Transport for NSW

Transport for NSW Economic Parameter Values

For economic modelling, appraisal, and evaluation of the NSW Government Transport Cluster initiatives.

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transport.nsw.gov.au

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Dollar values in Tables are as at January 2023 unless specifically stated otherwise.

Economic Advisory

Economics, Benefits and Evaluation

Investment Assurance and Business Case Advisory

Investment and Assurance Branch

Finance and Investment Division

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1 Introduction

1.1 Purpose

This document recommends economic parameter values for common benefits and costs in transport economic appraisals. By providing best-practice approaches and economic parameter values, this document supports the consistent application of cost-benefit analysis (CBA) across the NSW Transport cluster.

This document is targeted at CBA practitioners and includes accompanying Excel tools.

1.2 How to use this document

This document provides recommended economic parameter values to be used in the CBA of initiatives within the NSW Transport cluster. Recommendations begin with **bold text** for ease of use. However, it is not intended to enforce strict compliance with a particular approach where it does not support sensible analysis.

Parameter values that are not recommended in this document may still be used. This may occur when project specific information points to more relevant parameters, or when the relevant parameter value is not available within this document. If parameter values are used which are not recommended, they should be accompanied by evidence to support their validity. Good practice would involve calculating results with recommended and preferred parameters and explaining the difference.

This document should be read with the Transport for NSW Cost-Benefit Analysis Guide (the Guide), which provides overarching guidance for undertaking CBA and Transport for NSW (TfNSW) recommended approaches.

1.3 What has changed?

This document was previously included as Appendix 4 of the Principles and Guidelines: Economic Appraisal of Transport Investments and Initiatives (Principles and Guidelines). The Principles and Guidelines is in the process of being updated to reflect recent research and will be split into a suite of products targeted at various audiences.

The values in this document have been adjusted to reflect data available as of January 2023 and updated to reflect new information where available. Some additional information from other guidance documents has been included in this version for the first time.

Updated recommendations in this version are summarised in Table 1.1.

Table 1.1 Updated recommendations

Section	Updated recommendations
Changes in this version	
Placemaking (Section 16)	Adoption of the VASP+PERS amenity improvement methods
Active transport (Section 7)	Updated active travel health benefit values
Changes in previous version	
All	Indexation of all relevant parameter values to January 2023 prices.
Road vehicle operating costs (Section 3)	Recommends the use of ATAP VOC models for all projects and for all road vehicle types.
Environmental impacts (Section 6)	Adoption of carbon values from NSW Government Cost Benefit Guide TPG23-08. The updated carbon values include an increment per annum. Additional carbon price related sensitivity tests recommended as per NSW Treasury. Adoption of ATAP 2021 PV5 Environmental Parameter Values.
Active transport (Section 7)	Adoption of ATAP M4 Active Transport health benefit parameter values as core estimate, and recommend the use of TfNSW's and NSW Ministry of Health's values as sensitivities.

Source: Economic Advisory, TfNSW (2023)

Table 1.2 Appendices in this version

Appendices	Title	New / Existing
A1	Other methods of valuing travel time	Existing
A2	Vehicle classification	Existing
A3	Parameters for use with strategic demand models	Existing
A4	Key indices	Existing

Source: Economic Advisory, TfNSW (2023)

1.4 Urban and rural parameters

This document includes parameters that are valued differently depending on whether the impacts occur in urban or rural areas. For the purposes of cost-benefit analysis of NSW Transport cluster projects, 'urban' tends to refer to:

- Sydney
- Newcastle
- Wollongong
- Other town centres in NSW where the posted road speed limit is equal to or less than 80 kilometres per hour

Other areas are generally considered to be rural, especially where road traffic is free-flowing. However, it is good practice to consider whether urban or rural parameters are appropriate on a case-by-case basis for projects, and whether project-specific parameters may need to be estimated

1.5 Changes to come

The field of transport economics is constantly evolving and TfNSW is continually working to update the content of this document to reflect the most up-to-date research.

