well as national estimates were assessed for GDP and AHE but gave a poorer fit

[12] Other components, such as access time, can also be converted in dollars after they have been expressed in equivalent in-vehicle time minutes.

[13] Some studies produced estimates by trip purpose rather than peak/off-peak values. Where this was done, commuting to work trips were considered as peak and 'other' trips as off-peak with overall estimates treated as 50% peak and 50% off-peak.

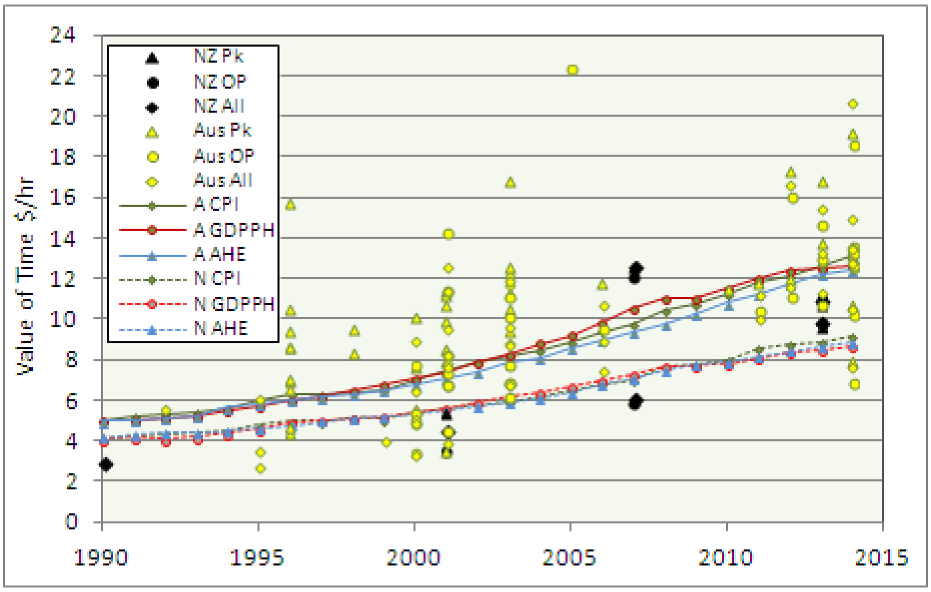
[14] The values are also expressed in 'market prices'. All the estimates are based on a 'trade-off' between travel time and fare and the fare includes Goods and Service Taxation (GST) when levied. It should be noted that before 2000, there was no GST in Australia. Since 2000, a 10% GST has been levied on public transport fares. In NZ, GST was set at 12.5% until 2010 when it was raised to 15%.

[15] Weekly Earnings divided by 38 hours per week.

[16] The use of 2,000 hours which is approximately 38 hours x 52 (1,976) puts the GDP figure on a comparable basis with the value of time and also hourly earnings. It is only a relative positioning factor however. If annual figures were used the regression parameter for GDP would have been 7.6 times smaller (the natural logarithm of 2000).

although the analysis was compromised by the large proportion of NSW estimates in the dataset.

Figure 4: Trend in the value of public transport in-vehicle time $/hr



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Note: Australian values of time in Australian dollars and NZ in NZ dollars

GDP is normally reported in constant prices since it measures changes in output. However, as the 'observed' VOTs reflect changes in prices, GDP in current (nominal) prices was used. Models in constant prices were also fitted with GDP expressed in constant 2014 prices. A GDP deflator was used for GDP and CPI was used for AEH. Constant elasticity models[17] were fitted as shown in equation 2.1.[18]

$$\ln(VOT) = \beta_o + \beta_x \ln(X) + \beta_{bus}BUS + \beta_{ferry}FERRY + \beta_{OP}OPK + \beta_{NZ}NZ \qquad .....(2.1)$$

Where:

X = economic index (CPI, GDPPH or AHE)

$BUS, FERRY, OPK, NZ$ = variables classifying observations by mode, time period and country with rail, peak and Australia the base categories

[17] Logarithms of the VOT and economic indicator (X) were taken to transform the model into a linear form. The model can be rewritten multiplicatively by taking the exponential of the constant and classificatory variables regression coefficients ($\phi_i = \exp \beta_i$) so that $VOT = (\phi_o.\phi_{bus}BUS.\phi_{ferry}FERRY.\phi_{op}OP.\phi_{nz}NZ).X^{\beta x}$.

[18] Classificatory variables were specified as 'dummy' variables (1 if true 0 if false). It was not possible to classify all the observations into a category so probabilities were used (e.g. 'all' time period observations were classified as 0.5 peak and 0.5 off-peak. Other variables were tested. For example, some studies gave values for car users but the values of time were not significantly different from rail users. Some studies gave study type (SP v RP). However, none of the classificatory variables produced an improvement in goodness of fit to warrant inclusion.

$\beta_o, \beta_x, \beta_{bus}, \beta_{ferry}, \beta_{OP}, \beta_{NZ}$ = estimated parameters.

Table 13 presented the estimated models. Using current prices gave a better fit than constant prices (adjusted R2 of 0.63 versus 0.39). There was less different between the economic indices which reflected the high correlation between CPI, AEH and GDPPH). [19]

The estimated elasticity for nominal GDPPH was slightly less than proportional (0.91) reflecting the slightly greater increase in GDPPH (a near tripling over the 24 years) than observed VOT. [20] By contrast, CPI inflation increased less over the period (190%) so the VOT elasticity, at 1.59, was greater. The increase in AHE at 240% fell midway between CPI and nominal GDPPH and the VOT elasticity was close to proportional at 1.07. Updating VOT proportional to AHE (i.e. parameter of 1) is supported by the analysis with Model 8 presenting the parameters with this constraint imposed.

Table 13: Value of time regression models

	Model X Statistic Prices Deflator Constrained	1 CPI Nat Current na	2 GDPPH Nat Current na	3 GDPPH State Current na	4 AHE Nat Current na	5 AHE State Current na	6 GDPPH Nat Constant GDP	7 AHE Nat Constant CPI	8 AHE Nat Current na Yes
Reg	Constant	1.790	-0.483	-0.517	-0.892	-1.167	-0.349	-1.329	-0.686
Coeff-	X	1.590	0.910	0.927	1.073	1.156	0.878	1.200	1.000
icient	Bus	-0.259	-0.251	-0.272	-0.259	-0.263	-0.251	-0.170	-0.269
	Ferry	0.254	0.269	0.266	0.263	0.226	0.269	0.264	0.233
	OffPk	-0.173	-0.180	-0.170	-0.171	-0.167	-0.183	-0.259	-0.152
	NZ	-0.124	ns	ns	-0.254	-0.242	ns	-0.251	-0.236
t value	Constant	27.6	2.1	2.0	3.3	3.9	0.7	1.5	16.4
	X	12.4	12.8	11.3	12.3	12.1	5.7	4.4	na
	Bus	4.5	4.4	4.5	4.5	4.6	4.4	4.5	4.60
	Ferry	2.8	2.9	2.7	2.9	2.4	2.9	2.9	2.50
	OffPk	3.0	3.1	2.8	3.0	2.9	3.2	2.9	2.60
	NZ	1.9	ns	ns	4.0	3.7	ns	3.9	3.60
Model	Adj R^2	0.64	0.62	0.57	0.63	0.61	0.41	0.39	0.61
Fit	Obs	132	132	132	132	132	132	132	132

State figures as well as national figures were fitted for GDP and AEH but goodness of fit worsened. Here, the dominance of NSW with three-quarters of the VOT observations should be noted. For NZ, a 'positioning' variable allowed for currency differences. For the GDP models, the coefficient was not statistically significant and was omitted. For the CPI and AEH models, the NZ coefficient was significant and implied a lower value of time than for Australia

[19] The correlation coefficient was 0.93 for GDP & AEH, 0.98 for GDP & CPI and 0.98 for AEH and CPI (log variables).

[20] The parameter was not significantly different from one: $((\beta_x - 1)/ste(\beta_x) = 0.05)$. A constrained model was fitted in which the GDP coefficient was set to 1. Unsurprisingly, the constraint had little effect on the other parameters.

(for a given level of CPI or AEH).

2.3 Values of time for 2014

The predicted values of time for 2014 were estimated by time period (peak and off-peak). The peak and off-peak values were averaged to calculate an overall VOT.

The values by mode weighted by patronage share using BITRE for Australia and NZ DoT data for NZ to derive an overall average as given in Table 14.[21]

Table 14: Travel mode weights

Country	Trips (Australia) / Boardings (NZ) share				
	Rail	Tram/LRT	Bus	Ferry	All
Australia	43.0%	12.3%	43.3%	1.4%	100%
NZ	16.8%	na	79.3%	4.0%	100%

Source: Australia BITRE Report 129 Table 2.1 figures for 2010, NZ DoT TV020 figures for 2013/14

Similar VOTs for 2014 were forecast as can be seen from Table 15. For Australia, the overall VOT ranged from $12.60/hr to $13.10/hr with an average of $12.80/hr. For NZ, the average was $8.90/hr.

There are a range of approaches to update the value of time. An important deciding factor on what index to use is whether the updating is to a new ‘base’ year or whether it is to project the value of time through an evaluation period.

To update the value to a base year, the indices used should be in current prices (nominal or prices of the day) whereas for projecting the value through an evaluation period, the indices should be in real (constant or inflation adjusted prices)

Figure 4 and Table 13 showed the value of time to increase well above consumer price inflation over the 24 year period and so an ‘elasticity’ above one was needed. Nominal wage rate and National GDP per capita were closer (and thus needed an elasticity closer to 1).

Wage rates have been used to update values of time in some Australia jurisdictions. The UK has used GDP per capita with GDP expressed in current prices (i.e. not the GDP measure commonly reported by the media which is ‘deflated’ for price inflation).

If the value of time is projected to rise in real terms through the evaluation period (rather than remain constant) then either real wages or real GDP per capita could be used. Capital and operating costs should be treated in a consistent manner however.

[21] For tram/LRT studies 38 and 39 were used which gave a value of time 90% that of rail and 120% of bus.

Table 15: Value of time estimates

	Model	1	2	3	4	5	6	7	8	9
	Locality	CPI	GDPPH	GDPPH	AHE	AHE	GDPPH	AHE	AHE Con	Av VOT
	Prices	Nat	Nat	State	Nat	State	Nat	Nat	Nat	Models
	Deflator	Current	Current	Current	Current	Current	Constant	Constant	Current	1,2&4
		na	na	na	na	na	GDP	CPI	na	
2014	Aus (X)	1.85	34.15	34.15	29.60	29.60	34.15	29.60	29.60	na
Peak	Rail	15.90	15.30	15.70	15.50	15.60	15.70	15.40	14.90	15.60
	Tram	14.50	14.00	14.30	14.20	14.20	14.40	14.70	13.50	14.20
$/hr	Bus	12.20	11.90	12.00	12.00	12.00	12.20	13.00	11.40	12.00
	Ferry	20.50	20.10	20.50	20.20	19.60	20.50	20.10	18.80	20.30
	Overall	14.20	13.70	14.00	13.90	13.90	14.10	14.30	13.30	13.90
Off-Pk	Rail	13.30	12.80	13.30	13.10	13.20	13.00	11.90	12.80	13.10
	Tram	12.20	11.70	12.00	11.90	12.00	11.90	11.30	11.60	11.90
$/hr	Bus	10.30	10.00	10.10	10.10	10.20	10.10	10.00	9.80	10.10
	Ferry	17.20	16.80	17.30	17.00	16.60	17.10	15.50	16.20	17.00
	Overall	11.90	11.50	11.80	11.70	11.80	11.70	11.10	11.40	11.70
Overall	Rail	14.60	14.10	14.50	14.30	14.40	14.40	13.70	13.90	14.40
	Tram	13.40	12.90	13.20	13.10	13.10	13.20	13.00	12.60	13.10
$/hr	Bus	11.30	11.00	11.10	11.10	11.10	11.20	11.50	10.60	11.10
	Ferry	18.90	18.50	18.90	18.60	18.10	18.80	17.80	17.50	18.70
	Overall	13.10	12.60	12.90	12.80	12.90	12.90	12.70	12.40	12.80
2014	NZ (X)	1.67	24.42	24.42	28.47	28.47	24.42	28.47	28.47	na
Peak	Rail	12.00	11.30	11.50	11.60	11.70	11.70	11.50	11.30	11.60
$/hr	Tram	na	na	na	na	na	na	na	na	na
	Bus	9.30	8.80	8.80	8.90	9.00	9.10	9.70	8.70	9.00
	Ferry	15.50	14.80	15.00	15.00	14.70	15.30	14.90	14.30	15.10
	Overall	10.00	9.50	9.50	9.60	9.70	9.80	10.20	9.40	9.70
Off-Pk	Rail	10.10	9.40	9.70	9.70	9.90	9.70	8.80	9.70	9.70
$/hr	Tram	na	na	na	na	na	na	na	na	na
	Bus	7.80	7.30	7.40	7.50	7.60	7.60	7.50	7.40	7.50
	Ferry	13.00	12.40	12.70	12.70	12.40	12.70	11.50	12.30	12.70
	Overall	8.40	7.90	8.00	8.10	8.20	8.20	7.90	8.00	8.10
Overall	Rail	11.10	10.40	10.60	10.70	10.80	10.70	10.20	10.50	10.70
	Tram	na	na	na	na	na	na	na	na	na
$/hr	Bus	8.60	8.10	8.10	8.20	8.30	8.40	8.60	8.10	8.30
	Ferry	14.30	13.60	13.90	13.90	13.60	14.00	13.20	13.30	13.90
	Overall	9.20	8.70	8.80	8.90	9.00	9.00	9.10	8.70	8.90

The ‘average’ values are given in Table 16 alongside peak and off-peak travel.22 The overall average of $12.80/hr was 43% of AHE for Australia23 and 37% of GDPPH and is an increase of $2.80/hr on the $10/hr figure in the 2006 ATC Guidelines.24 For NZ, the average value of $8.90/hr represents 36% of AHE and 31% of GDPHH.

For updating purposes, the ‘X’ coefficients (which are also elasticities) for the alternative economic indices in Table 13 could be used.[25]

Table 16: Average value of public transport in-vehicle time

Values in national currency (Australian or NZ dollars) in 2014 prices and include GST

	Aus (A$)	NZ (NZ$)
Peak	13.90	9.70
Off-Peak	11.70	8.10
Overall	12.80	8.90

Some studies require values of time by mode. Table 17 presents guideline figures.[26] For Australia, the overall values were $14.40/hr for rail, $13.10/hr for tram/LRT, $11.10/hr for bus and $18.70/hr for ferry.

Table 17: Values of Public Transport In-vehicle time by mode

Values in local currency in 2014 prices and include GST

Time	Australia (Aus $)					New Zealand (NZ$)				
Period	Rail	Tram	Bus	Ferry	All	Rail	Tram	Bus	Ferry^	All
Peak	15.60	14.20	12.00	20.30	13.90	11.60	na	9.00	15.10	9.70
Off-Peak	13.10	11.90	10.10	17.00	11.70	9.70	na	7.50	12.70	8.10
Overall	14.40	13.10	11.10	18.70	12.80	10.70	na	8.30	13.90	8.90

[22] Some of the studies included car users in the sample and the analysis was able to segment the results by user. The regression models did not find car users to be significantly different from rail users in their valuation of travel time.

[23] The Australian value is therefore close to the 40% wage rate assumption as recommended by the Austroads working group in 1997.

[24] The predicted VOT for 2006 was $9.40/hr.

[25] For projecting the value of time through an evaluation period, GDP per capita in constant prices could be used. This is the approach used by the UK Department of Transport which provides forecasts of GDP/capita for a 75 year period commenting “the Department uses HMT’s GDP deflator, which is a much broader price index than consumer price indices (like CPI, RPI or RPIX) as it reflects the prices of all domestically produced goods and services.
https://www.gov.uk/government/publications/webtag-tag-data-book .

[26] This is rather than a strict 100% valuation of the WTP for in-vehicle time savings. This explanation is particularly apposite for ferry where fares are generally higher in order to recoup the higher cost of providing the service. This elevation in price both selects users willing to pay the higher fare and also ‘conditions’ users to paying the higher fare. In theory, as the vehicle quality improves, a person’s WTP to save time on it should, other things being equal, reduce and not increase (since the person should be happier spending time on the vehicle whereas the opportunity cost of the time that would be saved remains the same).

2.4 The effect of trip purpose on the value of time

Some demand forecasting models segment by trip purpose. Table 18 presents VOT by trip purpose based on the results of five studies: three Sydney studies (22, 38 & 40) one Melbourne (39) and one NZ (37). All four surveys had large sample sizes and covered both peak and off-peak travel. The VOT estimates have been expressed as a ratio of the average VOT. In the second row, a 'guideline' share for each trip purpose is presented (based on the average of the four studies).

Table 18: Effect of journey purpose on values of time

Ratio of trip purpose VOT to average VOT

Statistic	To/From Work	Educ-ation	Personal Business	Company Business	Shop-ping	Visiting Friends/ Relatives	Entertainment/ Holiday	Other	All
VOT/Av Ratio	115%	74%	95%	163%	93%	83%	89%	88%	100%
Trip Share	47%	17%	9%	2%	7%	8%	8%	2%	100%

Based on studies 22, 37, 38, 39 & 40.

The value of time for commuting to/from work was 115% of the average. Trips to/from school, college and university had a value of time 74% of the average.[27] Company business trips had the highest VOT at 163% of the average.[28]

[27] The value for education trips related to passengers over the age of 12 since younger school children were not surveyed (following market research protocol). For children travelling to/from school, the value of time probably reflects the 'willingness to pay' of the parents.

[28] Some studies use a wage rate plus on-costs value for company business trips representing the opportunity cost of travel time (for the employer). If a wage rate value is used, there is a question as to whether multipliers should be applied to walking time, waiting time, and other non IVT components to account for their greater relative disutility since an employee out of the office for an hour has the same wage cost to the employer irrespective of how much time is spent sitting on the bus or waiting at the bus stop. There may be productivity effects however that would not be reflected in the hourly wage.

3. Walk (access/egress) time

Walk access/egress to and from bus stops, train stations and ferry terminals constitutes part of 'out of vehicle time' (OVT); the other part being waiting time. Given the extra effort involved in walking relative to sitting on a bus or train, transport models usually apply an IVT multiplier greater than one.

A total of 21 studies provided values for access/egress time relative to in-vehicle time. Of these, 18 were Australian studies (predominately NSW) and three were NZ. Altogether, the studies provided 49 values. Most of the studies were undertaken between 1995 and 2005. Some of the Australasian studies were not specific in terms of the type of access and egress that was measured lumping walking with car or referring to 'out of vehicle time' that included waiting at the bus stop.

The studies showed that access/egress was valued higher than seated in-vehicle time, but not markedly so. The average IVT multiplier was 1.32 with quite a wide scatter as Figure 5 and Table 19 illustrate.

Figure 5: Value of walk access /egress time

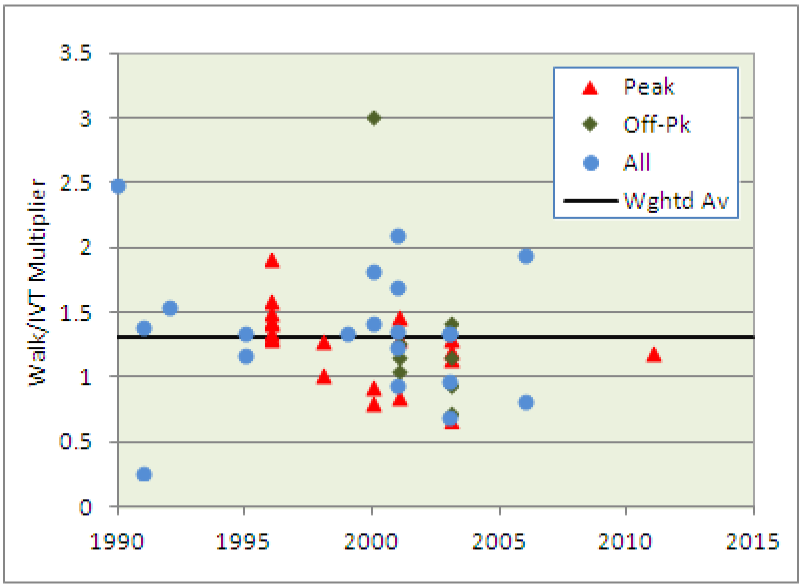


Table 19: Value of walk access /egress time

Minute of walk time in equivalent IVT minutes

Statistic	Peak	Off-Pk	All	Overall
Upper Quartile	1.42	1.30	1.59	1.42
Mean	1.30	1.27	1.26	1.32
Lower Quartile	1.11	1.02	1.12	1.04
Observations	20	8	20	48

All but two studies used Stated Preference (SP) market research and in this regard, it is worth mentioning a problem in getting respondents to think about bus stops and train stations located away from the ones they normally use. The two non-SP studies were calibrations of the Sydney Travel model in which the value of walk time was estimated cross-sectionally using household travel survey data. These two studies, based on actual behavior, gave a higher IVT multiplier of 1.5 which is close to the figure of 1.48 derived by Wardman (2001a) in a meta analysis of 143 UK estimates largely undertaken in the 1980s and 1990s. The OECD Review by Wardman (2013) which includes studies undertaken outside the UK reports a higher value of 1.75 to 2.0 for walk/wait time with the recommended value increasing to between 2 and 3.5 for crowded situations and to 4.0 for situations demanding more than normal effect such as ascending stairs (see section 6.4 on station crowding).