Comments or questions should be directed to EconomicAdvisory@transport.nsw.gov.au

2 Travel time savings

TfNSW recommends the following values of travel time (VTT) for CBA:

- VTT (private) = $19.45 per person hour
- VTT (business) = $63.09 per person hour

VTT (business) should only be applied for travel between two business locations. Commuting to and from work should use the private value of travel time.

The VTT per hour of vehicle travel can be calculated from the occupancy rate, value per occupant and value of freight (Table 2.1). An overall value, referred to as 'vehicle hour', can be estimated by weighing total traffic by vehicle composition (Table 2.4 and Table 2.5).

The values in Table 2.1 are based on average weekly earnings of private travellers and the cost of wages for business travellers (Australian Transport Assessment and Planning, 2016). It is assumed that the VTT for occupants is the same for both urban and rural roads. If available, values derived from project specific surveys can replace the occupancy rates from Table 2.4 and Table 2.5.

Many strategic transport demand models report travel time for light commercial vehicle (LCV) and heavy commercial vehicle (HCV). Where detailed commercial vehicle data is available, for example by vehicle type, specific values of travel time can be derived using the data outlined in Table 2.1.

If detailed commercial vehicle data is not available, TfNSW recommends the following values of time be used in CBA for urban areas.

- VTT of urban LCV = $39.85 per vehicle hour
- VTT of urban HCV = $68.65 per vehicle hour

Detailed commercial vehicle data should be used in CBA for rural areas. This is because the vehicle mix on rural roads differs significantly depending on its location, and particularly on key freight routes and corridors across NSW. Figures in Table 2.3 can be used where the assumed commercial vehicle mix is not likely to have a material impact on the CBA results.

2.1 Actual and perceived travel time

Travellers make travel decisions based on their perception of the total perceived cost of travel, including travel time, as well as several other quality and service factors such as comfort, reliability, security, and cleanliness.

Travellers may perceive one mode of transport as better than another even after these tangible benefits have been accounted for. For example, light rail can be preferred over bus even when accounting for travel time and vehicle quality attributes.

In strategic demand models, in-vehicle time weights are often applied to different public transport modes to correctly predict travel behaviour. This reflects that travellers may perceive their travel time to have reduced when they switch to a preferred mode, such as from bus to light rail. **TfNSW recommends** that these 'intrinsic mode preference' impacts are assessed and reported separately from travel time savings (for example, using the approach outlined in Section 11.5).

In addition, **TfNSW requires** that benefits estimated using perceived travel time must clearly report the proportion of travel time savings that are actual versus perceived.

Table 2.1 Value of travel time – urban and rural roads

Vehicle type	All	Non-urban		Urban		Non-urban		Urban	
	Value per occupant ($/ person-hour)	Occupancy rate (persons /vehicle)	Freight ($/vehicle-hour)	Occupancy rate (persons /vehicle)	Freight ($/vehicle-hour)	Value per occupant ($/km)	Freight ($/vehicle-km)	Value per occupant ($/km)	Freight ($/vehicle-km)
Cars (all types)									
Cars - Private	19.45	1.70		1.41		0.22		0.39	
Cars - Business	63.09	1.30		1.06		0.70		1.26	
Utility vehicles									
Courier van utility	32.97	1.00		1.00		0.37		0.66	
4WD mid-size Petrol	32.97	1.50		1.50		0.37		0.66	
Rigid trucks									
Light Rigid	32.97	1.30	0.98	1.19	1.92	0.37	0.01	0.66	0.04
Medium Rigid	33.37	1.20	2.65	1.19	5.21	0.37	0.03	0.67	0.10
Heavy Rigid	33.98	1.00	9.06	1.19	17.81	0.38	0.10	0.68	0.36
Articulated trucks									
4 Axle	34.78	1.00	19.48	1.19	38.37	0.39	0.22	0.61	0.67
5 Axle	34.78	1.00	24.83	1.19	48.93	0.39	0.28	0.61	0.86
6 Axle	34.78	1.00	26.79	1.19	52.76	0.39	0.30	0.61	0.92
Combination vehicles									
Rigid + 5 Axle Dog	35.29	1.00	38.29	1.19	79.01	0.39	0.43	0.62	1.38
B-Double	35.29	1.00	39.46	1.19	81.42	0.39	0.44	0.62	1.42
Twin steer + 5 Axle Dog	35.29	1.00	37.00	1.19	76.37	0.39	0.41	0.62	1.33
A-Double	36.30	1.00	51.81	1.19	106.93	0.40	0.58	0.63	1.87
B-Triple	36.30	1.00	52.89	1.19	109.14	0.40	0.59	0.63	1.91
A B combination	36.30	1.00	63.71	1.19	131.45	0.40	0.71	0.63	2.30
A-Triple	36.91	1.00	76.37	1.19	157.59	0.41	0.85	0.65	2.75
Double B-Double	36.91	1.00	77.25	1.19	159.41	0.41	0.86	0.65	2.79
Buses									
Heavy Bus (Driver)	33.37	1.00		1.19		0.37		0.58	
Heavy Bus (Passenger)	19.45	20.00		20.00		0.22		0.34	