Based on the Australasian evidence and taking into account the two reviews by Wardman, a figure of 1.5 for walk time is recommended for uncongested conditions and for 'normal effort'.

It is worth noting that, for many years, the convention was to use an IVT multiplier for walking time of 2.0. This origins for the multiplier of 2 dates back to a UK Department of the Environment Mathematical Advisory Note 179 by McIntosh and Quarmby in 1970. This should no longer be used.

4. Service interval, waiting time and displacement

4.1 Waiting time and service interval

The inability to travel when you want to due to timetable constraints is an inconvenience that car users typically do not face. The review looked at three inter-related timetabling issues: service interval, waiting time and travel time displacement. Service interval is the mirror image of service frequency and measures the number of minutes between departures: the higher the service frequency (buses per hour), the lower the service interval.

For high frequency services (more than 5 per hour or 12 minutes apart)[29], passengers tend to turn up 'at random' at the bus stop or train station. The average waiting time (assuming a regular service) for these people would be half the service interval.

Analysis of service interval and waiting time by Melbourne, Sydney and NZ PT users (studies 36, 37 & 38) supports this as can be seen from Figure 6. At a service interval of 14 minutes, the average wait time was exactly one half (i.e. 7 minutes).[30] At lower frequencies, the wait time flattened out so that for an hourly service, the average waiting time was just less than 15 minutes. The estimated relationship ($1.88\sqrt{SI}$) can be used to predict the waiting time for modelling and evaluation purposes given knowledge of the timetabled service frequency.

For high frequency services (service intervals less than 14 minutes), waiting times tend to be longer than half the service interval. For example, for a service every five minutes, the predicted waiting time was 4.2 minutes which is 84% rather than 50% of the SI. The longer wait may be due to 'rounding up' by respondents or service irregularity. The recommendation is therefore to assume half the service interval up to a service interval of 14 minutes. Then, for less frequent services, use 1.88 multiplied by the square root of the service interval up to a maximum predicted wait of 20 minutes (for a two-hourly service). Thus mathematically, the recommended wait time model is the minimum of half the service interval (headway), 1.88 times the square root of the service interval and 20 minutes as shown in equation 4.1.

$$WAIT = Min(0.5SI, 1.88\sqrt{SI}, 20) \quad .....(4.1)$$

---

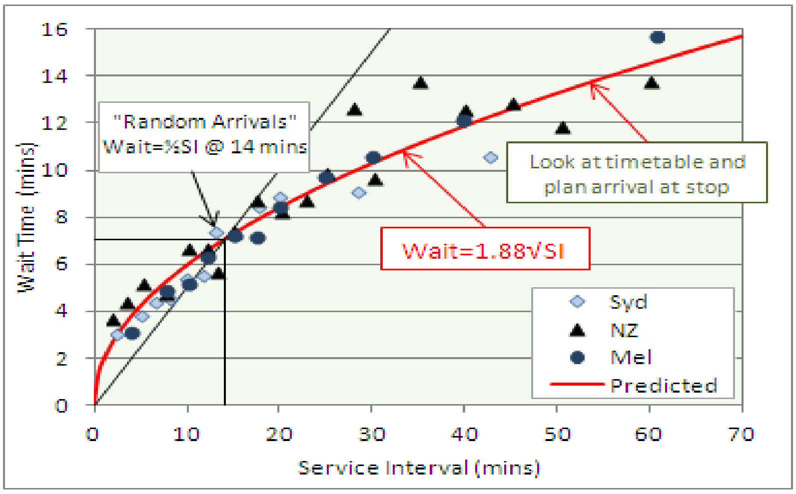
[29] London Transport uses a definition of more than 5 services per hour or an interval of 12 minutes or less.

[30] The square root function adopted means there are two solutions where wait time is half the headway $0.5SI = \alpha + \beta\sqrt{SI}$. The two solutions are $SI = 2\left(k \pm \sqrt{k^2 - \alpha^2}\right)$ where $k = \alpha + \beta^2$.

With $\alpha = 0$ and $\beta = 1.88$, the solutions are 0 and 14.1 minutes.

Figure 6: Relationship between wait time and service interval

Times as perceived by bus, train, tram and LRT users in Melbourne, Sydney and NZ



4.2 Average value of service interval/IVT

Thirty studies provided estimates of the relative valuation of service interval (SI/IVT). 25 studies were Australian (mainly NSW) and five were NZ. Table 20 summarises the ratio across the studies. Most were Stated Preference surveys that described services as 'every X minutes' with a few describing the 'maximum wait time'.[31]

The mean valuation of SI was 0.64 with an inter-quartile range from 0.45 to 0.77.[32] The valuation for Australia was 0.66. For NZ, the value was lower at 0.51 reflecting the effect of studies undertaken in the 1990s with lower services.

Table 20: Value of service interval/IVT

Statistic	NZ	Aus	All
Mean	0.51	0.66	0.64
75% tile	0.68	0.79	0.77
Median	0.45	0.69	0.67
25% tile	0.38	0.45	0.45
Observations	13	102	115
Studies	5	25	30

^ weighted in accordance to t value

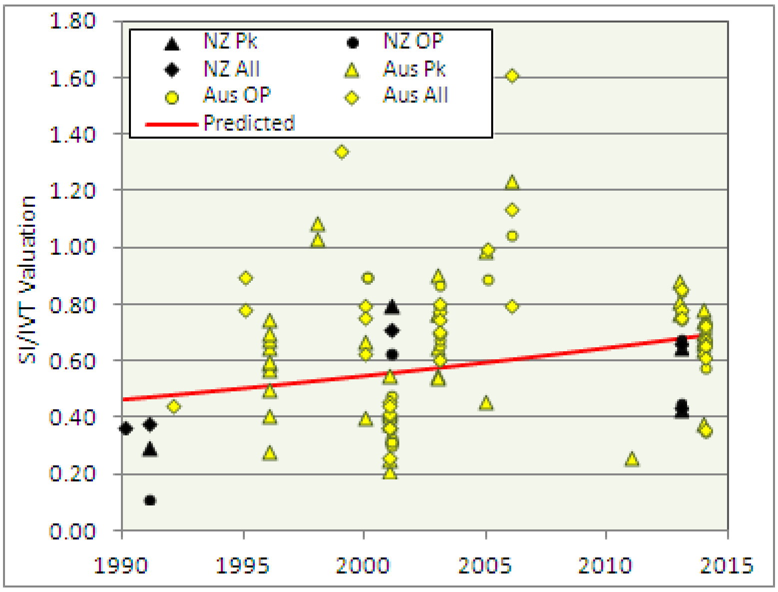
Over the 2½ decades for which studies were reviewed, the SI/IVT value trended upwards as can be seen from Figure 7. Superimposed on the scattergram is a trend line which increased from 0.49 in 1990 to 0.69 in 2014. Based on the trend analysis, a guideline figure of 0.7 is suggested which is close to the recommendation of 0.71 given in the Wardman OECD

[31] One survey measured 'service displacement' (the cost of not being able to travel at the desired time) and the resultant valuations low).

[32] The estimates in Table 4.2.1 were weighted according to the relative t value. Weighting had little impact however. Without weighting the mean value of SI was 0.65.

review (2013).

Figure 7: Increase in the valuation of service interval over time



4.3 Service interval function

Studies have shown that the relative valuation of SI/IVT varies with the frequency of service. For high frequency services, the valuation reflects the value of waiting time, whereas for low frequency services the value reflects displacement time. Two approaches were used to develop SI/IVT functions:

- Composite function based on five Australian and NZ studies
- Wait time and displacement valuations.

Six studies (2 NZ: 20 & 37 and four Australian: 28, 38, 39 and 40 estimated curvilinear SI/IVT functions whereby the valuation depended on the service interval itself. A composite function was estimated by regression that averaged the six functions.

Figure 8 presents the function (the dashed line) with a 'lookup' table alongside. For a high frequency service departing every 5 minutes, the tabulated SI/IVT valuation is 0.89. For a 20-minute service interval, which was the average across the six studies, the SI/IVT valuation is 0.68 and for an hourly service, the valuation is 0.35.

Equation 4.3.1 presents the equation to predict the SI/IVT multiplier:

$$SI/IVT = Min + \{Max - Min\}Z \quad .....(4.3.1)$$

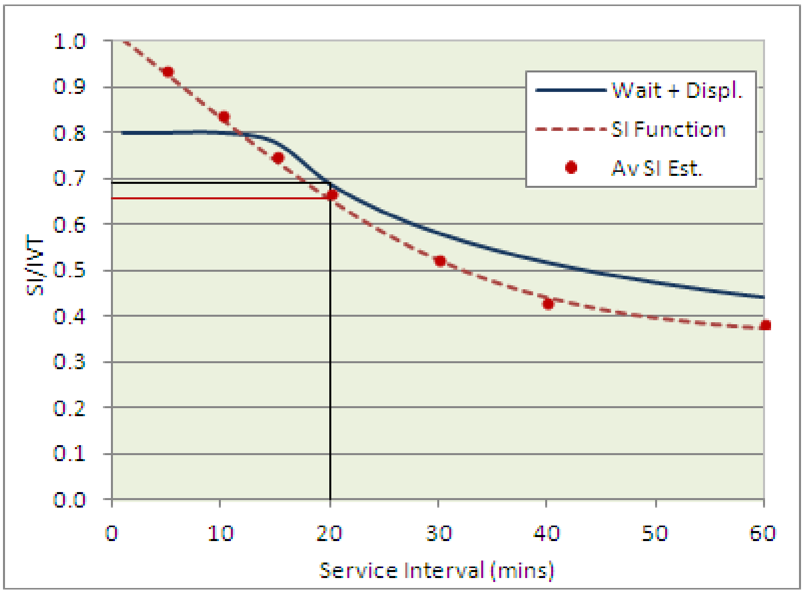
Where $Z = \dfrac{\exp(\alpha + \beta SI)}{1 + \exp(\alpha + \beta SI)}$

Max =maximum value of SI/IVT is 1.4

Min =minimum value of SI/IVT is 0.35

α = 0.57 & β = -0.07

Figure 8: Service interval /IVT function



SI	SI/IVT	
mins	SI Func	W+D
1	1.00	0.80
5	0.93	0.80
10	0.83	0.80
15	0.74	0.78
20	0.65	0.69
25	0.58	0.63
30	0.52	0.58
35	0.48	0.54
40	0.44	0.52
45	0.41	0.49
50	0.40	0.47
55	0.38	0.45
60	0.37	0.44

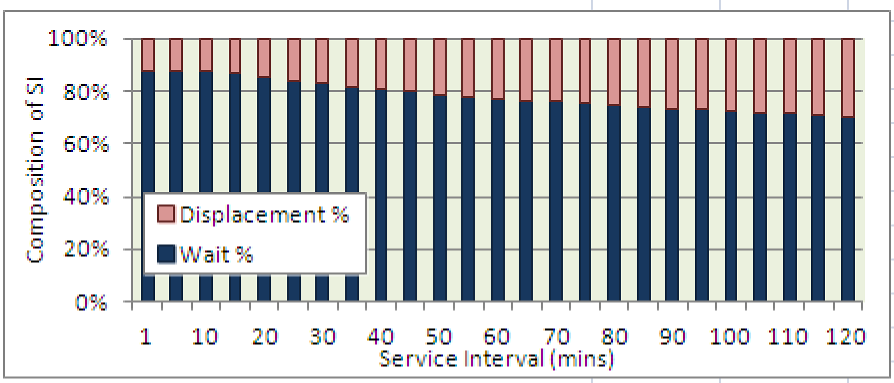
The alternative approach uses weighted waiting and displacement time. Theoretically, the SI/IVT value will depend on weighted waiting time (valued relatively highly) and timetable displacement time (valued relatively lowly). For high service frequencies, the SI/IVT will primarily reflect the wait/IVT valuation for which a relative IVT valuation of 1.4 has been used.

For less frequent services, the valuation of displacement (the cost of not being able to travel at the desired time) becomes important. The evidence is for displacement to be valued less than waiting time since it can be spent in the office, at home or down the pub rather than at a bus stop or train station. Section 4.4 reviews the value of displacement time. A multiplier of 0.1 has been used in Figure 8. Equation 4.3.2 shows the SI/IVT valuation function..

$$SI / IVT = \frac{1}{SI}\left[1.4\left\{Min\left(0.5SI, 1.88\sqrt{SI}\right), 20\right\} + 0.1SI\right] .....(4.3.2)$$

For service intervals under 15 minutes, the SI/IVT valuation (blue line in Figure 8: Service interval /IVT function) is constant at 0.8. The valuation then declines as waiting time becomes a smaller proportion of SI so that for an hourly service, the SI/IVT valuation is 0.44. For ten to 30 minute frequencies, the two approaches give similar SI/IVT multipliers. Figure 9 shows how the wait time value declines from 88% for a 5 minute service to 70% for a two hourly service.

Figure 9: Composition of service interval valuation



Of the two methods, the wait + displacement approach has appeal because it explains the valuation in terms of waiting time and displacement.

4.4 Valuing changes in service frequency

Using the estimated marginal service interval function does complicate calculations and for most applications, an average valuation could be used that is typical of the service frequencies on offer.

When large changes in service frequency are evaluated, the mid-point value between the ‘before’ and ‘after’ service intervals can be referenced in order to calculate an average value (from the marginal curve). Thus, as shown in Figure 10, to evaluate a frequency increase from every 40 to every 20 minutes (using the W+D function), the value at 30 minutes (0.58) is used which produces a benefit of 11.6 minutes. This is same as working out the area of the area of the trapezoid ABCDE.

Figure 10: Valuing a SI change

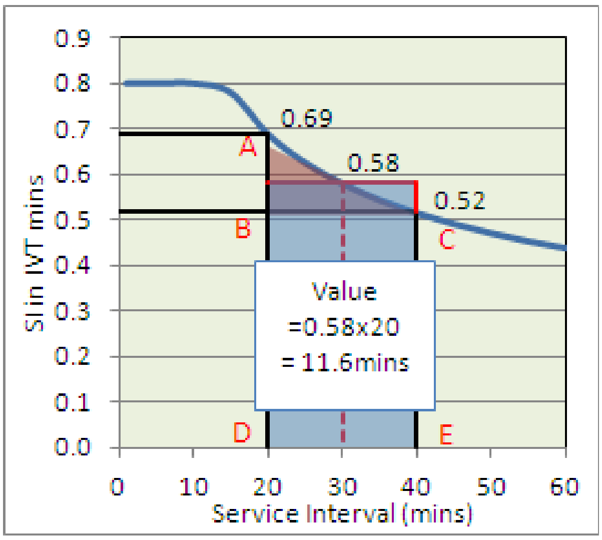
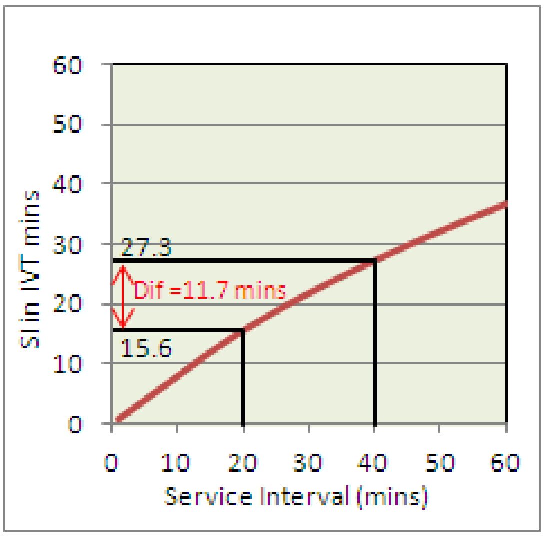


Figure 11: Cumulative SI function



A more accurate estimate taking the curvature of the SI function into account can reference

Table 21 which gives cumulative values by SI minute. Thus for a 40 to 20-minute SI reduction, 15.6 minutes is subtracted from 27.3 minutes to give a benefit of 11.7 minutes (0.1 minutes more than using the mid-point value). Figure 11 shows the cumulative function.

Table 21: Cumulative SI valuation function

SI interval in minutes and cumulative (total) valuation in IVT minutes

SI	Cml V	SI	Cml V	SI	Cml V	SI	Cml V	SI	Cml V	SI	Cml V
1	0.8	11	8.8	21	16.3	31	22.4	41	27.8	51	32.6
2	1.6	12	9.6	22	16.9	32	23.0	42	28.3	52	33.1
3	2.4	13	10.4	23	17.6	33	23.5	43	28.8	53	33.6
4	3.2	14	11.2	24	18.2	34	24.1	44	29.3	54	34.0
5	4.0	15	12.0	25	18.8	35	24.6	45	29.8	55	34.5
6	4.8	16	12.7	26	19.5	36	25.2	46	30.3	56	34.9
7	5.6	17	13.5	27	20.1	37	25.7	47	30.7	57	35.4
8	6.4	18	14.2	28	20.7	38	26.2	48	31.2	58	35.8
9	7.2	19	14.9	29	21.2	39	26.7	49	31.7	59	36.3
10	8.0	20	15.6	30	21.8	40	27.3	50	32.2	60	36.7

4.5 Travel time displacement

Travel time displacement arises from not being able to travel at the desired time. Since travel time displacement represents part of service interval (as outlined in the previous section), the two measures should not be double counted.33 Wardman (2013) notes that “whilst service frequencies can be readily observed and hence their use in generalized cost based applications is straightforward, this is not the case for displacement time where surveys are needed on desired departure times to convert timetabled departures into displacement time”. This task need not be unduly burdensome if station barrier data or vehicle load data to approximate the ‘desired profile’. Figure 12 presents the barrier exit profile for Sydney rail users as an example.

Two Australian studies (35 & 38) undertaken in Sydney provided valuations. Late displacement (travelling later than desired) was shown to have a higher cost (0.75) than early displacement (0.5) with an average value of 0.63.[34] Lower valuations would be required to derive the W+D function in Figure 8.[35] Guideline values of 0.33 for early and 0.5 for late displacement are therefore presented in Table 22 which compare with a range of 0.4 to 0.6 given by Wardman (2013) in his OECD review.

[33] In fact, it can be shown that the displacement value should be divided by 4 to be equivalent to service interval.

[34] The combined value is not the average of late and early displacement since passengers will travel earlier rather than later to minimise their overall displacement.

[35] Alternatively, a lower value of waiting time would be required.

Figure 12: Sydney Rail Barrier exit profile

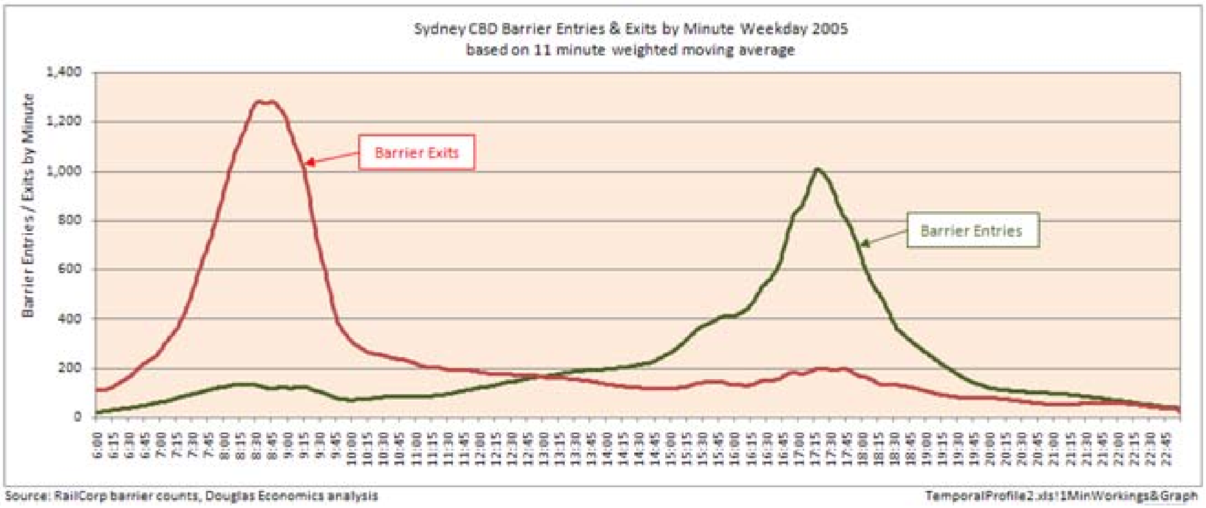


Table 22: Value of travel time displacement

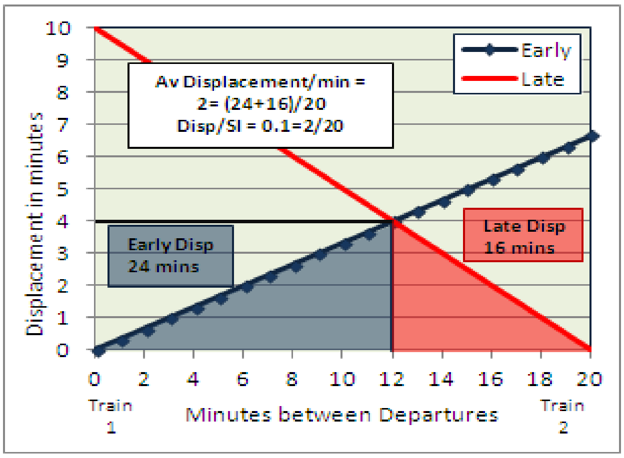
Estimate	Displacement per Minute Early	Late	Average	Timetable (SI) Displacement^
Sydney Estimates	0.50	0.75	0.63	0.15
Recommended	0.33	0.50	0.42	0.10

+ Average of estimates of studies 35 and 38.

Timetable displacement is effectively the displacement values divided by 4.

The displacement value needs to be divided by 4 to measure the cost of service interval as Figure 13 shows. With values of 0.33 for early displacement and 0.5 for late displacement, and a uniform distribution of desired travel times, the watershed between two services 20 minutes apart would be 12 minutes (as opposed to 10 minutes) with more people travelling on the earlier service. Early displacement would total 24 minutes (0.33 x 12 x 12 ÷ 2) and late displacement would total 16 minutes (0.5 x 8 x 8 ÷2). Thus total displacement would be 40 minutes. Displacement would average 2 minutes and the cost would be 0.1 minutes per minute of SI.

Figure 13: Displacement SI multiplier



5. Transfer penalties and connection time

5.1 Introduction

Changing trains or buses imposes a ‘transfer penalty’ associated with the ‘hassle’ of breaking a journey (packing up belongings, disembarking then reboarding), the anxiety from potentially missed connections and extra ‘information’ costs.

Gross and net transfer penalties are distinguished. Gross transfer penalties include the connection time, which is expressed in equivalent IVT minutes. Net transfer penalties exclude connection time.

Twenty one studies providing 75 interchange penalties were reviewed. Nineteen studies were Australian (mainly NSW) and two were NZ. Most of the penalties were ‘gross’ and did not deduct the transfer connection time but twelve studies did provide a valuation of the connection time (usually waiting time) which enabled the two types of transfer to be placed on the same basis. The studies provided estimates for rail, bus, LRT and ferry involving ‘same mode’ transfers (e.g. rail-rail transfers) and ‘different mode’ transfers (e.g. rail-bus). Most different mode transfers involved bus.[36]

5.2 Valuation of transfer connection time

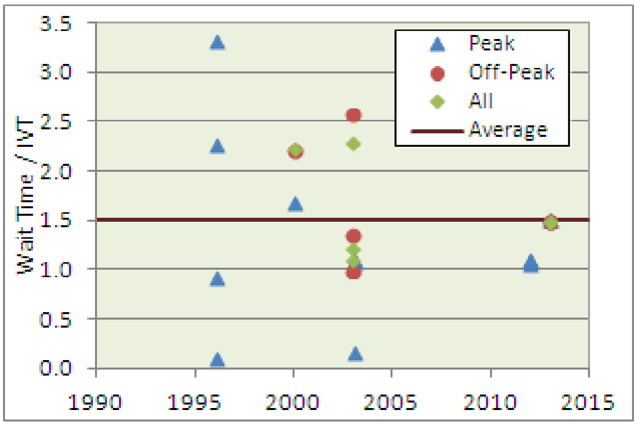
Thirteen studies provided 25 estimates of the value of time spent at the connection. In most studies, connection time was described as waiting time, but some studies also included walking time. Table 23 and Figure 14 present the estimates.

Table 23: Valuation of connection time in equivalent IVT

	Mean	Lower Quartile	Median	Upper Quartile	Obs
Weighted	1.50	1.1	1.2	2.2	25
Unweighted	1.48	1.1	1.5	1.95	25

[36] An area of uncertainty with different mode transfers estimated by SP research is that respondents may value the travel time on the two modes differently. Studies 5 and 38 attempted to take account of this by applying travel time weights to the IVT on the different modes.

Figure 14: Value of connection time in equivalent IVT

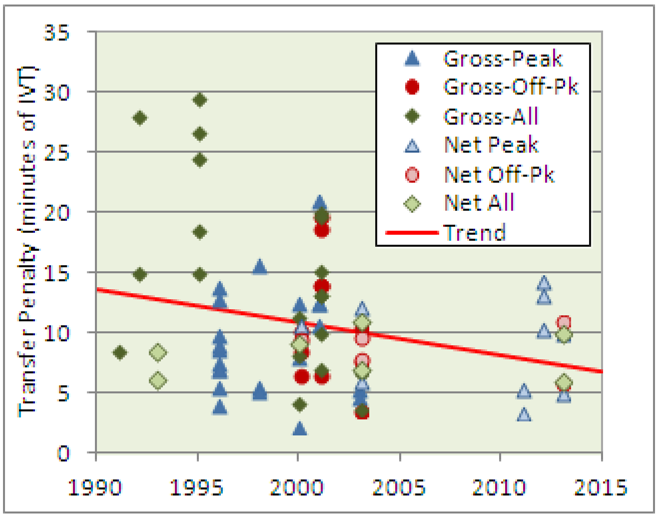


The average IVT valuation of connection time was 1.5. The valuation was therefore the same as walking time and slightly higher (0.1) higher than waiting time. Weighting the observations according to their relative accuracy had little effect and as can be seen from Figure 14 there was a wide spread in the estimates. The value compares with a value of 1.56 reported by Wardman (2001a) for wait time based on a meta analysis of UK studies.

5.3 Transfer penalty

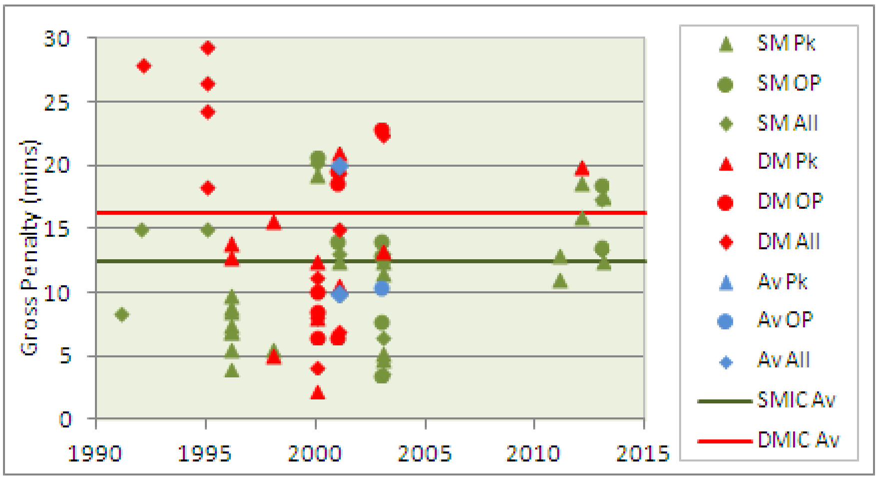
The 75 transfer penalty estimates are plotted by year of estimate in Figure 15. A downwards trend from 14 minutes in 1991 to 7 minutes in 2013 is evident but can be attributable to early estimates being 'gross' (including connection time) and later estimates being 'net'.

Figure 15: Gross and net transfer penalty estimates



After converting the net penalties into gross penalties by adding a connection time of 7.5 minutes (5 minutes of walk/wait multiplied by 1.5), the time trend became statistically insignificant. What emerged was for 'different mode' transfers (DM) to have a higher penalty than 'same mode' transfers (SM) as can be seen from Figure 16.

Figure 16: Gross transfer penalty estimates



Same mode penalties were valued at 12 minutes with an inter quartile range of 10 to 15 minutes. Different mode transfers were valued 4 minutes higher at 16 minutes and had an inter quartile range of 11 to 22 minutes). These are summarised in Table 24.

Table 24: Net transfer penalty and transfer waiting time

Estimates in equivalent IVT minutes

Type of Transfer	Mean	STE	Lower Quartile	Median	Upper Quartile	Obs^
Same Mode	12	0.6	10	13	15	44
Different Mode	16	1.3	11	16	22	29
All	14	0.7	10	13	19	75

^ 2 observations were not able to be categorised into same mode or different mode
observations weighted by relative t value

5.4 NSW 2013 interchange study

A detailed assessment of interchange penalties was undertaken by Douglas & Jones (2013). The study (included in the OECD Wardman review) to illustrate the variation in transfer penalty) was undertaken as part of forecasting the demand for a proposed North West Rail Link that would involve a 'forced' cross-platform transfer at Chatswood from single deck to double deck trains. 939 Stated Preference interviews were undertaken (354 bus and 585 rail) on rail station platforms and CBD bus stops using computer tablets. Table 25 provides a summary.

Table 25: Transfer penalty by type of user

Estimates in equivalent IVT minutes

Interchange Type	Bus Respondents Short <30 mins	Bus Respondents Medium >30 mins	Bus Respondents All	Rail Respondents Short <30 mins	Rail Respondents Medium >30 mins	Rail Respondents All	ALL
Rail - Cross Platform	9	14	13	7	7	7	9
Rail - Change Platform	11	14	13	10	9	9	11
Bus-Rail Interchange	11	17	15	16	19	18	17
Bus-Bus Transfer	15	15	15	18	29	23	21

Source: Douglas & Jones (2013)

The estimated transfer penalties were greater for long trips (over 30 minutes) than short trips (less than 30 minutes). The penalties were lowest for cross platform rail transfers at 9 minutes. A transfer involving a change of rail platform was valued two minutes greater at 11 minutes. Transfers involving bus were greater averaging 17 minutes for a bus/rail transfer and 21 minutes for a bus/bus transfer. The penalties differed according to the current travel mode. Rail respondents had a lower penalty for rail transfers and a higher penalty for bus transfers than did bus respondents.

5.5 Gross and net transfer penalty estimates

Table 26 presents guideline gross and net transfer penalty estimates. The gross penalties are the same as in Table 24. Six minutes was deducted (4 minute connection time multiplied by a weighting of 1.5) to calculate net penalties of 6 minutes for a same mode transfer and 10 minutes for a different mode transfer.

Table 26: Gross and net transfer penalty estimates

Penalty	Type of Transfer Same Mode	Different Mode	Rail Cross Plat
Gross Penalty^	12	16	10
Net Penalty^	6	10	4

* calculated for a 4 minute connection at 1.5 x IVT

Based on the findings of the Douglas & Jones (2013) 2 minutes was deducted for cross-platform rail transfers (compared to a same mode transfer involving a change in platform via stairs or escalators).

By comparison, the OECD review by Wardman (2013) concurs with Litman (2014) in suggesting transfer penalties of between 5 and 15 minutes, Wardman added the qualification that *"this is expected to be at the lower end where good information and comfortable waiting conditions are provided and there is a minimum of insecurity, stress and effort".* Wardman considered there was evidence for a lower transfer penalty amongst commuters than for occasional users unfamiliar with transport arrangements.

6. Seat availability and crowding

6.1 Introduction

Crowding onboard trains and buses, especially in crush conditions makes travel less pleasant. In doing so and by making reading and the use of electronic devices harder, crowding increases the 'cost' of travel time.

Fourteen studies (10 Australian and 4 NZ) were reviewed that provided 30 values for rail, bus and LRT. Three of the Australian studies were undertaken specifically to value crowding. Two studies looked at on-train crowding: a Sydney study (28) of double deck trains and a 'capital cities' study (33) that looked at crowding for single deck trains. The other study looked at crowding at rail stations in Sydney (25). The remaining studies included crowding as one attribute in a wider study. One thing that all the studies had in common was the use of SP choice experiments to estimate the valuations.

6.2 Crowding values

Figure 17 plots the values of crowding by year of study. The estimates are classified into crowded seating, stand and crush stand values. Superimposed on the graph is the mean value of crowding calculated as an additional cost item to onboard travel time (IVT).[37]

Figure 17: Value of crowding relative to uncrowded seated IVT

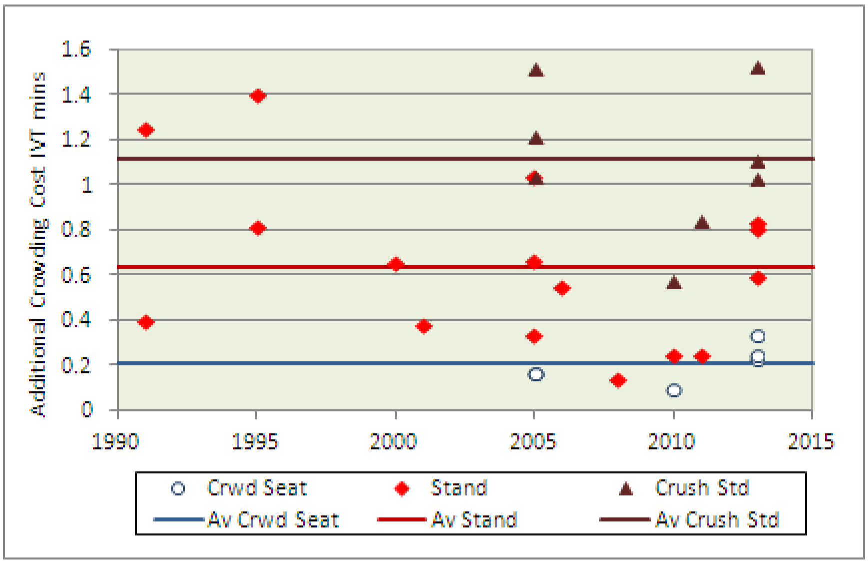


Table 27 presents the mean and quartile range. Crowded seating added 0.23 minutes per minute to the onboard travel time. Hence, 20 minutes of crowded seating adds 4.6 minutes

[37] Therefore, to express the values as an IVT multiplier, the values should be plus 1.

to the onboard time. Standing increased the cost to 0.65 minutes per minute of onboard time. Crush standing more than doubled the cost by adding 1.08 minutes per minute of onboard time.

Table 27: Cost of crowding

Cost (expressed in IVT minutes) is additional to the uncrowded seating time*

Statistic	Crowded Seat	Standing	Crush Standing
Mean	0.21	0.65	1.11
75% tile	0.25	0.83	1.29
Median	0.20	0.63	1.08
25% tile	0.17	0.37	0.98
Obs	6	16	8

* to calculate crowding IVT multipliers, 1 should be added.

Only one study (28) took account of the length of stand. The study found that standing for 20 minutes or more increased the 'per minute' cost by 40% compared with 'short stands' of up to 10 minutes. However, incorporating the length of stand into demand forecasts is not easy and requires information on the origin-destination of trips and a seat/stand algorithm.

The Sydney station crowding study (25) looked at the effect of crowding on waiting and walking time finding that high crowding doubled the cost of platform waiting time and increased the cost of walking by a multiplier of 1.6.

The OECD review by Wardman found a wide range in crowding values. For the UK, crowded seating added around 50% to the onboard time cost with standing adding between 0.62 and 1.93 minutes per minute depending on the load factor and the type of trip (leisure trips valuing crowding a fifth higher than commuters). Lower multipliers have been reported by Kroes (2013) for Paris with less difference between the seating (0.4) and standing (0.6) IVT multipliers.

6.3 Vehicle crowding cost functions

The easiest way of incorporating crowding into a demand forecast or evaluation is through crowding cost functions. These functions combine crowded seating and standing into a single IVT multiplier. The functions either reference the passenger load factor (passengers/seat capacity) or passenger density (passengers per square metre). Of the two measures, the load factor measure is the simplest since the base (uncrowded seating) can be set and maximum loads are usually known (200% being common) and sometimes 'legally imposed' in terms of a maximum number of standing passengers allowed on a bus. Passenger density on the other hand is less easy to define (because of seats, aisles and staircases) although the measure has found favour in the UK.

Five of the studies provided crowding cost functions (25 stations, 28, 33, 34 and 38). As an example, the functions developed for bus, rail and LRT in a 2013 Sydney study (38) are presented in Figure 18. The bus was a standard STA bus with 44 seats and space for 22 standing (150% max load factor). The LRT function was for a Variotram with 74 seats and

145 standing (300% max load factor) and the train was a Waratah double decker with 896 seats and capacity for 896 standing (200% max load factor).

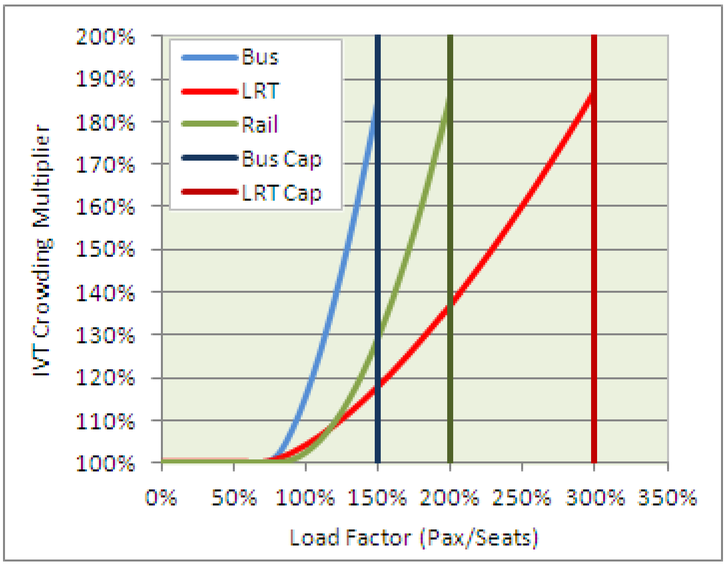
The crowding multiplier increases from a load factor of 80% and rises more steeply for bus and train than for LRT reflecting the greater space for standing on the LRT vehicle. The crowding IVT multiplier reaches a maximum at just under 1.9 at the maximum passenger load of each vehicle. The passenger cost of in situations where demand exceeds the maximum load could be assessed in terms of additional waiting time.

Figure 18: Crowding cost functions

Values estimated for standard Sydney buses, Sydney LRT Variotram and Waratah double deck train

Load Factor(1)	Bus	LRT	Rail
80%	102%	101%	100%
90%	108%	102%	101%
100%	116%	104%	102%
110%	126%	106%	105%
120%	138%	109%	109%
130%	152%	112%	115%
140%	168%	115%	121%
150%	184%	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



6.4 Station crowding cost functions

Passenger crowding in stations particularly on platforms and in access-ways can make waiting and movement less pleasant. In Sydney, several evaluations have been undertaken at CBD stations to assess the cost of crowding and the benefit from increased capacity (e.g. Town Hall station 2007). For bigger investment proposals, computer simulation models are typically used.[38] One output of simulation models is the number of passenger minutes spent walking and waiting under different levels of crowding. Crowding IVT multipliers can then be applied to determine the cost of the crowding. There have been few studies to estimate the station crowding IVT multipliers. One Sydney study (24) was undertaken specifically to provide crowding multipliers for use in station evaluations. The multipliers,

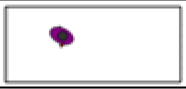
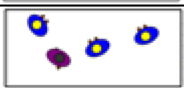
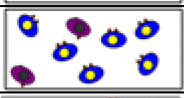
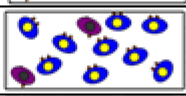
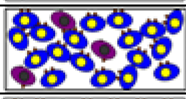
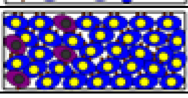
[38] Here the pioneering work of Gerry Weston at London Underground Operations Research in the development of station crowding models should be acknowledged. The 1987 Kings Cross tube station fire gave an impetus for the development of a general station pedestrian model in order to determine the evacuation time for each underground stations.

which were referenced against J. Fruin's station A - F classification, are given in Table 28.

Crowding reduces the walk speed and thereby increases the travel time. Hence, even without a crowding multiplier, station crowding will increase the generalised cost of travel at a rate of 1.5 IVT minutes per minute of walk time using the multiplier recommended in Section 2. It is only in environments E and F (when flow movement becomes heavily restricted) that walk times lengthen noticeably and the crowding cost multipliers become significant. For level E, the movement multiplier is 2.1 and the crowding multiplier is 1.1. Hence , the combined IVT multiplier would be 3.5 (1.5 x 2.1 x 1.1). For the most crowded environment, the multipliers rise exponentially to 3.61 and 2.77 giving a combined IVT multiplier of 15.

For waiting on platforms, there is no movement multiplier. However, the crowding multiplier is higher than for walking at 1.55 at level E and 3.66 at level F. These multipliers would be applied to the recommended wait time multiplier of 1.4 giving IVT multipliers of 2.12 and 5.1 respectively.