Source: Values are based on ATAP 2016 PV3 Road Parameter Values pg. 16-19, except Urban occupancy rates which are estimated from the 2014/15 Household Travel Survey (5 years pooled unlinked trips dataset provided by Transport Performance and Analytics, TfNSW). Values per occupant are indexed from May 2013 Average Weekly Earnings (AWE) to January 2023 AWE (ABS Series ID A84994877K). Freight values are indexed from June 2013 prices to January 2023 prices (ABS Series ID A2314058K)
Notes: To obtain values per km (last 4 columns), the following speeds were assumed: Non-urban – 90km/h; Urban (Cars, Utility vehicles, Rigid trucks) – 50km/h; Urban (All other vehicle types) – 57km/h.

Table 2.2 Average hourly value of travel time by vehicle type – urban

Period	Time + Freight value ($ per vehicle)	Default yearly hours	Proportion of AM peak hourly volume
Peak hours	34.03	1,200	1.00
Peak shoulders	34.03	800	0.75
Business hours	35.30	3,450	0.62
Other hours	27.29	3,310	0.17
Total		8,760	
Average hourly value ($ per vehicle hr, weighted by vehicle type and annual average kilometres travelled)			
Car			32.50
Light commercial vehicle (LCV)			39.85
Heavy commercial vehicle (HCV)			68.65
Bus (including driver and average of 20 passengers)			428.77

Source: Estimated by Evaluation and Assurance, TfNSW. Values have been indexed to January 2023 prices (ABS Series ID A84994877K)

Table 2.3 Average hourly value of travel time by vehicle type – rural

Vehicle type	% of vehicle type in vehicle fleet	Occupancy	VTT for occupants		VTT for freight ($/vehicle-hr)	Total VTT ($/vehicle-hr)
			$/person-hr	$/vehicle-hr		
Private car	62.56	1.7	19.45	33.06		33.06
Business car	8.79	1.3	63.09	82.02		82.02
Utility vehicle*	15.84	1 to 1.5	32.97	39.85		39.85
Heavy commercial**	8.07	1 and 1.3	34.08	36.20	13.52	49.72
Combination vehicles***	3.95	1	40.83	35.36	40.83	76.19
Bus	0.77	21	52.82	422.34		422.34
Average hourly value ($ per vehicle hr)						
Car						39.09
Light commercial vehicle (LCV)						39.85
Heavy commercial vehicle (HCV)						58.42
Bus (including driver and average of 20 passengers)						422.34

Source: Estimated by Economic Advisory, TfNSW. Values have been indexed to January 2023 prices (ABS Series ID A84994877K)
Vehicle composition is estimated using the ABS Survey of Motor Vehicle Use 2018. Split of private and business car trips estimated using BTS Household Travel Survey data 2014/15
*Light commercial/courier van utility and 4WD mid-size petrol
**Heavy commercial vehicles include rigid trucks and articulated trucks (4 axle, 5 axle and 6 axle)
***Combination vehicles include B-Double + Road Trains

2.2 Additional information: Value of travel time

This section is intended to aid in the application of the figures in Table 2.1.