Table 28: Station crowding cost multipliers

Crowding Level		Description	Pax Flow Pax/min	Walk Speed M/sec	Max Density (PSM)	Movt Time Factor	Wait Crwd Mult	Walk Crwd Mult
A		Movement restricted for majority, high restrictions for reverse flows. Sufficient waiting space.	1	1.32	0.31	1.00	1.00	1.00
B		Minor movement conflicts. Sufficent waiting space.	23	1.26	0.43	1.05	1.00	1.00
C		High probablity of conflict for reverse flows and adjustment of speed. Sufficient waiting space.	33	1.14	0.71	1.16	1.00	1.00
D		Movement restricted for majority, high restrictions for reverse flows. Sufficient waiting space.	49	1.12	1.08	1.18	1.02	1.00
E		Major flow restrictions. Extreme difficulty for reverse flows. Some waiting discomfort.	66	0.63	2.13	2.10	1.55	1.10
F		All movement extremely restricted. Complete flow breakdown. High discomfort for passengers.	82	0.37	3.60	3.61	3.66	2.77

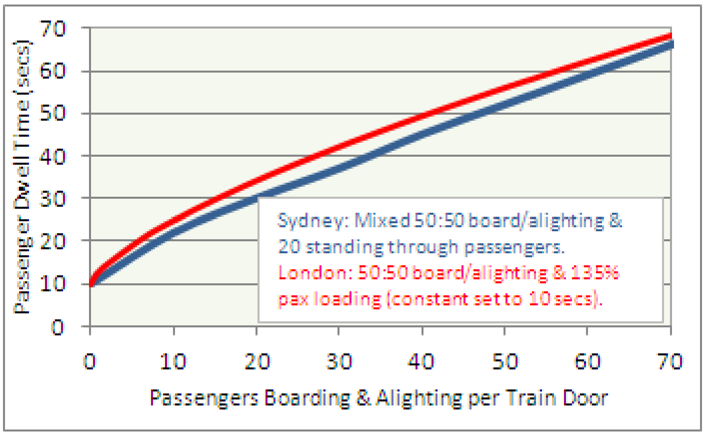
Sources: J.J. Fruin Station classification; *"Pedestrian Planning & Design"* (1971); Crowding multipliers from *"Value & Demand Effect of Rail Service Attributes"*, Report to RailCorp by Douglas Economics, July 2008.

6.5 Train and station crowding and train dwell times

Crowding onboard vehicles and also on platforms can lengthen board and alight times thereby constraining the overall passenger carrying capacity of a service. In most situations, the impact of crowding will be small enough to be ignored but on crowded 'through CBD" lines such as the North Shore/Main West rail line between Redfern and Wynyard in Sydney, where peak services are at, or approaching, maximum physical capacity, impacts can be significant. Indeed, catering for such passenger growth can be the trigger for new CBD rail line proposals costing billions of dollars.

To illustrate the effect of passenger numbers, Figure 19 shows how passenger dwell time increases with the number of passengers boarding and alight per train door. Two curves are plotted, one using a function developed by London Underground (Weston 1989) and one developed using Sydney statistics (Douglas Economics 2012). As can be seen, the functions are quite similar with dwell times increasing from 10 seconds to just over a minute with 70 passengers boarding/alighting per door. As a rule of thumb, one second per passenger per door can be used.

Figure 19: Passenger load and passenger dwell time



7. Timetable reliability

7.1 Importance of reliability

Although ‘reliability’ could apply to a range of service delivery aspects such as getting a seat, whether the vehicle is air conditioned or the accuracy of travel information, it is now synonymous with how well services run to a timetable.

Surveys of customer opinion have consistently shown that timetable reliability is one of the most important determinants of overall service quality from a passenger’s perspective. A 2009 survey of Sydney bus users by the Independent Transport Safety and Reliability Regulator (ITSRR) found 88% of respondents considered that ‘buses keeping to timetable’ was important or very important (ITSRR 2009). In the UK, a national survey of rail passengers by MVA ranked service punctuality first out of 30 attributes in importance in 2005 and third in 2006 (MVA 2007). For Sydney, a 2006 survey found reliability to be the dominant factor in explaining rail passengers’ overall rating of service accounting for 25% of the overall rating (Douglas & Karpouzis 2006). Finally, Wardman (2013) placed reliability in the ’most important’ category of convenience related attributes.

7.2 Reliability measures

Reliability is generally measured in terms of the reliability in the departure times at bus stops or the reliability in the travel time spent on the bus.[39] Unlike other travel time attributes, reliability is less easy to measure and predict. The following five measures have been the most frequently used:

- Average Mean Lateness (AML)
- Schedule Delay Early (SDE) and Schedule Delay Late (SDL)
- Standard Deviation in travel time (SD) often expressed as ratio of the mean travel time and called the Reliability Ratio (RR)
- Buffer Index
- Customer Journey Time Delay.

Average Mean Lateness (AML) has been the most used in Australia and NZ for performance statistics and in SP valuation surveys. Likewise, In the OECD review, Wardman (2013) notes that AML has been widely used in the UK underpinning the regulatory mechanism, driving fines and compensation payments on operator and infrastructure providers. For buses, the measure tends to be calculated in terms of the arrival time at bus stops and is viewed by

[39] Kittelson & Associates (2003), Mazloumi et al. (2008), Trompet et al. (2011) provide reviews of alternative reliability measures.

passengers as excess waiting time. For trains, reliability is usually calculated at key arrival stations and is reported as the percentage of trains arriving more than X minutes late. For the rail passenger the focus is therefore more towards delays on the train than at the stop. AML is simple to calculate and to understand: if 10% of trains are 10 minutes late, AML is 1 minute. Quite often however, the degree of lateness is not measured in operator statistics with the mirror image reported: 90% of trains are on time (with on time being within 5 minutes of the scheduled arrival time).

Schedule Delay Early (SDE) and Schedule Delay Late (SDL) are measured relative to a preferred arrival time. In this regard they are like the displacement (Section 4). A related measure is the buffer index which defines the additional travel time a passenger should allow in order to arrive at their destination at a given time.

The standard deviation is the statistical measure of dispersion in arrival times around the mean arrival time. To standardise the measure, the SD is often divided by the mean travel time to compute a reliability ratio (RR). The RR measure is used in the UK and in Europe.

The ‘buffer index’ is the extra time travellers build into their journey time to take into account of expected travel time variability. The measure requires knowledge of the distribution of travel times and is usually calculated by subtracting the median time from the 95 percentile time. The resultant buffer time is then multiplied by the Reliability Ratio (usually 1).[40]

Customer journey time delay measures the difference between the customers expected and actual travel time from the start to the finish of a trip.[41] Waiting time as well as the in-vehicle time is included so that the measure represents the travel time reliability of the whole trip. To do this, knowledge of a customer’s origin and destination stops/stations are required. Moreover, departure and arrival times for the origin and destination bus stops need to be combined, both scheduled and actual. Calculation of the measure is therefore far more complex than the ‘single index’ measures.

Wardman in a 2013 OECD review considered that *“official values for public transport are either based around mean lateness (AML) or the RR”*.

7.3 Valuation of average mean lateness

Ten studies were reviewed (Australian and NZ studies). All 10 studies were undertaken before 2009 and are therefore somewhat dated. The most recent study was a 2008 study by Vincent which had the specific aim of valuing reliability. Earlier studies included reliability as one attribute in a more general survey.

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[40] See for example Wang (2014) *“Economic Evaluation of Travel Time Reliability in Road Project Planning: a Practitioner’s* Perspective”, Paper given at the 26th ARRB Conference – Travel Time Reliability, Sydney, New South Wales 2014.

[41] Currie et al. (2013) evaluated customer delay against nine other measures for measuring bus service reliability. Customer delay was ranked equal first with excess waiting time.

Most of the studies predated the introduction of real time information (RTI) electronic displays and the provision of timetable and service disruption messages via mobile phones and computers. It is likely that these sources of information would have reduced the uncertainty and anxiety of service unreliability and with it the IVT multiplier for reliability.[42]

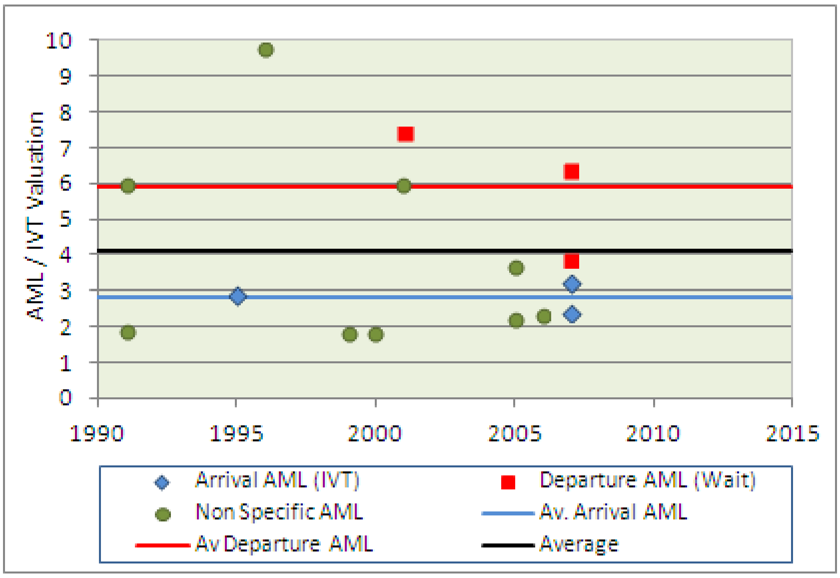
All 10 studies measured reliability using Average Mean Lateness (AML). Altogether 15 estimates were collated which are presented in Figure 20 and Table 29. Three estimates measured AML at the departure station (or stop) and three at the arrival station but nine were nonspecific.

Of the two measures, departure AML with an IVT multiplier of 5.9 was twice as costly as arrival AML at 2.8; the higher valuation probably reflecting the cost of waiting at stops versus delays onboard vehicles. The nine non-specific reliability estimates had an IVT multiplier of 4.0.

The overall average AML multiplier was 4.1 which is probably the most useful measure for CBA purposes.

The values are comparable to the 'official values' reported in an OECD review by Wardman (2013) which ranged from 1.5 to 6.

Figure 20: Valuation of average mean lateness



[42] A 'Metro' study by Hensher undertaken in 2011 did include 'expected' travel time as a variable.

Table 29: Valuation of average mean lateness

AML Estimate	Mean	Median	Interquartile Range*	Obs
Departure (Wait)	5.9	6.4	3.9 - 7.4	3
Arrival (On-Vehicle)	2.8	2.9	2.4 - 3.2	3
Non specific	4.0	2.3	1.9 - 6.0	9
Average	4.1	3.2	2.2 - 6.0	15

* 25 percentile - 75 percentile; unweighted obs. (weighted mean = 4.4)

7.4 Other values of reliability

The Vincent study (32) attempted to produce valuations using measures other than AML but the results were unsuccessful. Therefore in , overseas estimates for SDE, SDL and the RR are tabulated. SDL at 1.8 was valued just under half AML. SDE was valued around half SDL with RR valued between SDE and SDL.[43] Assuming these ratios applied to Australia/NZ, the value of SDE would be 1, SDL 2.3 and RR 1.5.

Table 30: Values for other reliability measures

	Wardman			Teng	Carrion & Levinson			All	Australia&NZ
Measure	Mean	Range		Mean	Mean	Range		Average	Estimate+
SDE	0.86	0.52	1.2	0.75	-	-	-	0.81	*1.0*
SDL	1.94	nk		1.65	-	-	-	1.80	*2.3*
RR	1.02	0.20	1.2	1.33	1.2	0.1	3.3	1.18	*1.5*
AML^	3.24	1.5	6	-	-	-	-	3.24	4.1
Studies	nk			16	17			nk	12
Obs	SDE 48, SDL 54, AML 27 & RR 31			74	68			nk	15

^ range (observations combined with SDL by Wardman). nk not known
\+ based on average value multiplied by the ratio of AML Australia&NZ (3.9) / Wardman estimate (3.24)
Sources: Wardman (2013), Teng (2008), Carrion & Levinson (2013)

7.5 Valuing reliability benefits in practice

Applying a valuation is the easiest part of forecasting the effects of reliability. The more difficult part is forecasting the change in reliability itself. For larger projects, computer simulation is often used. For rail, there are 'off-the shelf' packages available to model timetable performance. Likewise, road traffic simulation packages can be used to model bus reliability.

Two examples of computer simulations are Sydney CBD & South East Light Rail and the Bus and Train Tunnel in Brisbane. For the Sydney Light Rail project, forecast reliability

[43] Bates (2001) has shown that SDE, SDL and the RR measure are mathematically related through the equation:

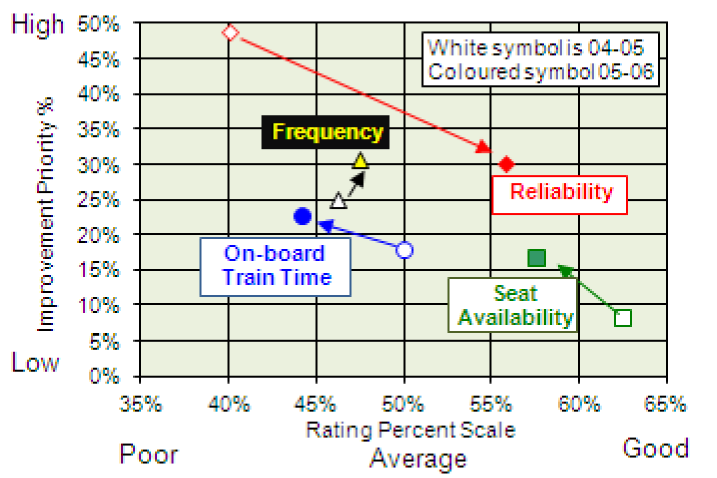
$$RR = SDE \ln\left(1 + \frac{SDL}{SDE}\right)$$

benefits amounted to 13% of time savings plus amenity benefits. For the Brisbane bus and rail tunnel, reliability benefits represented 30% of time saving benefits.

What will largely determine the size of benefit is how much unreliability can be countenanced in any system. A reasonable starting position is to assume that unreliability will not get materially worse than in the present system and that timetables would be ‘slowed’ to accommodate extra services or that passengers would be ‘displaced’ out of the peak hour. The passenger disbenefit would then be longer onboard travel times and/or travel time displacement but no extra unreliability.

As an example, in 2004/05, Sydney rail users rated reliability particularly poorly scoring it 40% (on a 0% very poor to 100% very good scale), much lower than for frequency, in-vehicle time and seat availability (Douglas Economics 2006). In terms of importance, reliability accounted for one half of passengers’ priority for improvement with onboard time, seat availability and frequency improvements accounting for the other half. In response to adverse public and media reaction, RailCorp changed the timetable by slowing or removing some services. In response, the reliability rating improved but on the downside, the rating of onboard time and seat availability declined. The net effect, as can be seen from Figure 21, was a more balanced passenger assessment and it is this ‘balance’ that should be the aim in developing future timetables for forecasting purposes.

Figure 21: Sydney Rail – effect of timetable change on passenger ratings



Service Attribute	Rate % 04-05	Rate % 05-06	Improvement Priority % 04-05	Improvement Priority % 05-06
Onboard Time	50%	44%	18%	23%
Service Frequency	46%	48%	25%	31%
Reliability	40%	56%	49%	30%
Seat Availability	63%	58%	8%	17%

Source: RailCorp Surveys, Douglas Economics Analysis QSF06_Analysis_4.xls!Imp2

For proposals that are expected to improve timetable reliability on current levels, one practical approach is to ‘factor up’ travel time savings. In an evaluation of bus lane proposals for Wellington, Wallis & Associates added a quarter of the travel time savings to take account of expected reliability gains (Wallis 2008) based on ‘before and after’ studies of London bus lanes,

7.6 Wider Impact of Unreliability

One issue that can be overlooked is the impact on others of bus and train service unreliability. Meeters and greeters for instance will usually have to wait longer at the train station when trains are delayed. Meetings may have to be re-arranged and dinners re-heated. These costs impact on ‘non-users’ and unless the public transport user took these wider costs into account when surveyed, the total cost of unreliability will be underestimated.

8. Vehicle quality

8.1 Introduction

Valuing vehicle attributes that are essentially qualitative is a rubbery 'science': what one passenger likes another may dislike. 'What type and 'how much' therefore is ultimately a subjective question. Nevertheless, by using a rating approach which is the basis of the values presented here, the views of users can be averaged and measured in a continuous fashion. The method has also been designed so that the addition of individual attribute values remains within a total package value, therefore avoiding the 'capping' or 'scaling down' of estimates.

The values presented relate to actual provision of facilities and also the ongoing level of 'quality' of service. In terms of provision, the values can measure the effect of introducing such features as air conditioning or onboard information. In terms of quality, the valued can measure the cleanliness of the vehicle, the friendliness and helpfulness of the driver and the smoothness and quietness of the ride.

The values used the results of three large-scale market research studies undertaken in NZ (Auckland, Christchurch and Wellington 37) Sydney (38) and Melbourne (39) between 2012 and 2014 as well as an earlier Sydney passenger surveys undertaken between 2002 and 2008. The values are also supplemented by a literature review of Australasian and overseas values undertaken as part of the NZ study.

Rail is based on surveys of passengers using metropolitan rather than longer distance regional rail services. The Sydney studies (2002-2008) did include Blue Mountains and Newcastle/Central Coast intercity trains but not CountryLink. The NZ study (37) surveyed the Wairarapa rail line which caters for trips of up to 1½ hours. The Melbourne study (39) was limited to metropolitan services.

For ferry, the most recent study undertaken in Australia was a 2001 study undertaken by Booz Allen & Hamilton (19). Section 8.8 presents the results which have been updated to be consistent with the bus, LRT/tram and rail values.

8.2 Studies reviewed on vehicle quality valuations

The value of vehicle quality was derived from two sources:

- Quality rating surveys undertaken in NZ, Melbourne and Sydney
- A literature review of studies that have estimated values for vehicle and stop quality.

The literature review draws heavily on a *'Pricing Strategies for Public Transport'* study undertaken by Douglas Economics for NZTA in 2012/13. Thirteen studies were reviewed of which five were Australian, two were NZ and seven were 'international' (5 UK, 1 USA and 1 Norway). Most of the studies used SP surveys or the Priority Evaluator technique (a shopping list of improvements). Summary details of the studies reviewed are provided in

Table 55.[44]

The rating approach originates from a 2006 study by Douglas & Karpouzis (26) which used passenger ratings to value station and train attributes. The resultant values were used by RailCorp NSW to evaluate rolling stock and station upgrades. In 2012/13, the 'Pricing Strategies' study (37) developed the approach by using Stated Preference surveys to derive 'package' values for overall vehicle and stop/station quality.

In 2012/13, 12,500 bus and rail passengers were surveyed in the three main centres of NZ. Soon afterwards, the technique was used in Sydney (38) to estimate service quality parameters for the Bureau of Transport Statistics TfNSW and a year later the technique was used in Melbourne to estimate values for Public Transport Victoria (39).

The technique involves a rating and a SP survey. The rating survey measures the quality of the public transport vehicles and stop/stations as perceived by users. By asking passengers to rate vehicle attributes such as cleanliness and graffiti, the relative importance of individual attributes can be established through regression analysis. By recording the vehicle and stops surveyed, the ratings can be compared with 'objective' data such as vehicle age, vehicle type and whether air conditioning is provided etc. The Stated Preference survey estimates the value in equivalent IVT minutes that passengers place on the overall vehicle package which can then be 'atomised' via the rating data.

8.3 Valuation of overall vehicle quality

The rating/SP surveys undertaken in NZ, Sydney and Melbourne (see Table 31) valued a high quality vehicle (80% rating) compared with a low quality vehicle (40% rating) the same as 5.2 minutes of IVT or 0.19 minutes per minute of the average trip of 27 minutes.[45] The values ranged from 4.3 minutes for bus to 7.8 minutes for rail with tram/LRT quality valued at 3.7 minutes. It should be noted that the values include operational aspects of quality such as cleanliness and driver/staff.

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[44] The reader is referred to the Pricing Strategies report for more information on the studies: Douglas Economics (2014) *"Pricing Strategies for Public Transport - Literature Review",* report prepared for the New Zealand Transport Agency dated January 2014.

[45] The Rating/SP surveys measured vehicle quality on a percentage scale with very poor scored at 0%, poor 25%, average 50%, good 75% and very good at 100%. Although some respondents did rate vehicles as very poor and some very good, when the ratings were grouped, the average ratings were moderated such that over all the types of buses and trains surveyed across the five cities, the range narrowed to between 40% and 80%.

Table 31: Valuation of overall vehicle quality

Study/Estimate	Measure	Bus	Tram /LRT	Rail	Average	Comment
Aus/NZ Rating/SP (1)	Per Minute	0.17	0.19	0.22	0.19	Weighted estimate (3 Bus, 2 Tram/LRT & 4 Rail) for a 40% to 80% pax rating change.
Average trip	minutes	25	20	35	27	Onboard in-vehicle time (based on survey results).
Aus/NZ Rating/SP (1)	Per Trip	4.3	3.7	7.8	5.2	Calculated for the average onboard trip times
Literature Review (2)	Per Trip	4.4	-	3.6	3.8	Median value calculated on 16 observations (9 Bus & 7 Rail)

(1) Studies 26, 37, 38 & 39. (2) Studies 2, 8, 12,13,14, 26, 41, 42-45.