Table 2.4 and Table 2.5 present vehicle occupancy and traffic composition for cars on urban roads. Figures are categories by the time of day:

- peak hours are trips arriving from 7:00AM to 10:00AM and 4:00PM to 7:00PM
- business hours refer to trips arriving from 10:00AM – 4:00PM
- other hours refer to all other times.

Table 2.4 Vehicle occupancy – urban

Hours	Private car	Business car	Commercial	
			Light	Heavy
Peak hours	1.41	1.07	1.21	1.19
Business hours	1.43	1.06	1.17	1.19
Other	1.39	1.07	1.16	1.19
All	1.41	1.06	1.19	1.19

Source: Estimated by Economic Advisory, TfNSW using the 2014/15 Household Travel Survey (5 years pooled unlinked trips dataset provided by Transport Performance and Analytics, TfNSW)

Table 2.5 Vehicle composition – urban

Hours	Private car %	Business car %	Commercial	
			Light %	Heavy %
Peak hours	71	9	16	4
Business hours	66	11	16	7
Other	67	9	18	6
All	68	10	16	6

Source: Estimated by Economic Advisory, TfNSW using the 2014/15 Household Travel Survey (5 years pooled unlinked trips dataset provided by Transport Performance and Analytics, TfNSW)
Note: Proportions are based on the number of trips by vehicle type, weighted by average trip length

2.3 Value of access, waiting, transfer and unexpected delay time

TfNSW recommends the multipliers to be applied for access / egress walking, waiting times and unexpected delays in Table 2.6.

When travel times are unreliable, travellers will include buffer times on their journey. **TfNSW recommends** additional buffer time built into a journey (because of travel time variability) be treated equally as costly as the time spent traveling.

Table 2.6 Access, waiting, transfer and unexpected delay time multipliers

Category	ATAP recommended	TfNSW recommended
Access / egress walking	1.5	1.5
Waiting time		
Bus stop/rail platform waiting time	1.4	1.4
Transfer waiting time	1.5	1.5
Unexpected delay time		
Departure delay time	6.4	3.2
Arrival on vehicle delay waiting	2.9	
Non-specific delay waiting	2.3	
Average delay waiting	3.2	

Source: Australian Transport Council (ATC) Guidelines Public Transport Parameter Review Report by Douglas Economics, October 2015

Parts of the journey are less comfortable than others. For example, waiting times, egress walking and unexpected delays are less comfortable to the traveller than on-board time. TfNSW recommends the multipliers provided in Table 2.6 which convert less comfortable parts of the journey into equivalent on-board time. For example, 1 minute walking time is equivalent to 1.5 minutes on-board train time, and a 1-minute train-delay is equal to 3.2 minutes of on-board train time.

The value of waiting time can be used to evaluate initiatives which change frequency. An increase in service frequency would reduce waiting time. The unexpected delay time multiplier is used for valuing unexpected service delays, for example, delays as a result of incidents.

Unexpected delays are more costly to the traveller compared to expected delays. Travellers are likely to build a buffer into their journey consistent with expected delays, this is unlikely to disrupt the rest of their day. However, an unexpected delay is more costly to the traveller, as this is unlikely to have been planned for.