The literature review gave a lower median value of 3.8 minutes with rail at 3.6 minutes and bus at 4.4 minutes although it was difficult comparing the estimates because of differences in the way the vehicle 'packages' were described.[46]

8.4 Valuing changes in vehicle quality rating

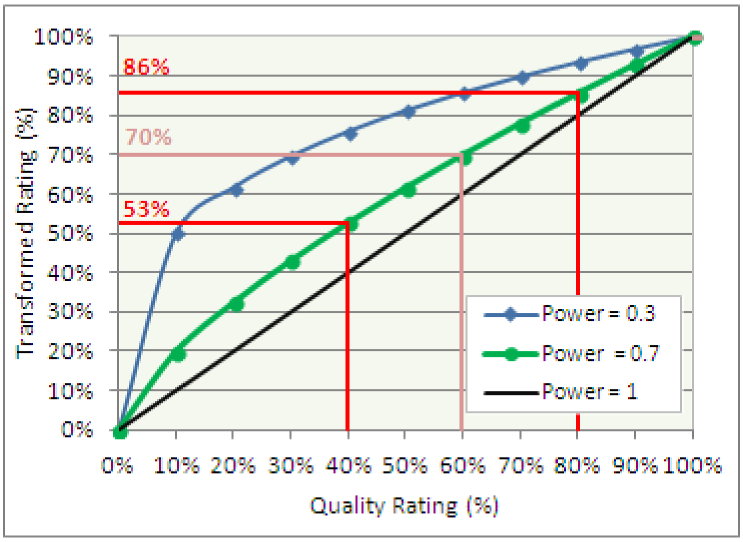
An advantage of the rating/SP approach is its flexibility. The values given in Table 31 were for ratings of 40% to 80% but the full range from very poor to very good (0% to 100%) can be valued.

The NZ, Sydney and Melbourne studies allowed for the 'willingness to pay' for quality to diminish as the rating increased by applying a 'power' function to the rating of vehicle quality $\left(VQ^{\phi}\right)$. In this way, a change from poor (25%) to average (50%) was valued higher than a change from average (50%) to good (75%) even though the rating difference is the same (25% points).

Figure 22 shows how the power function 'transforms' the percentage rating. At the end points (0% and 100%) the ratings are unaffected but between 0% and 100%, the rating is bent above the diagonal as the power value reduces. With a value of 0.7, a rating of 40% is transformed to 53% and a rating of 80% is transformed to 86%. Hence, the transformed rating difference is 33% points rather than 40%.

[46] Median values have been reported for the Literature Review because of two high estimates.

Figure 22 Diminishing returns from improved vehicle quality



The full range in vehicle ratings from 0% to 100% can be valued using the power function. The values vary by mode from 0.6 for bus to 0.7 for LRT/Tram and 0.75 for rail with an average of 0.68 as set out in Table 32.

Table 32: Vehicle power function and max vehicle quality values

Vehicle quality values are expressed per minute of travel time

Vehicle Quality	Bus	LRT/Tram	Rail	Average
Power Function (ϕ)	0.60	0.70	0.75	0.68
Theoretical Max 100% - 0% Value per IVT min	0.58	0.57	0.65	0.60
High (80%) - Low (40%) per IVT min	0.17	0.19	0.22	0.19
40-80% Range as Percent of Theoretical Max	30%	33%	34%	32%

Also presented are valuations for the maximum range in quality from very poor (0%) to very good (100%). The more realistic 40% to 80% range in vehicle quality is around a third of the full range (the exact percentage varying slightly by mode in accordance with the power function value).

8.5 Range in vehicle attribute ratings

The three 2012 to 2014 NZ and Australian rating/SP studies estimated the relative importance of a set of vehicle attributes.[47]

Table 33 summarises the passenger ratings by attribute. The average rating is presented by

[47] The rail ratings for Sydney were supplemented by a 2012 survey by Sydney Trains (1,956 surveys).

mode based on the unweighted average of the NZ, Sydney and Melbourne surveys. The maximum and minimums provide a guide as to the likely increases in rating that could be achieved from vehicle improvements.

Table 33: Vehicle ratings in NZ, Sydney and Melbourne

Attribute	Average Rating				Bus		Tram/LRT		Rail		All	
	Bus	TrmL	Rail	All	Max	Min	Max	Min	Max	Min	Max	Min
Outside Appearance	72%	72%	66%	70%	77%	55%	81%	62%	84%	44%	84%	44%
Ease of On & Off	76%	76%	75%	75%	82%	55%	83%	66%	84%	66%	84%	55%
Seat Avail & Comfort	73%	73%	70%	72%	81%	61%	82%	69%	80%	52%	82%	52%
Space for Bags	64%	63%	64%	64%	75%	52%	71%	59%	74%	53%	75%	52%
Smooth & Quiet	63%	70%	65%	66%	81%	58%	77%	62%	80%	50%	81%	50%
Heating & Air Con	69%	70%	68%	69%	73%	44%	78%	57%	78%	38%	78%	38%
Lighting	73%	76%	74%	74%	76%	61%	82%	68%	84%	57%	84%	57%
Inside Clean & Graf.	71%	76%	67%	71%	80%	58%	84%	65%	87%	53%	87%	53%
Information	56%	65%	67%	62%	64%	38%	74%	55%	79%	48%	79%	38%
Computer & Internet	44%	59%	47%	50%	54%	12%	71%	50%	58%	30%	71%	12%
Driver/Staff	73%	76%	73%	74%	83%	65%	82%	69%	81%	66%	83%	65%
Environ Impact	61%	69%	63%	64%	69%	44%	77%	58%	73%	49%	77%	44%
Toilet Avail & Clean	na	na	59%	59%	-	-	-	-	76%	27%	76%	27%
Overall Rating	70%	75%	69%	71%	81%	37%	81%	66%	82%	54%	82%	37%

There was little difference in the overall ratings by mode: tram/LRT was the highest rated at 75% with bus on 70% and rail on 69%. The range in rating by vehicle type was just over 40% points. The lowest rated vehicle scoring 37% was a 29-year old Volvo B12 bus. The highest rated, scoring 82%, was the Matangi train used in Wellington which was less than a year old when surveyed. Figure 23 provides photographs of the highest and lowest rated vehicles surveyed in NZ.

Figure 23: Range in bus and train ratings in NZ

NZ Bus Rating Range

Two year old 37 seater Alexander Dennis (ADL) used on the Outer Link Auckland service scored 75%, the highest overall bus rating.

A 29 year old Volvo B10 scored the lowest overall bus rating of 37%.

NZ Train Rating Range

The Matangi Electric Multiple Units which were only one year old when surveyed scored 82% which was the highest of the trains surveyed

The Ganz Mavag introduced between 1982-83 (refurbished 1999-03) scored the lowest overall train rating of 59%.

8.6 Valuing vehicle attribute improvements

The three studies determined the relative importance of each vehicle attribute by regressing the overall rating on the individual attribute ratings. Linear and logistic models were fitted to individual rating data.[48] The resultant parameter estimates were then combined with the SP 'package' value to enable changes in the passenger rating of individual vehicle attributes to be valued.

Table 34 presents the parameter estimates and the value of improving each attribute from a rating of 40% to 80%. Benefit is estimated for a 25-minute trip for bus, tram/LRT and rail. For rail, the benefit for a 50-minute rail trip is also given (which includes the value of toilet availability and cleanliness).[49]

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[48] The models were fitted on the individual rating data (9,980 observations over the three studies). Linear and logistic models were fitted. The linear model had the advantage of easy interpretation of the coefficients since they were percentages. The logistic model had the advantage of constraining the predicted overall rating to within the 0% and 100% interval. Robust estimation available on NLOGIT5 was used for the logistic model. The logistic parameters have been used to estimate the valuations presented in this report.

[49] Toilet availability and cleanliness was only included as an attribute on the Wairarapa line in the NZ study. The Wairarapa line is a longer distance service operated by diesel hauled carriages which have toilets.

Table 34: Value of improving vehicle attribute ratings from 40% to 80%

Attribute	β	Value (mins) by mode & trip length (mins)				Attribute Share 25 min
		Bus	LRT	Rail		
		25	25	25	50	
Vehicle's Outside Appearance	0.60	0.72	0.75	0.88	1.76	13%
Ease of Getting On & Off	0.29	0.35	0.37	0.43	0.86	7%
Seat Availability & Comfort	0.47	0.57	0.59	0.70	1.40	11%
Space for Personal Belongings	0.16	0.19	0.20	0.24	0.47	4%
Smoothness & Quietness of ride	0.42	0.51	0.53	0.62	1.25	9%
Heating & Air-conditioning	0.42	0.50	0.52	0.61	1.23	9%
Lighting	0.30	0.36	0.38	0.44	0.88	7%
Inside Cleanliness & Graffiti	0.47	0.57	0.59	0.70	1.39	11%
Onboard Information & announcements	0.32	0.38	0.40	0.47	0.94	7%
Bus/Tram Driver, Onboard Staff	0.50	0.60	0.62	0.74	1.47	11%
Ability to use computer/internet connectivity	0.07	0.09	0.09	0.11	0.21	2%
Environmental Impact (emissions, noise)	0.45	0.54	0.56	0.66	1.33	10%
Toilet Availability & Cleanliness * IVT>40mins	0.10	na	na	na	0.29	na
Sum of Individual Attributes *	4.57	5.38	5.60	6.60	13.48	100%
Modelled Package	na	4.33	4.66	5.57	11.30	
40%-80% Change in all attributes	na	4.33	4.66	5.58	11.16	na

* 4.83 excluding toilet avail & cleanliness

Five attributes explained half the overall rating with each attribute explaining 10% or more. The five attributes were: outside vehicle appearance; seat availability and comfort; inside cleanliness and graffiti; driver/staff; and environmental impact (emissions/noise). Four attributes accounted for just less than 10% each: smoothness and quietness of ride; heating/air conditioning; lighting and onboard information; and announcements. Of relatively low importance were space for personal belongings, ability to use computer/internet connectivity and toilet availability and cleanliness.

The sum of the individual attribute improvements exceeds the modelled package. For bus, the sum of the attribute valuations was 5.38 minutes compared with 4.33 minutes for the modelled package. The difference of just over a minute results from (i) not using the logistic formulation that has the effect of dampening the prediction and (ii) not taking account of the 'diminishing returns effect'.

The approach can be used to value different packages of improvements from any 'base' quality.[50] Equation 8.6.1 shows the calculation which has three parts: (i) the trip length; (ii) the maximum overall vehicle quality value (0% to 100%) and (iii) the change in the overall vehicle rating (predicted - base). The third part is forecast using an incremental logit model as shown in equation 8.6.2.

$$Value = (IVT)x(MaxV\ /\min)x\left(VQ_2^{\phi} - VQ_1^{\phi}\right) \qquad .....(8.6.1)$$

[50] A simpler forecasting approach has also been developed which is described in Appendix B.

Where: $$VQ_2 = \frac{VQ_1 \exp\left(\sum_i \beta_i \Delta AQ_i\right)}{VQ_1 \exp\left(\sum_i \beta_i \Delta AQ_i\right) + (1 - VQ_1)} \quad ......(8.6.2)$$

Value = value of improvement in equivalent IVT minutes

IVT = in-vehicle trip length in minutes

$MaxV\ /\min$ = Maximum value of improvement for 0% to 100% rating change (Table 32)

ΔAQ =Change in the attribute rating of attribute i

VQ = Vehicle quality rating before (1) and after (2) improvement transformed by the power function value ϕ (Table 32)

β = beta parameter for attribute as given in Table 33 above.

A layout improvement for a tram is used as an example to demonstrate the calculation. The improvement is expected to improve 'ease of getting on and off' and 'seat availability and comfort'. The clairvoyant engineer forecasts that the 'ease of on/off' rating would increase by 20% points and 'seat availability and comfort' rating by 30%. The average trip length on the tram is 20 minutes and the base overall rating for the tram service is 60%. The predicted overall rating of the tram with the improvements would increase to 65.1% (equation 8.6.3). The predicted value of the improvements is 0.424 minutes of IVT per trip (equation 8.6.4) which is 2.3% of the 20 minute trip.

$$VQ_2 = 65.1\% = \frac{60\% \exp(0.29x0.2 + 0.47x0.3)}{60\% \exp(0.29x0.2 + 0.47x0.3) + (100\% - 60\%)} \quad ....(8.6.3)$$

$$Value = 0.424 \min s = (20)x(0.464)x\left(65.1\%_2^{0.7} - 60\%_1^{0.7}\right) \quad ....(8.6.4)$$

8.7 Halo effects

The analysis has so far assumed that individual attributes are independent. Thus improving one attribute improves the overall vehicle rating but leaves other individual attribute ratings unaffected. It is more likely however that improving one vehicle, for example train lighting would produce some increase the rating of other attributes such as ease of getting on/off and by so doing would increase the overall rating.

In 2015, the Sydney rail survey (38) was extended to cover the full metropolitan network (including Blue Mountains, South Coast and Newcastle intercity services) and an analysis of halo effects was undertaken using a two-step approach The first step determined the direct effect (as described in section 8.6), Douglas Economics (2015). The second step determined the halo effect. This was done by explaining (through regression) the ratings of each attribute on the other attributes. The estimated coefficients were then summed by explanatory attribute. Table 35 presents the estimated effects.

Table 35: Halo effects for train attributes – Sydney Rail (2015)

Attribute	Direct*	Halo*	Total*	Multiplier
Outside Appearance	0.07	0.10	0.17	2.43
Ease of On/Off	0.11	0.08	0.19	1.73
Seat Av & Comfort	0.10	0.09	0.19	1.90
Space for Belongings+	0.01	0.07	0.08	8.00
Smoothness/Quietness	0.08	0.13	0.21	2.63
Heating & Air Conditioning	0.06	0.06	0.12	2.00
Lighting	0.09	0.11	0.20	2.22
Cleanliness/Graffiti	0.10	0.07	0.17	1.70
Onboard Information	0.05	0.06	0.11	2.20
Ability to use elect devices (wifi)	0.04	0.04	0.08	2.00
Personal Security	0.05	0.08	0.13	2.60
Onboard Staff	0.06	0.04	0.10	1.67
Environment	0.05	0.05	0.10	2.00
Toilets	0.02	0.03	0.05	2.50
Layout	0.12	0.08	0.20	1.67

Notes: Parameters are for a 100% increase. ^ Total effect divided by Direct effect. + direct effect parameter was statistically weak. * Numbers rounded two decimal places. Douglas Economics (2015)

The typical multiplier was around 2 implying that halo effects doubled the direct effect. The tabulated multipliers are only valid for a single attribute however since as more attributes are improved, the direct effect will increase and the halo effect decrease. Thus in extremis, if all attributes were improved by the same percentage amount (say by 10%), there would be no halo effect with the total effect increasing by the same amount (10%).

8.8 Valuing facility provision

Table 36 combines the results of the rating surveys and the valuation methodology to value a range of onboard facilities including the age of the vehicle. Two values are tabulated. The value per trip in minutes and the valuation expressed as a ratio of onboard trip length. The latter figure enables the values to be applied to other trip lengths.

The biggest benefit was for replacing old with new vehicles. A new train was worth 4.18 minutes per trip or 8% of the trip length. This was an average of two Sydney and one Wellington estimate. The benefit was less for trams at 0.89 minutes or 4.5% of the onboard trip length reflecting a shorter trip length, a lower difference in ratings and a lower sensitivity to quality. For buses, an age / value function was established. At 3.9 minutes per trip or 17% of the onboard time, the greatest benefit was for a new 1.5-year old Alexander Dennis Bus versus a 29-year old Volvo bus. The benefit reduced to 5.9% for a 20-year old bus and 2.7% for a 10-year old bus versus a new bus.

For train, the benefit of a major refurbishment was worth 2 minutes or 5.4% of the onboard time based on Sydney Tangara.

In terms of onboard facilities, electronic information displays were valued at 0.4 minutes on trains 0.12 minutes on trams and 0.15 minutes on buses. The valuation when expressed as a ratio of the onboard time was similar at 0.8% for trains, 0.6% for trams and 0.7% for buses conditioning was worth 0.35 minutes per trip of 1% of the onboard time based on Sydney and Wellington rolling stock comparisons.

Table 36: Value of facility provision

Mode	Comparison	Attribute Rating	IVT Valuation		Comment
			mins per trip	Percent of IVT	
Rail	Old v New Train	Overall	4.18	8.0%	Sydney CK sets vs Waratah; V set vs Oscar; WTN Ganz Mavag vs Matangi
	Old v Refurb Train	Overall	2.00	5.4%	Sydney Tangara refurbishment.
	Diesel v Electric	Overall	1.78	5.9%	AUC DMUs vs WTN EMUs
	Diesel v Electric	Environ Rating	0.26	0.9%	AUC DMUs vs WTN EMUs
	Onboard Elect. Info Displays	Onboard Info. & announcements	0.40	0.8%	SYD CK Sets vs Waratah, V set vs OSCAR; MEL Comeng vs Xtra; WTN G.Mav vs Matangi
	Air-Conditioning	Heating and air conditioning	0.35	1.0%	Sydney S vs CK set; WTN Ganz Mavag vs Matangi.
	Security CCTVs	Feeling of Personal Security	0.43	1.2%	Sydney Tangara,C, K & S sets vs Waratah (uses Study #25 Personal Security estimate).
	Onboard Staff	Staff availability & helpfulness	0.70	2.3%	Auckland & Wellington Onboard Staff with ticketing duties (vs guards on train).
	Toilets	Toilet availability & cleanliness	0.43	0.5%	Sydney intercity OSCAR & V sets; WTN Wairarapa Line.
Tram	Old v New Tram	Overall	0.89	4.5%	MEL Z class versus E class
	Onboard Elect. Info Displays	Onboard Info. & announcements	0.12	0.6%	MEL A,B vs C,D,E class tram
	Onboard Staff	Staff availability & helpfulness	0.11	0.6%	MEL driver only trams versus SYD LRT with onboard staff
	Low Floor	Ease of On/Off	0.09	0.5%	MEL Z class vs CDE
Bus	29 year old v New	Overall	3.90	17.0%	NZ: 29 year old vs 1.5 year old bus
	20 year old v New	Overall	1.36	5.9%	NZ: Pred rating for 45 seater for 20 year old v brand new (0 years)
	10 year old v New	Overall	0.62	2.7%	NZ: Pred rating for 45 seater for 10 year old v brand new (0 years)
	Premium Routes	Overall	0.91	4.0%	NZ: Std routes vs AUC Inner/Outer Loop & WTN Airport Flyer
	Premium Routes	Onboard Info. & announcements	0.15	0.7%	NZ: Std routes vs AUC Inner/Outer Loop & WTN Airport Flyer
	Diesel vs Trolley	Overall	0.35	1.5%	NZ: WTN Trolley bus vs Diesel bus
	Diesel vs Euro 5	Overall	0.70	3.0%	NZ: Non Euro 5 Diesel vs Euro 5 Diesel bus
	Pre Euro vs Trolley	Environ Rating	0.11	0.5%	NZ: Pre Euro vs WTN trolley
	Pre Euro vs Euro 5	Environ Rating	0.10	0.4%	NZ Pre Euro vs Euro 5 rated bus
	Midi vs Std Bus	Seat Avail & Comfort	0.08	0.3%	NZ: Midi 20 seat vs Std 45 seat
	Std vs Artic Bus	Seat Avail & Comfort	0.09	0.3%	NZ Std 75 seat vs 45 seat, Syd Std vs Artic
	Std vs Low Floor	Ease of On/Off	0.06	0.3%	NZ: Std bus vs low floor bus

Air

Onboard staff on trams was worth 0.11 minutes per trip of 0.6% of the onboard time based on a comparison of Melbourne (driver only) with Sydney LRT (staff onboard trams to issue/check tickets).

For rail, the provision of toilets was valued at 0.43 minutes per trip (0.5%) for trips above 40 minutes.

Having onboard staff on trains to check tickets and provide assistance was 0.7 minutes per trip (2.3%) based on the NZ ratings.

The value of security cameras on trains was valued at 0.43 minutes per trip (1.2%) based on the integrating the results of the Sydney 2002-06 (26) results.

Electric trolley buses used in Wellington were valued 0.35 minutes per trip (1.5%) higher than a standard diesel bus. When limited to the environmental rating (noise/emissions) the benefit of a trolley bus was 0.11 minutes (0.5%) more than a per Euro rated diesel. By comparison, a Euro 5 engine rated bus was valued slightly less in terms of its environmental rating but higher overall at 0.7 minutes per trip (0.7) reflecting the higher general specification and newness of the vehicle compared with a pre Euro standard diesel.

A higher value was also estimated for longer buses with greater seating. An articulated 75-seater bus was valued 0.09 minutes (0.3%) higher than a standard 45-seater which was in turn valued 0.08 minutes (0.3%) higher than a 20-seater midi bus.

8.9 Value of ferry improvements

For completeness, values for improved ferry quality are presented in Table 37. The values are quite dated being based on market research undertaken in 2000 by Booz Allen Hamilton as part of a business development study.[51] The study included Stated Preference questions to estimate values of time and service frequency and a Priority Evaluator (a shopping list of improvements) to assess passenger priorities for vessel and wharf improvements. The improvements were reported in cents per trip which were converted into IVT minutes using a value of time of $12.50/hr.[52] The values were also factored so that the package value totalled 5.9 minutes (the average of the bus, tram/LRT and rail values in Table 36).[53]

Minimising boarding delays and stopping fumes entering the seating area were the most important accounting for 13% to 14%. Next at just under 10% each were real time information displays, cleaner/well maintained toilets and onboard security cameras.

[51] In 2017, after this review update was completed, the results of a study for Transport for NSW became available which used the same rating/SP method as used for buses and trains to measure ferry ‘vehicle’ and wharf quality. See Douglas (2017).

[52] Booz reported values of time and attribute values for different types of ferry which were averaged after taking account the likely trip length.

[53] The Booz study estimated a package value of 1.13 minutes (for a 25-minute trip), By comparison, the rating approach estimated a value of 5.9 minutes. The difference was considered to reflect differences in approach. The Booz study valued improvements from the current standard whereas the rating approach valued the difference between low (40%) and high (80%) quality.

Table 37: Value of Improved Ferry Quality

Vessel Improvement	Scaled to a Rating Increase of 40-80%		Share
	Per Trip*	Per Min	
Onboard security cameras	0.48	0.019	8%
Help point and emergency phone	0.35	0.014	6%
Real time arrival time and position display	0.51	0.020	9%
Clearer onboard passenger announcements	0.29	0.012	5%
No delays when boarding and alighting	0.75	0.030	13%
Outdoor seat always available	0.26	0.010	4%
Indoor seat always available	0.13	0.005	2%
More efficient, quieter, air conditioning and heating	0.41	0.017	7%
No engine fumes enter seating area	0.85	0.034	14%
An always open food, beverage, newspaper kiosk	0.39	0.016	7%
Onboard ticket vending machine	0.43	0.017	7%
Cleaner graffiti free seats	0.15	0.006	3%
Cleaner well maintained toilets	0.45	0.018	8%
Refurbished ferry interior appearance	0.35	0.014	6%
Refurbished ferry exterior appearance	0.09	0.004	2%
Total	5.90	0.236	100%

* for a 25 minute trip

9. Stop and station quality

9.1 Introduction

The same approach as for vehicles is used to value bus and tram stops and train stations. The values are based on passenger ratings ranging from ‘very poor’ to ‘very good’ that were converted to a percentage scale. As with vehicle quality, the approach allowed for a diminishing ‘willingness to pay’ with respect to quality and has been specified so that individual attribute values are consistent with overall package values.

A question sometimes raised by evaluators is how the values should be applied. Unless otherwise stated, the values are ‘per passenger boarding’ at the bus stop or train station. To work out the total benefit, the values should therefore be multiplied by the number of passengers boarding at the stop or station in question. There may be benefit to alighting passengers or passengers making transfer trips albeit at a lower level. Based on the Sydney 2013 study (38), some guidance is provided in Section 9.11 on the values that can be applied to alighting and transfer passengers.

A distinction is made between bus (and tram) stops and train stations. This is because of the longer list of facilities typically provided at train stations. As will be shown from the NZ study (37) however bus stations were similarly rated to larger ‘hub’ train stations.[54] Therefore, for attributes that are not shown for bus stops such as toilets and staff, but for which values are required, the rail station values can be used. No values were available for ferry. If values are required, the train station estimates could be used as a basis.

Like vehicle quality, no values were available for ferry. For completeness, Section 9.12 presents the results of a 2001 Booz study of Sydney Ferries (19) that valued a range of wharf improvements.

9.2 Studies reviewed on stop quality valuations

The main source of values were the three large-scale Sydney, Melbourne and NZ 2012 to 2014 studies, the literature review of studies undertaken as part of the NZ study plus the Wardman OECD review.

9.3 Valuation of overall stop quality

The rating/SP surveys undertaken in NZ, Sydney and Melbourne (see Table 38) valued a high-quality bus stop or train station at 4.3 minutes of in-vehicle time compared to a low-

[54] At the other end of the scale, bus stops were comparable to small train stations that, in some instances, were nothing more than a bus stop mounted on a rail platform.

quality stop. These valuations are based on passenger ratings of 80% for a high quality stop and 40% for a low quality stop.

Rail station quality was valued just over a minute higher than bus or tram/LRT stop quality at 5.2 minutes versus 3.8 to 3.9 minutes. The valuations were similar to the findings of the literature review which produced values of 6 minutes for bus stops and 5.4 minutes for rail stations.[55] As with vehicle quality, comparisons were made difficult due to differing 'quality' definitions used by researchers. For the rating/SP surveys, attributes include operational aspects such as staff availability and helpfulness and cleanliness/graffiti.

Table 38: Valuation of overall stop quality

Study/Estimate	Measure	Bus	Tram /LRT	Rail	Average	Comment
Aus/NZ Rating/SP (1)	Per Trip	3.8	3.9	5.2	4.3	9 Estimates (3 Bus, 2 Tram/LRT & 4 Rail) for a 40-80% rating difference
Literature Review (2)	Per Trip	6.0	-	5.4	6.0	Median value calculated on 15 observations (8 Bus & 7 Rail).

(1) Studies 26, 37,38 & 39 (2) Studies 2, 8, 12-14, 27, 41, 43-46.

9.4 Valuing changes in stop quality rating

As with vehicle quality, a 'power' function was applied to the rating of stop quality $\left(SQ^{\phi}\right)$ in the rating/SP studies to allow for the 'willingness to pay' for quality to diminish as the rating increased.

Table 39 presents the power function values. The value for bus and tram/LRT stop quality was the same at 0.6 with the value for slightly higher at 0.65 for rail.

The value was the same for bus stop quality as for bus vehicle quality but was slightly lower for LRT/Tram and for rail.

[55] Median values have been reported from the literature review because of the effect of two studies that produced high estimates. The mean values were 7.4 minutes for bus and 13.1 minutes for rail.

Table 39: Vehicle power function and stop quality values

Stop Quality	Bus	LRT/Tram	Rail	Average
Power Function (ϕ)	0.60	0.60	0.65	0.62
Theoretical Max 100% - 0% Value in IVT mins	12.8	13.1	16.6	14.2
High (80%) - Low (40%) in IVT mins	3.8	3.9	5.2	4.3
40-80% Range as Percent of Theoretical Max	30%	30%	31%	30%

Also presented in Table 39 are valuations for the maximum range in stop quality from very poor (0%) to very good (100%). The range is a theoretical maximum however and is unlikely to be ever realised in practice. The values for, what would be a 'realistic' range in stop quality of 40% to 80% would be 30% of the 'theoretical' maximum (31% for rail because of the 0.65 power parameter).

The relative importance of stop quality versus vehicle quality can be assessed by dividing the stop values by the vehicle values in Table 32. Up to 20 minutes of in-vehicle time, stop quality improvements are valued more highly than vehicle quality improvement but for longer trips of over than 20 minutes, vehicle quality improvements are valued more highly.

9.5 Range in stop attribute ratings

The three 2012 to 2014 NZ and Australia rating/SP studies estimated the relative importance of a set of stop quality attributes. The list of attributes differed with a shorter list used for bus and tram/LRT stops and a longer list for rail stations.

Table 40 summarises the passenger ratings by attribute. The average rating is the average of the NZ, Sydney and Melbourne estimates. The maximum and minimum ratings provide a guide to the range in rating achieved from stop/station improvements.

The overall average rating was 66% with negligible difference between bus, tram/LRT and rail. The overall rating ranged from a low of 25% to a high of 81%.[56]

[56] Only stops/stations where the sample size was at least 20 were used in determining the minimum and maximum ratings. Apart from NZ rail stations and Sydney LRT stops, response was aggregated.

Table 40: Stop attributes ratings in NZ, Sydney and Melbourne

Attribute	Average Rating				Bus		Tram/LRT		Rail		All	
	Bus	TrmL	Rail	All	Min	Max	Min	Max	Min	Max	Min	Max
Weather Protection	58%	64%	66%	62%	13%	79%	40%	84%	40%	88%	13%	88%
Seating	57%	61%	54%	57%	37%	76%	46%	75%	23%	74%	23%	76%
Timetable Information & Announcements	66%	64%	66%	65%	47%	81%	38%	75%	39%	78%	39%	81%
Lighting	65%	63%	67%	65%	31%	77%	41%	82%	38%	79%	31%	82%
Cleanliness & Graffiti	63%	69%	64%	65%	44%	86%	56%	91%	30%	83%	30%	91%
Ease of Ticket Purchase	na	53%	62%	58%	na	na	20%	83%	9%	77%	9%	83%
Platform Surface	na	na	66%	66%	na	na	na	na	45%	79%	45%	79%
Ease of getting to & from the plaform e.g. stairs, lifts, escalators	na	na	70%	70%	na	na	na	na	40%	81%	40%	81%
Toilet Availability & Cleanliness	na	na	44%	44%	na	na	na	na	4%	71%	4%	71%
Availability & Helpfulness of Staff	na	na	58%	58%	na	na	na	na	14%	75%	14%	75%
"Retail" - Ability to buy food, drinks and newspapers etc	na	na	52%	52%	na	na	na	na	3%	75%	3%	75%
Car Parking and Car Passenger Pick Up and Set Down Facilities	na	na	54%	54%	na	na	na	na	27%	81%	27%	81%
Ease of Transferring to & from Bus	na	na	63%	63%	na	na	na	na	13%	78%	13%	78%
Overall Rating	65%	68%	66%	66%	46%	80%	36%	81%	25%	79%	25%	81%

Figure 24 provides some photographs of the range in rating of NZ bus and train stations.

The highest rated attribute was ‘ease of getting to and from the platform’ which averaged 70%. The lowest attribute was toilet availability and cleanliness at 44%. Both these attributes were only included on the rail survey. The average ratings were similar for the five attributes ‘common’ to all three modes (ranging from 57% to 65%) but there were wide ranges by stop and station. For example, the rating of weather protection ranged from a low of 13% for bus stops to a high of 88% for rail stations.

Figure 25 ranks the bus, tram/LRT stop and rail stations according to their overall rating. A summary is provided in Table 41. Bus stations were classified into bus station, city centre and suburban stops. LRT/tram stops were classified into stations, city centre and suburban stops. Train stations were classified into hub, major and local stations. The bus and rail ratings are based on the NZ survey with the LRT/tram ratings based on the Sydney and Melbourne surveys.

Figure 24: Range in NZ bus stop and rail station ratings

NZ Bus Stop Rating Range

The bus stations on Auckland North Shore Busway scored the highest ratings of 80%.

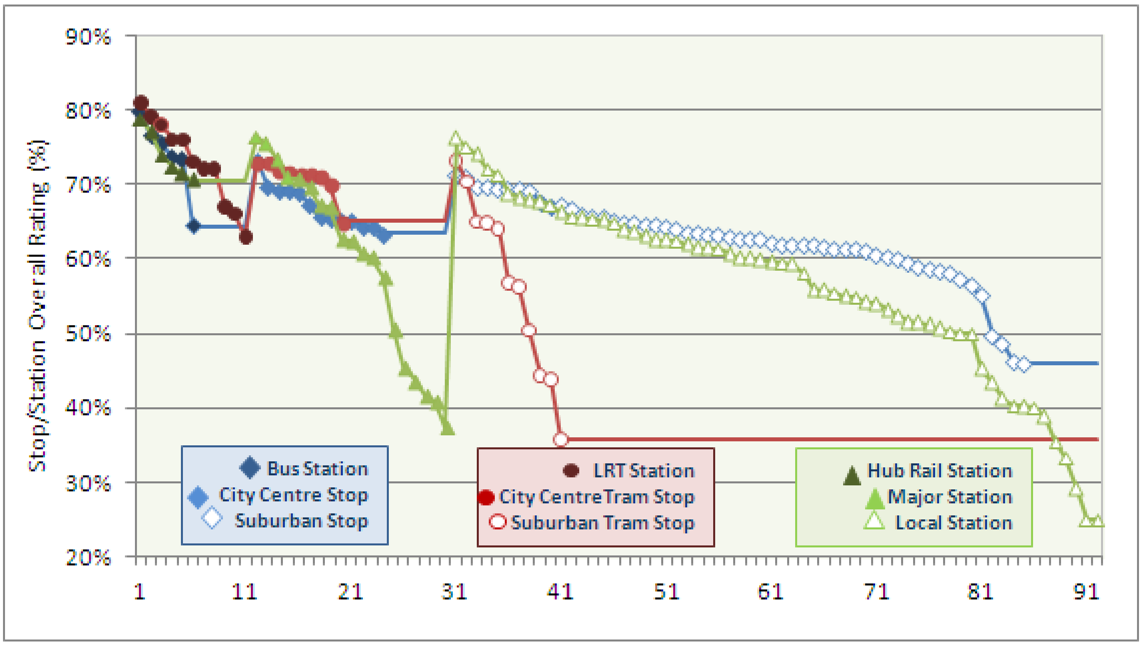
The lowest rated bus stops had no shelter or seating and scored 46%.

NZ Rail Station Range

Newmarket Station in Auckland which was upgraded in 2010 was the highest rated station at 79%.

Ava station in Wellington which suffers from repeated graffiti attacks was the lowest rated at 25%

Figure 25: Ranking of stops and stations by overall rating and type



Bus stations, tram stations and hub rail stations achieved similar ratings of 73-74% reflecting a similar level of facility provision and operational quality. There was a greater range in the bus station ratings however from a high of 80% for the Albany Northern Expressway station down to 64% for the bus stop at Wellington Airport.

The six hub rail stations ranged from 79% at Newmarket down to 71% at Porirua. City centre tram/LRT stops (71%) rated higher than both city centre bus stops (67%) and major rail stations (60%) although there was a considerable overlap in the individual ratings.

Suburban bus stops rated higher at 62% than suburban tram stops (57%) and local rail stations (56%) with the tram and rail averages reduced by some low rated stops and stations.

Table 41: Rating of stops and stations by type

Bus & Tram/LRT Stop					Rail Staton		
Stop Type	Bus Av Rating+	Range	Tram/LRT Av Rating^	Range	Station Type	Rail Av Rating+	Range
Station	74%	80% to 64%	73%	81% to 63%	Hub Station	74%	79% to 71%
City Centre	67%	73% to 63%	71%	73% to 65%	Major Station	60%	76% to 38%
Suburban	62%	71% to 46%	57%	73% to 36%	Local Station	56%	76% to 25%

+ NZ (Auckland, Christchurch (bus only) & Wellington)
^ Sydney LRT and Melbourne tram/LRT

9.6 Valuing improvements in stop / station attribute ratings

The value of improving stop attributes was calculated in the same way as for vehicle attributes (Section 8.6). Table 42 presents the valuations for improving attribute ratings from 40% to 80%.

As with vehicle quality, the sum of the individual attribute valuations exceeded the package value (due to the logistic function and power parameter). For bus and tram/LRT stops, the attribute sum was a quarter higher than package value (4.6 minutes versus 3.8 minutes for bus stops). For rail stations the difference was 10% (5.7 minutes versus 5.2 minutes). To value combinations of improvements (as will be described shortly) the model should therefore be used so the sum of attributes is the same as the package value.

The relative importance of each attribute was smaller for rail stations reflecting the longer list of attributes. There was also a slight difference between bus and tram stops due to the inclusion of ticket purchase facilities for tram stops which lowered the importance of the other attributes.

Table 42: Value of improving stop attribute ratings from 40% to 80%

Attribute	β			Value mins/boarding			Attribute Share^		
	Bus Stop	Tram/L Stop	Rail Stat	Bus Stop	Tram/L Stop	Rail Stat	Bus Stop	Tram/L Stop	Rail Stat
Platform Weather Protection	1.13	1.07	0.56	1.18	1.14	0.79	25%	24%	12%
Platform Seating	0.96	0.91	0.54	1.00	0.97	0.77	22%	20%	12%
Timetable Information & Announcements	0.97	0.92	0.47	1.01	0.99	0.67	22%	20%	10%
Station Lighting	0.54	0.51	0.37	0.57	0.56	0.53	12%	11%	8%
Cleanliness & Graffiti	0.85	0.80	0.63	0.89	0.86	0.90	19%	18%	14%
Ease of Ticket Purchase	na	0.28	0.40	na	0.30	0.58	na	6%	9%
Platform Surface	na	na	0.48	na	na	0.68	na	na	11%
Ease of getting to & from the plaform e.g. stairs, lifts, escalators	na	na	0.41	na	na	0.59	na	na	9%
Toilet Availability & Cleanliness	na	na	0.11	na	na	0.16	na	na	2%
Availability & Helpfulness of Staff	na	na	0.16	na	na	0.23	na	na	4%
"Retail" - Ability to buy food, drinks and newspapers etc	na	na	0.13	na	na	0.18	na	na	3%
Car Parking and Car Passenger Pick Up and Set Down Facilities	na	na	0.19	na	na	0.27	na	na	4%
Ease of Transferring to & from Bus	na	na	0.08	na	na	0.11	na	na	2%
Sum of Individual Attributes	4.45	4.49	4.54	4.65	4.82	5.70	100%	100%	100%
Modelled Package	na	na	na	3.79	3.88	5.19			
Change in all attributes	na	na	na	3.81	3.90	5.21	na	na	na

^ βi/ Sum βi

For bus and tram stops, weather protection was the most important attribute, accounting for a quarter of the overall valuation. For rail stations, weather protection only accounted for 14%. Seating and information accounted for 20% to 22% at bus and tram stops with cleanliness and graffiti accounting for 18% to 19%. Lighting was of lesser importance at 11% to 12%. For tram stops, ticket purchase facilities accounted for 6%.

For rail stations, the six 'common' attributes plus platform surface and ease of platform on/off (lifts, stairs/escalators)[57] explained between 9% and 16% of the overall rating. Of lesser importance (explaining no more than 5% each) were: toilet availability and cleanliness; staff availability and helpfulness; retail facilities; car access facilities; and bus access facilities.

Dampening the importance of car parking/set down facilities and ease of transfer to bus was the 'non-proportion' using these access/egress modes (i.e. a high proportion walking). It is therefore recommended that for bus waiting facilities at rail stations, the values for bus stops are used (and multiplied by the number of transferring rail passengers).

As with vehicle quality, the advantage of using ratings is flexibility. Any rating change from 0% to 100% can be valued with the calculation multiplying the theoretical maximum quality

[57] It should be noted that the valuations are for the 'average' rail user. Passenger lifts are often introduced to improve accessibility primarily for the wheel chair passengers. Some studies have estimated values of lifts, ramps and escalators for passengers of different mobility status such as Maynard (2007), Duckenfield et al. (2010) and Douglas (2010, 2011).

(9.6.1) by the change in the predicted overall stop rating (new - base) given in equation 9.6.2.

$$Value = (MaxV\ / \min)x\left(SQ_2^{\phi} - SQ_1^{\phi}\right) \quad .....(9.6.1)$$

Where: $$SQ_2 = \frac{SQ_1 \exp\left(\sum_i \beta_i \Delta AQ_i\right)}{SQ_1 \exp\left(\sum_i \beta_i \Delta AQ_i\right) + (1 - SQ_1)} \quad ......(9.6.2)$$

$Value$ = value of improvement in equivalent IVT minutes

$MaxV\ / \min$ = Maximum value of improvement for 0% to 100% rating change (Table 39)

ΔAQ =Change in the attribute rating of attribute i

SQ =Stop quality rating before (1) and after (2) improvement transformed by the power function value ϕ (Table 39)

β = attribute beta parameter as given in Table 42.

As an example, a bus stop improvement is expected to increase the weather protection rating by 40% (from 30% to 70%) and the seating rating by 20% (from 50% to 70%). The bus stop is assessed to have a current rating of 50%. The overall rating is predicted to increase to 65.6% (equation 9.6.3) and to be valued equivalent to 1.49 minutes (equation 9.6.4).

$$SQ_2 = 65.6\% = \frac{50\% \exp(1.13x0.4 + 0.96x0.2)}{50\% \exp(1.13x0.4 + 0.96x0.2) + (100\% - 50\%)} \quad ....(9.6.3)$$

$$Value = 1.49 \min s = (12.8)x\left(65.6\%_2^{0.6} - 50\%_1^{0.6}\right) \quad ....(9.6.4)$$

The analysis has assumed that individual stop/station attributes are independent. As with vehicles, improvements to individual station attributes are likely to have halo effects (see section 8.7). The Sydney study estimated a halo multiplier of around 2 for individual attribute improvements, Douglas Economics (2015).

9.7 Valuing bus and tram stop facility provision

The NZ, Sydney and Melbourne studies (37, 38 & 39) asked bus and tram passengers whether facilities were provided at the stop they boarded at and were asked to rate. Facilities included whether there was a timetable, electronic real time information, seating and weather protection. For tram, whether the stop was a raised platform and whether ticket purchase facilities were available were also included.