2.4 Value of transfers

Changing vehicles during a journey is inconvenient; consequently, a traveller attaches a disutility to a transfer. TfNSW recommends the equivalent in-vehicle times (IVT) for vehicle transfers in Table 2.7. For example, a bus-to-bus transfer is equivalent to 14.8 minutes of IVT. These figures were derived from a stated preference study commissioned by TfNSW. (Douglas Economics, 2014)

Table 2.7 Value of transfer

Mode	TfNSW recommended (1) (IVT min / transfer)			ATAP recommended (2) (IVT min / transfer)
	Train	Bus	Light Rail	
Train*	7.2	13.7	4.1	Same mode transfer: 6 Different mode transfer: 10
Bus		14.8	3.8	
Light Rail			5.2	

Sources: (1) Douglas Economics, 2014. TfNSW values sourced from Passenger service quality values for bus, LRT and rail in inner Sydney, report to Bureau of Transport Statistics, TfNSW. (2) ATAP values sourced from ATC Guidelines Public Transport Parameter Review Report by Douglas Economics, October 2015

Note: *The train to train penalty is higher than the value estimated by RailCorp Economic Unit in 2011, which recommended a transfer penalty equivalent to an IVT of 6 min. IVT of 7.2 is preferred as the stated preference surveys used to calculate this figure are more recent

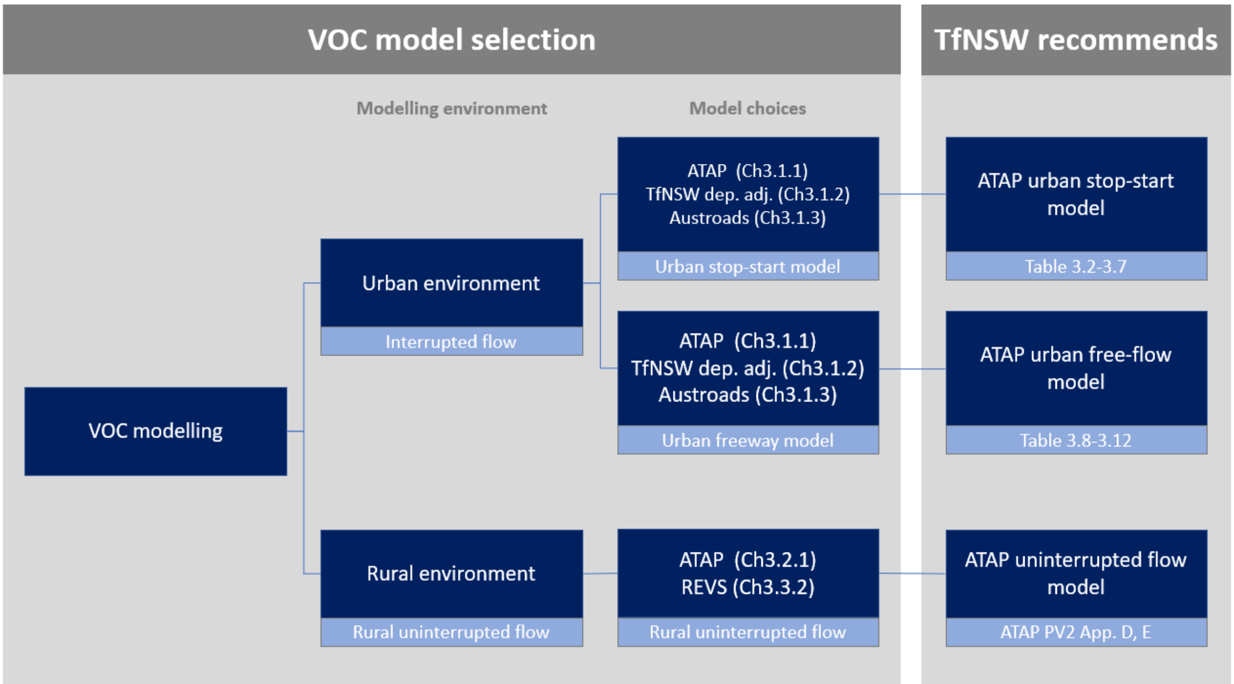
3 Road vehicle operating costs

TfNSW recommends the Vehicle Operating Cost models in Australian Transport Assessment and Planning (ATAP) National Guidelines for both urban and rural projects. It should be used in Commonwealth funded project. Accepted by both by Infrastructure Australia and Commonwealth Department of Infrastructure, Transport, Regional Development, Communications and Arts (DITRDCA), it is an Australian-wide VOC approach which will ensure that the VOC saving benefits in the business case and investment proposals are consistent and comparable at the national level.

TfNSW accepts the use of TfNSW depreciation-adjusted VOC model and the Austroads VOC models in a CBA. TfNSW's Technical Note on Calculating Road Vehicle Operating Costs (VOC Technical Note 2022) is available at the Economic Advisory' SharePoint site, which discusses a range of techniques for estimating the VOC for urban and rural projects.

The following flow chart demonstrates the range of models included in this document and the considerations under different circumstances. It can be used to assist in selecting a VOC model.

Figure 3.1 Vehicle operating costs model selection



Source: TfNSW Economic Advisory 2023

For urban vehicle operating cost models, kilometres travelled at speeds below 5kph should be treated as travelling at 5kph for the purpose of calculating VOC, unless evidence can be provided for their inclusion. This is because the ATAP and Austroads VOC models produce high per-kilometre values at speeds below 5 kilometres per hour, which may be inappropriate for inclusion in economic appraisals when applied to outputs from strategic demand models.

Table 3.1 Urban vehicle operating cost models: low speed resource costs ($/km)

Vehicle operating cost model	Speed (km/h)									
	1	2	3	4	5	6	7	8	9	10
Diverted estimate of VOC when the speed is below 5 km/ h - medium car										
ATAP VOC model value	17.97	9.07	6.10	4.62	3.73	3.14	2.71	2.40	2.15	1.95
TfNSW depreciation-adjusted model value	7.20	3.71	2.54	1.96	1.61	1.38	1.21	1.09	0.99	0.91
TfNSW recommended value	3.73	3.73	3.73	3.73	3.73	3.14	2.71	2.40	2.15	1.95

Source: Estimated by Economic Advisory, TfNSW. Estimates based on the coefficients in Table 3.2 then indexed from June 2013 to January 2023 prices (ABS Series ID A2326616R).

3.1 Urban vehicle operating cost models

3.1.1 ATAP PV2 Urban VOC model

The Urban Stop-Start Model predicts VOC where vehicles stop and start, and the average speed is less than 60 km/h. The freeway model predicts VOCs for operations over freeways and high-quality arterials where average travel speeds over 60 km/h. The functional forms of the two models are:

Equation 1 Urban Stop-Start Model

$$c = A + \frac{B}{V}$$

Equation 2 Freeway Model

$$c = C_0 + C_1 V + C_2 V^2$$

Where:

- **c** represents VOCs (cents/km)
- **V** represents journey speed (km/h)
- **A**, **B**, **C_0**, **C_1**, and **C_2** are model coefficients

The model coefficients by vehicle types are given in Table 3.8. Under the freeway condition, VOC initially decreases as speed increases, as C_1 is negative. Beyond a certain speed threshold, VOC increases when speed increases.

Table 3.2 Coefficients for the ATAP Urban Stop-Start Model and the Freeway Model

Vehicle Type	Stop-start		Free-flow		
	A	B	C_0	C_1	C_2
Car (all types)					
Small car	16.9442	1134.1444	34.8987	-0.1695	0.0014
Medium car	17.1163	1779.7837	47.4156	-0.2369	0.0016
Large car	19.5222	2487.3008	62.4729	-0.3005	0.0019
Utility vehicles					
Courier van utility	23.1185	1968.8685	55.8429	-0.2669	0.0020
4WD mid-size Petrol	28.4763	1797.7458	54.8715	-0.2083	0.0018
Rigid trucks					
Light Rigid	49.2821	2239.3367	74.7278	-0.3599	0.0036
Medium Rigid	51.9429	3278.5933	90.9330	-0.4355	0.0038
Heavy Rigid	82.9258	3708.2697	119.3835	-0.8015	0.0077
Bus - heavy bus	93.6570	6720.1713	180.9126	-0.9382	0.0068
Articulated trucks					
4 axle	122.6929	4820.9106	161.9956	-1.0504	0.0104
5 axle	132.2088	5351.3096	173.9460	-0.9865	0.0096
6 axle	143.1765	5790.4085	186.6960	-0.9978	0.0096
Combination vehicles					
Rigid + 5 Axle Dog	177.7930	5411.1339	197.5392	-0.9289	0.0094
B-Double	178.4326	6662.1843	219.7499	-1.0486	0.0099
Twin steer + 5 Axle	184.5335	6354.3144	217.5148	-1.0026	0.0097
A-Double	208.9002	8257.7659	266.2669	-1.2085	0.0107
B-Triple	216.7645	10350.4288	310.6713	-1.4331	0.0118
A B combination	247.0964	9078.6728	302.7858	-1.3082	0.0116
A-Triple	276.5859	10351.1114	343.9305	-1.4698	0.0125
Double B-Double	289.5300	10121.0011	346.3338	-1.4336	0.0125