Models were then fitted that explained the stop rating against facility availability and determine the value of facility provision (to the quality rating perceived by passengers) in equivalent IVT minutes. Equation 9.7.2 specifies the model in absolute form and equation

9.7.3 incrementally (i.e. pivoting on a base rating).

$$Value = (MaxV)x\left(SQ_2^{\phi} - SQ_1^{\phi}\right) \qquad .....(9.7.1)$$

where $$SQ\% = \frac{\exp\left(\beta o + \sum \beta iAi\right)}{1 + \exp\left(\beta o + \sum \beta iAi\right)} \qquad .....(9.7.2)$$

or $$SQ\% = \frac{SQ_1 \exp\left(\sum \beta iAi\right)}{SQ_1 \exp\left(\sum \beta iAi\right) + (1 - SQ_1)} \qquad .....(9.7.3)$$

where $Ai = 1$ if attribute i is provided else 0 if not provided.

Table 43 presents the beta parameters which combine the results of the three studies. The parameters were then used to forecast the rating from introducing a facility by pivoting on the observed 'without' rating.

Providing shelter at a bus stop increased the bus stop rating from an observed 48% rating to a predicted 63%. The valuation of the improved stop rating was worth 1.63 minutes which was the highest of the six facilities. Providing ticket purchase facilities at tram stops was the second highest valued attribute at 0.91 minutes with seating third with a value of 0.75 minutes. Real time information (RTI) was valued at 0.67 minutes compared with 0.5 minutes for providing a timetable. Providing a raised platform tram stop was the least valued attribute at 0.12 minutes.

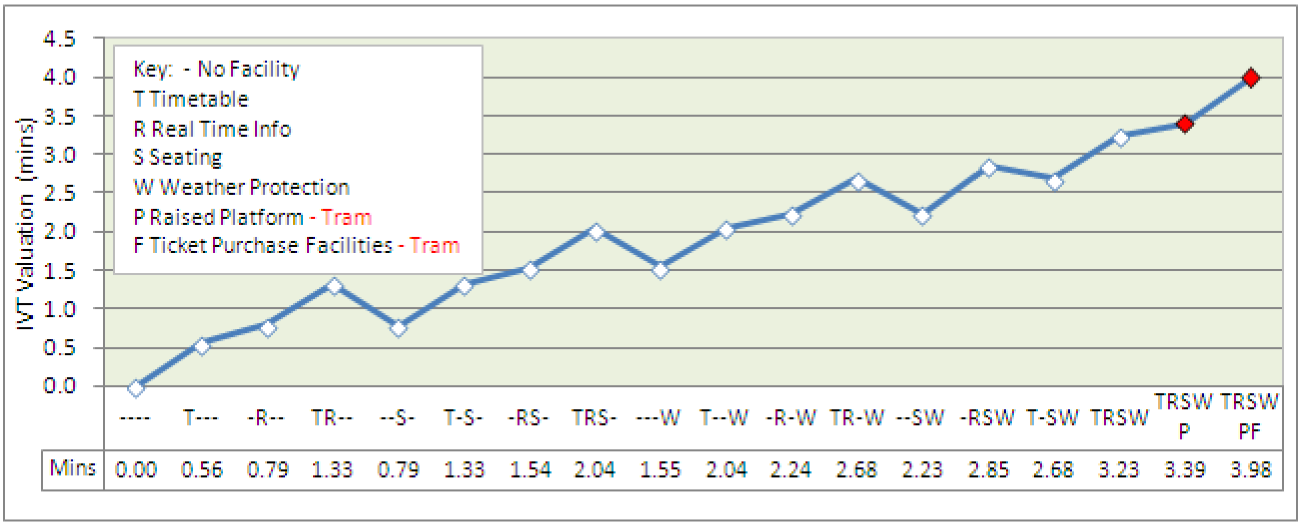
Table 43: Value of bus and tram stop facility provision in IVT minutes

Attribute	β	Stop Rating % No+	Stop Rating % Yes^	Value IVT mins
1. Shelter	0.602	48%	63%	1.43
2. Seating	0.299	47%	55%	0.75
3. Timetable	0.213	55%	60%	0.50
4. RealTime Information	0.300	57%	64%	0.67
5. Raised Platform - Tram	0.047	47%	49%	0.12
6. Ticket Purchase - Tram	0.389	53%	62%	0.91
Constant	-0.404	na	na	na
Sum of Attributes (1-4)	na	na	na	3.47
Sum of Attributes (1-6)	na	na	na	4.39
All Facilities (1-4)	na	40%	73%	3.23
All Facilities (1-6)	na	40%	81%	3.98

+ observed NZ, Syd & Mel average; ^ Predicted using model

Figure 26 graphs the value of providing facilities. All 16 combinations of timetable (T) RTI (R) weather protection (W) and seating (S) are graphed. On the right, the added benefit from providing a raised platform and from providing ticket purchase facilities at tram stops is shown.

Figure 26: Value of bus and tram stop facilities in IVT minutes



The benefit from providing RTI at a stop with shelter, seating and a timetable can be determined by subtracting T-SW (2.68) from TRSW (3.23) which is 0.55 minutes. By contrast, if RTI was provided at a stop with no other facilities, the benefit would be 0.79 minutes.

Likewise, the benefit of providing ticketing facilities at a raised platform tram stop is TRSWPF (3.98) minus TRSWP (3.39) which is 0.59 minutes.

Figure 26 above shows how the valuation is affected by the 'order' of introduction. Introducing an attribute has more value if is first than when it is last. In practical evaluations, if the passenger rating is known or can be approximated, equation 9.7.3 above can be used to assess the attribute 'incrementally'.

9.8 Valuing rail station facility provision

For rail stations, the value of providing different facilities was based on a cross-sectional comparison of passenger ratings 'with and without' provision. Unlike bus and trams, facility provision was based on 'actual' data provided by operators and territorial authorities rather than passenger perceptions. Table 44 presents the valuations.[58]

[58] To be consistent, the valuations applied the parameters in Table 9.6) to the difference in passenger rating rather than the specific parameters in the NZ, Sydney and Melbourne studies.

Table 44: Value of rail station facility provision in IVT minutes

Attribute	Value Mins	Comment
Passenger Information Displays (PIDs)	0.28	Mel: Comparison of stations with/without PIDs (adjusted for more facilities at PIDs stations) for suburban trains.
Ticket Purchase Facilities	0.18	NZ: Based on difference in ticket rating at stations with/without ticket purchase facilities.
Staff Presence	0.15	NZ & SYD: Based on staff rating at stations with/without staff.
Retail Facilities	0.13	NZ: Based on retail rating for stations with/without.
Toilets	0.06	NZ & SYD: Based on toilet avail/cleanliness rating for stations with/ without.
Ease of Bus Access	0.03	NZ & SYD: Difference in whether bus transfer available or not
Car Park / Drop Off	0.06	NZ & SYD: Based on car access rating with/without car park.
Bike Racks/Lockers	0.03	SYD: Based on bike rating with/without bike rack/locker (pivoted on Sydney rating model).
Taxi Rank	0.02	SYD: Based on rating of taxi rating (pivoted on Sydney model).
Provision of Lifts/Escalators	0.08	NZ: Based on platform on/off rating with/without lifts/escalators at stations with overbridge.
Provision of Lifts	0.08	SYD: Based on platform on/off rating at stations with/without lifts. The value increased to 0.1 after taking account the increase in use by mobility challenged users.^
Flat versus Overbridge	0.05	NZ: Based on plt on/off rating for stats with o'bridge vs flat.
Newly Upgraded/Built	2.33	NZ: Major upgrade/0-5 five years old.
Recently Upgraded/Built	1.32	NZ: Major upgrade/built 5-10 years old.

^ average station user - Lifts mainly benefit to 'Mobility Challenged' (MC) users (eg wheelchair, infirm, pax with heavy luggage, strollers etc). Taking account trip generation, the benefit was 0.1 mins per trip.

At the top of the table is the value for electronic passenger information displays (PIDs) which provide real time information on train arrivals. The estimated value of 0.28 minutes was based on a comparison of the observed passenger rating at Melbourne stations with and without PIDs (with a downwards adjustment for a correlation with ‘other facility’ provision).[59]

The second highest attribute valuation, at 0.18 minutes, was for ticket purchase. The estimate was based on the difference in the rating of ‘ease of ticket purchase’ at NZ stations with and without ticketing facilities.[60]

Providing staff at rail stations was valued at 0.15 minutes based on the average of NZ (0.16) and Sydney (0.13) survey results and providing a toilet was worth 0.06 minutes. Based on NZ data, retail facilities (a shop, kiosk or cafe) at rail stations were worth 0.13 minutes based on NZ station data.

The value of providing car parking at 0.06 mins and of bus transfer at 0.03 minutes was low. However, the car parking value should be treated with caution since, as Section 9.9 below will show, the value of upgrading station car parks is higher. Providing bike racks/lockers at

[59] It was not possible to derive a similar value for NZ because all stations had PIDs.
[60] The valuations that involved individual ratings used Equation 9.7.3.

stations was valued at 0.3 minutes and taxi ranks at 0.02 minutes based on Sydney data.

For NZ stations, the benefit of lifts and escalators at stations with overbridge platform access was valued at 0.08 minutes. Sydney ratings gave a similar value for the introduction of lifts. The main aim from introducing passenger lifts at rail stations is to cater for wheelchair and other mobility challenged users. As Table 45 shows, the introduction of passenger lifts can increase usage by these user groups quite markedly. Taking account patronage generation amongst mobility challenged users suggests a higher benefit of 0.1 minutes from lifts is appropriate.

Table 45: Value of passenger lifts at rail station by passenger mobility status

Estimate	Wheel-chair	Pram/ Stroller	Bike	Heavy luggage	Old/ Infirm	Total MC	Non MC	All
Station Trips without Lifts	0	8	4	10	13	35	965	1,000
Station Trips with Lifts	1	13	5	14	26	59	965	1,024
Benefit (without profile) mins						1.9		0.08
Benefit (with profile) mins	3.19	1.98	1.14	1.55	2.39	2.0	0.01	0.13
Benefit (average) mins						2.0		0.10

Source: "*Estimating the User Benefit of Rail Station Lifts*" Douglas (2012)

9.9 Station upgrading

The NZ study (37) was able to combine the results of two near identical passenger station rating surveys undertaken 10 years apart.[61] Ten stations out of 46 (where there were sufficient responses) had been upgraded in a 'major' way and 29 stations had some facilities upgraded with seven stations unimproved.[62]

Table 46 presents some of the estimated valuations.[63] The value of a major station upgrade which typically would involve rebuilding the main station building was worth 3.35 minutes per boarding trip. This is the 'brand new' value (i.e. the day after completion). The value then gradually decreased such that after 5 years, it was worth 2 minutes, 0.32 minutes after 10 years and was close to zero after 11 years as Figure 27 shows.[64]

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[61] The first set of passenger ratings were surveyed in 2002-04 with the later set in 2012/13. Both samples were large with 3,290 in 2002-04 and 5,423 in the 2012/13 and provided 46 stations with large enough samples in both years.

[62] The stations that were judged to have had a 'major' upgrade were Petone, Epuni, Naenae, Plimmerton, Paraparaumu, Waikanae, Solway, Matarawa, Renall Street and Masterton.

[63] Sydney Trains has undertaken a similar analysis using data collected over a ten year period.

[64] The values are similar to the cross-sectional values presented in section 9.8 which estimated the benefit of an upgrade undertaken between 0 and 5 years previously at 2.33 minutes and 1.32 minutes for an upgrade undertaken 5 to 10 years previously. The values from Table 9.9 are 2.34 minutes and 0.91.

Table 46: Value of rail upgrading in IVT minutes

Upgrade	Attribute Rating Affected	Valuation Minor Upgrade	Valuation Major Upgrade	Comment
Platform Shelter	Shelter	0.09	0.36	Based on predicted effect on weather protection rating
Seating	Seating	0.16	0.41	
Platform Surface	Platform Surface	0.19	0.44	Major upgrade included rebuilding platforms with access paths to 'street'
" " "	Platform On/off	0.24	0.41	
Information	Information	na	0.30	
Lighting	Lighting	0.11	0.21	
Cleaning/Graffiti	Cleanliness/Graffiti	0.25	0.62	
Toilets	Toilet	na	0.09	
Retail	Retail	na	0.18	Opening of café/small shop on platform or near platform.
" " "	Staff	na	0.04	'Staff' presence from retail facility
" " "	Ticket Purchase	na	0.46	Ability to sell rail tickets from retail outlet.
Car Park	Car Access	na	0.17	Major upgrade of car parking area including resurfacing,lighting, signing and walkways.
Bus Facilities	Bus Access	na	0.03	Improvement of bus waiting area including shelter and signage.
Overall Station	Sum of Attributes	1.04	3.73	Sum of individual valuations
Station Upgrade	Overall Rating	0.94	3.35	Valuation of major upgrade on opening day, on year 5 and on year 10.
After 5 years	" " "	na	2.01	
After 10 years	" " "	na	0.32	

Figure 27: Value of station upgrading by year

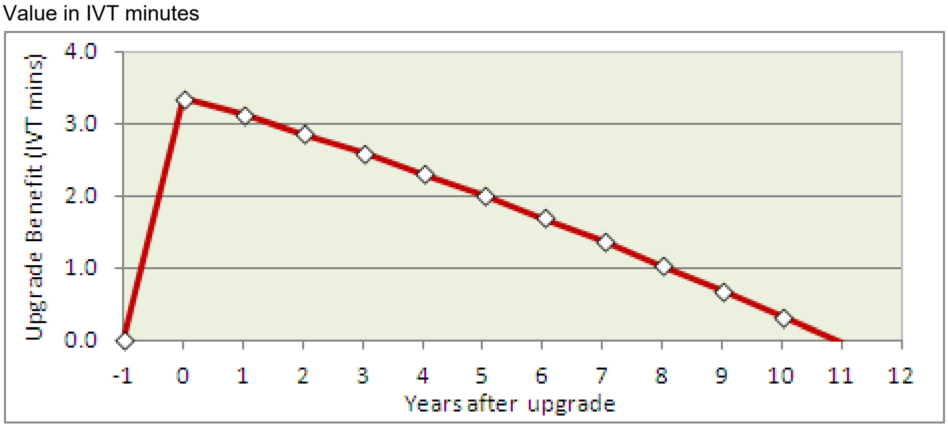

Table 46 also shows the effect of upgrades on the ratings of specific attributes such as platform shelter and seating. Some upgrades uplifted more than one rating such as retail facilities (with staff) which increased the ticket purchase, staff and retail ratings to giving a combined benefit of 0.68 minutes.

When summed, the attribute upgrades totalled 1.04 minutes for a minor upgrade and 3.73 minutes for a major upgrade. The sum of attribute valuations was therefore a little higher than the package value.

The rating approach can be used to value the 'disruption' cost to passengers during a station rebuild. As an example, the evaluation of upgrade options for Redfern station (Douglas 2009), predicted the overall rating to drop from 63.5% to 60.7% during construction. Using the figures presented here, the rating reduction would impose a cost of 0.36 minutes per boarding.[65]

9.10 Stop / station values for alighting and transfer passengers

So far, the analysis has been framed in terms of the benefit to passengers boarding at the stop/station. Accordingly, the 'per trip' values presented in Sections 9.1 to 9.9 should be multiplied by the number of passengers boarding at the bus stop or train station.

Some benefit may also accrue to passengers who alight or transfer at the station. It would be wrong to multiply the boarding values by alighting or transfer volumes since the benefit is likely to be lower. Table 47 sets out some estimates for alight and transfer movements.

Table 47: Benefit factors for boardings, alightings and transfers

	Relative Importance			Attribute Importance		
Stop/Station Attribute	Board	Transfer	Alight	Bus	TramL	Rail
Weather Protection	100%	100%	15%	25%	24%	12%
Seating	100%	100%	0%	22%	20%	12%
Information	100%	100%	15%	22%	20%	10%
Lighting	100%	100%	15%	12%	11%	8%
Cleanliness & Graffiti	100%	100%	15%	19%	18%	14%
Ticket Purchase	100%	0%	0%	na	6%	9%
Platform Surface^	100%	200%	100%	na	na	11%
Platform On/Off^	100%	200%	100%	na	na	9%
Toilet Avail & Cleanliness	100%	100%	100%	na	na	2%
Staff	100%	100%	100%	na	na	4%
Retail Facilities	100%	100%	75%	na	na	3%
Car Access Facilities	100%	0%	100%	na	na	4%
Bus Access Facilities	100%	0%	100%	na	na	2%

Given that the 'reference' movement is boarding, the relative importance percentage for these trips are 100%. Most of the transfer percentages are also 100% except for ticket purchase, car access and bus access which are 0%. For rail, the benefit for platform surface and platform 'on/off' have been doubled which assumes that a transfer involves a change of platform. If not, the benefit should be close to 100%. For alighting movements, zero benefit is assigned for seating, ticket purchase and 15% benefit for weather protection, information,

[65] Also included were the financial and economic costs of bussing passengers during construction.

lighting and cleanliness/graffiti (since there is no 'waiting' time).

The benefit for a rating improvement from 40% to 80% per board, transfer and alight movement is given in Table 48.[66] For rail, the benefit per alight trip is 1.53 minutes (30% of the board value) and 3.97 minutes per transfer movement (77%). The alight values for bus and tram stops are lower at just over 0.4 minutes per movement.

Table 48: Package stop / station value for boardings, alightings and transfers

Movement	Value of Station Rating Improvement from 40% to 80%					
	Benefit/Movement (mins)			Percent of Board (%)		
	Bus	TramL	Rail	Bus	TramL	Rail
Board	3.79	3.88	5.19	100%	100%	100%
Transfer (Same Mode)	3.79	3.56	3.97	100%	92%	77%
Alight	0.45	0.42	1.53	12%	11%	30%

^ assumes transfer involves a change of rail station platform

9.11 Stop / station values by service interval and waiting time

Unlike the vehicle quality values which are expressed on a per minute basis, the stop/station values are 'constants' per trip. Although they can be used in evaluations by expressing the effect of a station upgrade as a time saving, there are problems in including the values in a multi-modal study.

One approach is to look how the value of service interval is affected by stop/station quality. The Sydney study (38) found that around half the sensitivity to service interval was related to stop quality and the other half was invariant. Of the half that did vary, most variation was at the very poor to poor end of the stop quality spectrum.

In terms of waiting time, improving stop quality from low (40%) to high (80%), reduced the cost of waiting by 35%. For a 10-minute wait, the cost of waiting time would therefore reduce by 3.5 minutes or 4.9 minutes of in-vehicle time.

Four facilities each accounted for 10% of total improvement or a time saving of 0.45 minutes. The facilities were help points and emergency phone; ticket vending machines; provision of well-maintained toilets and repainted, refurbished what appearance. Accounting for just less than 10% were security cameras and real time information displays.

[66] The benefits were calculated by multiplying the relative importance column by the respective attribute share (taken from Table 9.6) by the package value.

9.12 Value of ferry wharf improvements

Values for improved ferry wharf are presented in Table 49. The values are based on a Booz Allen Hamilton study undertaken in 2000 scaled to equal the package value of 4.29 minutes for a 40% to 80% rating change (see Table 42).[67]

Table 49: Value of improved wharf quality

Wharf Improvement	Per Trip^	Share
Brighter lighting at wharf and approach ways	0.32	7%
Security cameras	0.40	9%
Help point and emergency phone	0.45	11%
Clear wharf announcements	0.22	5%
Computerised real time information display	0.37	9%
Provision of ticket vending machine(s)	0.46	11%
More car parking at wharf	0.19	5%
Secure bike rack	0.08	2%
Large weather protected waiting area	0.25	6%
More seating in waiting area	0.36	8%
Provision of well maintained toilets	0.44	10%
Clean, no rubbish, all graffiti regularly removed	0.26	6%
Repainted, refurbished wharf appearance	0.49	11%
Total	4.29	100%

^ Values scaled to equal average of bus, tram and rail value (Table 9.6)

67 The Booz study estimated a package value at 1.48 minutes which compares with an average of 4.29 minutes estimated by the rating surveys. The difference reflects the methodologies used. The Booz study valued improvements from the current standard whereas the rating approach valued the difference between low (40%) and high (80%) quality.

10. Mode Specific Constants

10.1 Introduction

Mode Specific Constants (MSCs)[68] measure the residual difference in modal quality after differences in travel convenience notably access/egress time, in-vehicle time, service frequency, transfer, crowding, reliability and fare have been deducted.[69]

MSCs are often used in multi-modal studies such as forecasting the patronage for new services such as a new Bus Rapid Transit route or a new Light Rail service where there may be an absence of information to 'position' the proposed new mode relative to existing public transport services.

As the previous two sections have shown, the quality of vehicles, stops and stations will vary with the age, facilities and operational aspects (i.e. cleanliness and staff). Distilling the 'intrinsic' MSC from the 'gross' MSC (which includes age, facility and operational aspects) can ensure that the nature of the comparison is understood. Is the proposed service being compared with, for example, an elderly bus fleet that would probably be replaced in 5 or so years? Should the comparison instead be 'like for like' (i.e. new versus new or mid-age versus mid-age).

Fourteen Australia and NZ studies provided MSC estimates. Eleven of the studies were undertaken as part of producing patronage forecasts for new transport services and for these estimates it is probably unlikely that the reported MSCs were purely 'intrinsic' since often a brand 'new' service was compared with a 'mid aged' existing service (at least in the eyes of the respondent). Moreover, the estimates reflect perceptions of future services rather than actual experience of existing services and are therefore more prone to misperception and potential 'policy response bias' (deliberately responding to influence a policy decision rather than reflect likely future use).