Source: TfNSW Economic Advisory (2023) based on ATAP Guidelines PV2 Road Parameter Values (2016).
Note: Coefficients produce VOC estimates in January 2023 prices

VOC values are presented in Table 3.3 to Table 3.7. The VOC are calculated for different speeds and indexed to January 2023 prices. Three types of vehicle operating costs (VOC) are presented:

- **Resource costs:** should be used in a CBA. Resource costs represent the value of a resource to society, which is often estimated as the market price excluding taxes and subsidies. Taxes and subsidies are transfers between individuals and government and do not reflect the underlying value of a resource. The resource costs are presented in Table 3.3 and Table 3.4,
- **Perceived costs:** should be used for travel demand modelling, as well as in CBA which assesses the impacts of induced demand. This is the cost perceived by drivers. The values Table 3.5 can be used for cars (all types) while the figures in Table 3.6 and Table 3.7 can be used for commercial vehicles, which fully perceive all financial costs.
- **Financial cost:** can be used in a financial appraisal. It only incudes the direct effect on an organisation's investment portfolio and uses accounting concepts. The financial cost will include market costs, including taxes and subsidies. The financial costs are presented in Table 3.6 and Table 3.7.

Table 3.3 ATAP Urban Start-stop Model VOC: Resource cost (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
ATAP PV urban VOC model (Equation 1: stop-start)										
Cars (all types)										
Small car	73.65	54.75	45.30	39.63	35.85	33.15	31.12	29.55	28.29	27.25
Medium car	106.11	76.44	61.61	52.71	46.78	42.54	39.36	36.89	34.91	33.30
Large car	143.89	102.43	81.70	69.27	60.98	55.06	50.61	47.16	44.40	42.13
Utility vehicles										
Courier van utility	121.56	88.75	72.34	62.50	55.93	51.25	47.73	44.99	42.81	41.02
4WD petrol	118.36	88.40	73.42	64.43	58.44	54.16	50.95	48.45	46.45	44.82
Rigid trucks										
Light Rigid	161.25	123.93	105.27	94.07	86.60	81.27	77.27	74.16	71.68	69.64
Medium Rigid	215.87	161.23	133.91	117.51	106.59	98.78	92.93	88.37	84.73	81.75
Heavy Rigid	268.34	206.53	175.63	157.09	144.73	135.90	129.28	124.13	120.01	116.64
Bus - heavy bus	429.67	317.66	261.66	228.06	205.66	189.66	177.66	168.33	160.86	154.75
Articulated trucks										
4 axle	363.74	283.39	243.22	219.11	203.04	191.56	182.95	176.26	170.90	166.52
5 axle	399.77	310.59	265.99	239.23	221.40	208.66	199.10	191.67	185.72	180.86
6 axle	432.70	336.19	287.94	258.98	239.68	225.90	215.56	207.51	201.08	195.82
Combination vehicles										
Rigid+5 Axle Dog	448.35	358.16	313.07	286.02	267.98	255.09	245.43	237.92	231.90	226.99
B-Double	511.54	400.51	344.99	311.68	289.47	273.61	261.71	252.46	245.05	239.00
Twin steer+5 Axle	502.25	396.34	343.39	311.62	290.44	275.31	263.96	255.14	248.08	242.30
A-Double	621.79	484.16	415.34	374.06	346.53	326.87	312.12	300.65	291.48	283.97
B-Triple	734.29	561.78	475.53	423.77	389.27	364.63	346.14	331.77	320.27	310.86
A B combination	701.03	549.72	474.06	428.67	398.41	376.79	360.58	347.97	337.88	329.63
A-Triple	794.14	621.62	535.36	483.61	449.10	424.46	405.97	391.60	380.10	370.69
Double B-Double	795.58	626.90	542.55	491.95	458.21	434.12	416.04	401.99	390.74	381.54