Two of the studies used observed travel data of existing services and such data has advantages over 'stated preferences', there is the disadvantage that the MSCs may incorporate statistical modelling artefacts rather that solely measure passenger preferences.

10.2 Gross Mode Specific Constants

Four gross MSCs, expressed in IVT minutes, were estimated for rail, LRT, Transitway (Busway) and Ferry. The MSCs compare each mode to travelling by bus.

The Bus – Ferry MSC was the largest at 16 minutes but should be treated with caution since it was based on only one Sydney study undertaken in 2001 (19). The bus trip time was

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[68] Sometimes referred to as Alternative Specific Constants (ASCs).

[69] Of the convenience factors, frequency, in-vehicle time, fare and transfer are the easiest to separate out. Access, crowding and reliability are more difficult and often the MSC will include them either partially or fully.

estimated at 40 minutes which implies an IVT multiplier of 0.4.

The Bus – Transitway (Busway) – MSC was the smallest at 5 minutes for a 40-minute trip implying an IVT multiplier of 0.12.

The Bus-Rail MSC was 10 minutes calculated on 22 observations from 13 studies. When divided by average trip length (33 minutes), the MSC time multiplier was 0.3. It is worth noting that the IVT times for bus and rail are likely to differ. The recommendation is to apply the IVT multiplier to bus and use the bus IVT.

For LRT-Bus MSC was 12 minutes based on 10 observations from 4 studies. The MSC was therefore 2 minutes larger than the Rail-Bus (10 minutes). In 3 of the 4 studies, LRT was a 'new' mode thus the evidence for a higher LRT constant was therefore not compelling.

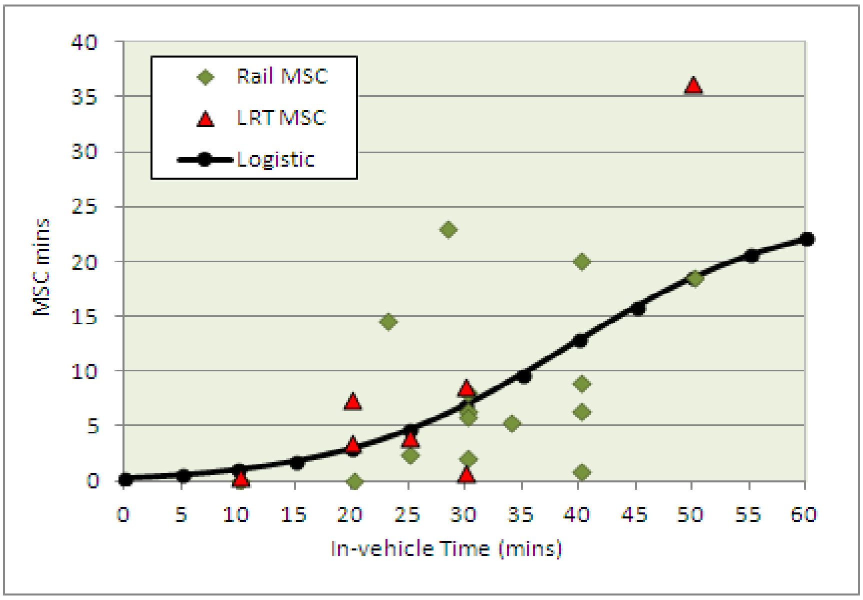
Table 50: Mode Specific Constants in IVT minutes

	Bus - Rail	Bus - LRT	Bus- (Rail/LRT)+	Bus - TW	Bus - Ferry
MSC mins	10	12	7	5	16
Bus IVT mins	33	28	30	40	40
MSC Multiplier	0.30	0.43	0.23	0.12	0.40
MSC 75%tile	14	15	na	6	25
MSC Median	6	4	na	5	18
MSC 25%tile	0	1	na	4	7
Obs	22	10	32	5	3
Studies	13	4	13	4	1

The third column presents a combined Rail/LRT MSC based on a regression (logistic) of the 32 observations taking account trip length. Figure 28 presents the data.[70] There was little difference between rail and LRT. For a 30 minute trip, the MSC was 7 minutes implying an IVT multiplier of 0.24.

[70] The fitted regression line was -8.8+0.564(IVT) with t values of 1.8 for the constant and 3.7 for the slope parameter with observations weighted according to the relative t value.

Figure 28: Estimated LRT/Rail-Bus MSC in IVT minutes



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The MSC increased with trip length. For trips under 15 minutes, a linear regression would have predicted a negative MSC (i.e. a preference for bus). However, the 'estimate' would have been largely by extrapolation since the shortest observed trip length was 10 minutes.

There were few observations of trips longer than 40 minutes so care should be taken in extrapolating the results. Equations 10.2.1 and 10.2.2 set out the logistic model with Table 51 presenting the predicted MSCs for trips ranging from 5 minutes to 1 hour (bus times).

$MSC = -0.2 + 25(Z)$ .....(10.2.1)

Where $Z = \frac{\exp(\alpha + \beta IVT)}{1 + \exp(\alpha + \beta IVT)}$ .....(10.2.2)

with estimated parameters of

Estimated parameters: $\alpha = -3.95\ \ t = 5.3$ and $\beta = -0.102\ \ t = 4.4$ with weighted observations.

Table 51: LRT/Rail - Bus predicted MSC

Bus IVT mins	5	10	15	20	25	30	35	40	45	50	55	60
MSC (mins)	0.6	1.1	1.8	3.0	4.6	6.9	9.7	12.9	15.9	18.6	20.6	22.1
IVT multiplier	0.11	0.11	0.12	0.15	0.19	0.23	0.28	0.32	0.35	0.37	0.37	0.37

For a 25-minute trip, the IVT multiplier is 0.19 minutes. The multiplier is therefore close to the 'quality control' value of 0.2 recommended by the US Federal Transit Administration (FTA) for forecasting rail and LRT patronage for 'new start' funding applications (FTA, 2006).[71]

10.3 Intrinsic Mode Specific Constants and quality difference

The Sydney 2013 study (38) attempted to estimate an intrinsic Mode Specific Constant for LRT and rail compared to bus after standardising for differences in quality (measured by ratings).[72] The study found little difference in the intrinsic MSC between LRT and rail. For LRT/Rail versus bus, a 2.7 minute intrinsic MSC was estimated for a 25-minute trip, an IVT multiplier of 0.11 (see Table 52).

Table 52: Bus - (LRT/Rail) intrinsic mode specific preference

	IVT mins	Per Min^
Intrinsic Modal Preference	2.7	0.11

^ for a 25 minute trip

Having established the 'intrinsic' MSC, differences in stop/station and vehicle quality can be added. Table 53 sets out the calculation for different quality ratings for a 25-minute trip.

Given that different modes are compared, the average parameters for the quality rating power function and also the maximum valuation of quality (0% to 100%) have been used. As can be seen, for a 25-minute trip, the stop/station and vehicle quality values are quite similar.[73]

Table 33 (vehicles) and Table 40 (stop/stations) showed little difference in the average ratings between bus, LRT/tram and train with vehicles averaging around 70% and stops/stations around 65%. New systems are likely to improve on the average rating. To illustrate the approach, a proposed LRT system is assessed where the vehicle rating increases from 70% to 80% and the stop/station rating from 65% to 75%.

From Table 53, the vehicle improvement (70% to 80%) would be worth 1.1 minute per trip (12.9 to 11.8) and the stop/station improvement (65% to 75%) 1 minute (11.9 to 10.9). Therefore, combined quality improvement from the proposed LRT system compared with the existing bus service would be worth 2.1 minutes.

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[71] The FTA values were the mirror image of 0.8 which was multiplied with the rail time when compared to bus (i.e. the mirror image of a 0.2 bus time multiplier).

[72] Passengers may rate modes differently because their expectations of quality may differ (i.e. their 'rating ruler' varies by mode). To address this, the Sydney survey asked passengers to also rate the alternative mode based on their experience of using it. Bus users therefore rated Sydney Light Rail (if they had used it) and/or Sydney rail services. The study found a tendency for respondents to rate their current mode higher than the 'alternative' and as a result, the ratings for all three modes reduced but the rating differences remained roughly the same.

[73] The total stop/station value could be increased to take account of alighting passengers benefiting. This could be done by using an average of the figures in Table 9.10.1.

Table 53: Value of vehicle and stop / station quality differences in IVT mins

	Parameters+		Valuation of Quality Rating (mins) for a 25 minute trip										
Attribute	Power	Max Val	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%
Vehicle	0.68	0.6	7.3	8.0	8.7	9.4	10.0	10.6	11.2	11.8	12.3	12.9	13.4
Stop/Station	0.62	14.2	7.4	8.0	8.7	9.2	9.8	10.3	10.9	11.4	11.9	12.4	12.8
Total	na	na	14.8	16.1	17.4	18.6	19.8	20.9	22.1	23.2	24.2	25.3	26.3

+ average values taken from Table 8.4 for vehicle and Table 9.4 for stop/staton

The value of the quality improvement can then be added to the intrinsic MSC difference of 2.7 minutes to get a gross MSC of 4.8 minutes for a 25-minute trip. In this example, quality therefore accounts for 44% of the gross MSC and intrinsic MSC 56%.

The gross MSC of 4.8 minutes is very close to the 4.6 minute figure given in Table 51 for a 25 minute trip as predicted by the logistic model.

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Appendix

Table 54: List of Australian & NZ studies reviewed

#	Label	Loc	C	Year	Ref	Client	By	Survey	Type	Users	Method	Sample	ASC	Access	Freq	Wait	Disp	IVT	Fare	Transfer	Crowd	Reliab	Veh Qual	Stop Qual	Description
1	WR90	WTN	N	1990	SDG (1990)	NZ Rail	SDG	SP	RvBvC	Rail	Int	1005	y	y	y			y	y						Forecasting the demand effect of bus competition on rail
2	WQ91	WTN	N	1991	SDG (1991)	WRC	SDG	SP	PTvPT	All	Int	335			y				y		y	y	y	y	Effects of Quality Improvements in PT
3	ALRT91	AKL	N	1991	SDG (1991)	ARC	SDG	SP	LvB	All	Int	750	y	y	y			y			y		y	y	Public Preferences for Auckland LRT & Busway for ARC / No VOT reported
4	SydR92	SYD	A	1992	SDG(1992)	City Rail	SDG/T	SP	RvBvCv W	Rail	Int	1077	y	y	y			y	y	y					Estimation of Elasticities for Primary Service Attributes for Sydney Rail
5	Per93	PER	A	1993	Piotrowski(1993)	WA DoT	TM	SP	PTvPT	PT	SCQ	1616	y							y					Before and after SP of transfer penalties as part of modelling impact of new service.
6	SL95T	SYD	A	1995	TM (1995)	NSW DoT	TM	SP	B/L v C	B,C,W	Int	nk	y	y	y			y	y	y	y				Mkt research for Demand forecasts for Western CBD Extension of Sydney LRT
7	SL95B	SYD	A	1995	BAH (1995)	NSW DoT	BAH/PC	SP	PTvPT & Trnsfr	B,R,W	Int	≈500	y	y	y			y	y		y				Parameters for Ultimo Pyrmont Light Rail Pax Study 2 SPs (Main Mode & Glebe Trf)
8	SRQ95	SYD	A	1995	PCIE (1995)	City Rail	PCIE	2 SP/PE	RvR	Rail	Int	2780									y	y	y	y	2 SP surveys plus Priority evaluator to value rail service quality
9	PC96	SYD	A	1996	PCIE (1996)	NSW DoT	RPPK	SP	PTvPT PTvCar	C,B,R	Int	nk	y	y	y			y	y	y					Estimate parameters for forecasting patronage for Parramatta-Chatswood rail link
10	M2_96	SYD	A	1996	RPPK (1996)	NSW DoT	RPPK	SP	PTvPT PTvCar	C,B	Int	nk	y	y	y			y	y	y		y			Estimate parameters for forecasting patronage for M2 Busway
11	STM96	SYD	A	1996	Hague (2001)	NSW TDC	Hague	RP	MMRP	All	HSTS	nk	y	y	y	y		y	y	y					Sydney Travel Model based on Household Travel Survey. Calibration report
12	LivTW98	SYD	A	1998	PPK (1998)	NSW DoT	PPK	SP/PE	PTvPT PTvCar	C,B,R	Int	1196	y	y	y			y	y	y					SP+Priority Evaluator to estimate parameters for Liv-Par TWay pax forecasts
13	SBQ99	SYD	A	1999	Hensher (2002)	STA NSW	ITS Syd	SP	Bus	Bus	SCQ	3849		y	y			y	y			y			Estimation of model to develop service quality index for bus service
14	SBQ00	SYD	A	2000	Hensher (2003)	STA NSW	ITS Syd	SP	Bus	Bus	SCQ	1478		y	y			y	y		y	y			Estimation of model to develop service quality index for bus service
15	BSG00	BRI	A	2000	PCIE (2000)	Ove Arup	PCIE	SP	PTvPT	C,PT	Int	623	y	y	y			y	y						Parameters estimation for demand forecasts for suburban Brisbane rail services
16	BJ00	SYD	A	2000	Halcrow (2000)	Lend Lease	Halcrow	SP	RvR	C,B,R	Int	1649		y		y		y	y						Estimate parameter for patronage forecasts for extending Bondi Junction rail line
17	SdNw00	SYD	A	2000	PCIE (2000)	SRA	PCIE	SP	RvR	Rail	Int	255			y			y	y	y					Parameter estimation for demand forecasts for faster Sydney-Newcastle rail
18	Bri01	BRI	A	2001	Douglas (2003)	BCC	BAH/PCIE	SP	PTvPT PTvCar	C,B,R,F	Int	≈3000	y	y	y			y	y	y					Estimate demand forecasting parameters
19	SFry01	SYD	A	2001	BAH (2001)	SydFerry	BAH/PCIE	SP	FvB FvC	B,F	Int	841	y	y	y			y	y	y		y			Estimate demand parameters for business model of Sydney ferries
20	NZEM02	ACW	N	2001	Beca (2002)	Transfund	SDG	SP	BvB RvR	B,R	SCQ	815			y			y	y	y	y	y			2 SPs (VOT & Rel/Crwd) of AUC, CHC & WTN PT users. Values were basis of NZ EEM.

#	Label	Loc	C	Year	Ref	Client	By	Survey	Type	Users	Method	Sample	ASC	Access	Freq	Wait	Disp	IVT	Fare	Transfer	Crowd	Reliab	Veh Qual	Stop Qual	Description
21	Can03	CAN	A	2003	BAH(2003)	ACT	BAH	SP	BvB BvTxi/C	C,B,T	Int	586	y	y		y		y	y						Estimate parameters for fare elasticities for Canberra bus services
22	SydR03	SYD	A	2003	Douglas (2003)	SRA	DEL	SP	RvR	Rail	Int	1578			y			y	y	y					Estimate primary service parameters for economic appraisal of rail services.
23	SNW03	SYD	A	2003	Hensher (2003)	NSW DoT	ITS Syd	SP	Multi Modal	C,B,R	SQC	453	y	y	y	y		y	y	y					Estimation of parameters for model to forecast demand for new PT in NW Sydney
24	SLRT03	SYD	A	2003	BAH (2003)	NSW DoT	BAH/DE	SP	LvB LvBvR	C,B,R	Int	1063	y	y	y	y		y	y	y					Parameter estimation for Sydney LRT ext. demand forecasts.
25	SRSC04	SYD	A	2005	Douglas(2005)	Rail Corp	DEL	SP	RvR	Rail	Int	335		y		y					y				Estimation of station crowding values relative to platform waiting
26	SRQ05	SYD	A	2005	Douglas(2006a)	Rail Corp	DEL	Rating	RvR	Rail	Int	nk						y	y			y	y	y	Estimation of service quality via passenger ratings
27	DND05	MEL	A	2005	Halcrow (2005)	VTIDpt	Halcrow	SP/PE	RvR	Rail	Int	103					y	y	y		y	y	y		Rail study. VoT too high (> $30/hr) and omitted
28	SRTC06	SYD	A	2005	Douglas (2006b)	Rail Corp	DEL	SP	RvR	Rail	Int	584				y		y	y		y				Valuation of Sydney train crowding for economic evaluations
29	STM06	SYD	A	2006	Fox (2010)	BTS Syd	Rand	RP	MMRP	All	Int	55812	y	y	y	y		y	y						Sydney Travel Model based on Household Travel Survey
30	SunV06	MEL	A	2006	BAH (2006)	VDoI	BAH	SP	RvR	Rail	Int	2031			y			y	y		y	y	y	y	Survey of suburban and longer distance rail into Melbourne. SP and priority evaluator for quality attributes.
31	WTLY08	WTN	N	2008	Wallis (2008)	NZ Bus	IWA	SP	BvB	Bus	Int	122						y	y		y				Mkt research on trolley bus seat layout
32	NZRI08	A&W	N	2007	Vincent (2008)	Transfund	BAH	SP	RvR BvB	B,R	Cint	751						y	y			y			Internet survey of Auc bus & Wel bus and rail users. Surveys undertaken in 2007.
33	AusTC10	CAP	A	2010	CRC (2010)	CRC	CRC	SP	RvR	All	Cint	1800						y	y		y				Internet survey of rail & non rail users about train crowding in Adl, Bri, Mel, Syd, Per
34	SMet11	SYD	A	2011	Hensher (2011)	NSW DoT	ITS Syd	SP	Multi Modal	All	Cint	524	y	y	y			y	y	y	y				Internet survey of parameters to forecast demand for Metro services in NW Sydney
35	SRVoT12	SYD	A	2011	DEL(2012)	Rail Corp	DEL	SP	RvR	Rail	Int	1672					y	y	y						Valuation of time and displacement for rail economic appraisals
36	SIC12	SYD	A	2012	Douglas (2013)	BTS Syd	DEL	SP	PTvPT	B,R	Int	939						y	y	y					Value of different types of interchange
37	NZPS13	ACW	N	2013	Douglas (2014)	NZTA	DEL	SP	BvB RvR	B,R	SCQ	5048			y	y		y	y				y	y	Value of quality survey of bus & rail users in AUC, CHC & WTN. Large sample of 12,557 incl 5048 SP surveys.
38	InSyd13	SYD	A	2013	DEL (2014)	BTS Syd	DEL	SP	PT v PT	B,L,R	SCQ& Int	4674	y		y	y	y	y	y	y	y		y	y	4674 SP + 2036 Rating surveys using self-comp q'aires & interviewers of bus, LRT & rail users in Inner Sydney.
39	MelInfo	MEL	A	2014	DEL/SW(2014)	PTV Mel	DEL/Sweeney	SP	PT v PT	B,L,R	SCQ	1800			y	y		y	y				y	y	Value of quality survey of bus, tram (L) & rail users in MEL. (900 Rating & 900 SP surveys)
40	Syd14	SYD	A	2014	Legaspi(2015)	TfNSW	DEL	SP	PTvPT	B,L,R,F	SCQ				y	y		y	y				y	y	Systemwide survey of rail, bus, LRT and ferry users covering Sydney, Newcastle and Wollongong. Some overlap with study 38.

Table 55: List of 'Vehicle & Stop Quality' studies reviewed

#	Ref	Label	Description	Ref	Client	Location	Year	Modes
1	2	WQ91	*Quality of Public Transport*	*SDG (1990)*	*WRC*	Wellington	1991	Bus & Rail
2	8	SRQ95	*Value of Rail Service Quality*	*PCIE (1995)*	*City Rail*	Sydney	1995	Rail
3	12	LivTW98	*Liverpool-Parramatta Transitway*	*PPK (1998)*	*NSW DoT*	Sydney	1998	Bus
4	13& 14	HenBS	*Developing a Bus Service Quality Index*	*Hensher (2002,03)*	*STA NSW*	Sydney	1999-02	Bus
5	25	SRQ05	*Value of Sydney Rail Service Quality*	*Douglas (2006a)*	*City Rail*	Sydney	2004-5	Rail
6	27	DND05	*Survey of Dandenong Rail Quality*	*Halcrow (2005)*	*VTIDpt*	Victoria	2003	Rail
7	41	UKRS	*Valuing UK Rolling Stock*	*Wardman (2001)*	*UK Rail*	UK	Pre 2001	Rail
8	42	WTNRST	*Wellington Station Quality*	*Doug Econ (2005)*	*Tranz Metro*	Wellington	2002/05	Rail
9	43	SDGLND	*London, Bus & Train Values*	*SDG (1995,07)*	*TfL*	London UK	1995-07	Bus & Rail
10	44	LDSSQ	*Bus Quality Package Values*	*Evmorf-opoulos (2007)*	*MSc Dissertation*	Leeds UK	2007	Bus
11	45	AECOMBS	*Soft Measures influencing Bus*	*AECOM (2009)*	*UK DoT*	UK Cities	2009	Bus
12	46	USPT	*Valuing Premium Public Transport*	*Outwater (2010)*	*US FTA*	4 US Cities	2010	Bus & Rail
13	47	NORPT	*Universal Design Measures in PT*	*Hammer (2007)*	*Public Roads*	Norway	2007	Bus

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