Source: Estimated by Economic Advisory, TfNSW. Estimates based on the coefficients in Table 3.2

Table 3.4 ATAP Urban Freeway Model VOC: Resource cost (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
ATAP PV urban VOC model (Equation 2: Freeway)										
Cars (all types)										
Small car	32.05	31.03	30.28	29.80	29.60	29.66	30.00	30.60	31.48	32.62
Medium car	43.33	41.77	40.54	39.63	39.05	38.79	38.85	39.25	39.96	41.00
Large car	57.22	55.16	53.48	52.18	51.26	50.72	50.56	50.77	51.37	52.34
Utility vehicles										
Courier van utility	51.32	49.66	48.41	47.57	47.14	47.11	47.49	48.27	49.46	51.06
4WD petrol	55.13	53.84	52.92	52.38	52.22	52.44	53.04	54.01	55.36	57.08
Rigid trucks										
Light Rigid	68.98	67.19	66.13	65.80	66.19	67.30	69.15	71.71	75.00	79.02
Medium Rigid	83.73	81.26	79.55	78.59	78.38	78.93	80.23	82.29	85.10	88.67
Heavy Rigid	106.43	102.26	99.62	98.53	98.97	100.95	104.47	109.53	116.12	124.25
Bus - heavy bus	164.88	158.90	154.29	151.05	149.17	148.65	149.49	151.70	155.28	160.21
Articulated trucks										
4 axle	145.17	139.89	136.69	135.59	136.58	139.65	144.82	152.07	161.42	172.85
5 axle	158.05	152.97	149.81	148.56	149.22	151.81	156.30	162.72	171.04	181.29
6 axle	170.57	165.38	162.10	160.74	161.30	163.77	168.15	174.45	182.66	192.79
Combination vehicles										
Rigid+5 Axle Dog	182.73	178.16	175.47	174.67	175.75	178.72	183.58	190.32	198.95	209.46
B-Double	202.72	197.17	193.59	191.98	192.35	194.69	199.00	205.28	213.54	223.77
Twin steer+5 Axle	201.35	196.18	192.96	191.68	192.35	194.96	199.51	206.01	214.45	224.84
A-Double	246.39	239.67	235.10	232.68	232.41	234.28	238.30	244.46	252.77	263.23
B-Triple	286.71	278.26	272.15	268.40	266.99	267.94	271.23	276.88	284.88	295.22
A B combination	281.27	273.99	269.03	266.39	266.08	268.08	272.41	279.06	288.03	299.32
A-Triple	319.53	311.07	305.10	301.63	300.66	302.18	306.20	312.71	321.72	333.22
Double B-Double	322.65	314.55	308.95	305.84	305.23	307.11	311.49	318.37	327.74	339.60

Source: Estimated by Economic Advisory, TfNSW. Values for Car (all types) are indexed from June 2013 prices to January 2023 prices (ABS Series ID A2326616R). Values for commercial vehicles have been indexed from June 2013 prices to January 2023 prices (ABS Series ID A2314058K).

The fuel costs in an urban environment are presented in Table 3.5. They can be used as perceived costs for cars (all types). The values are calculated based on the fuel consumption model published in ATAP PV2. This is converted into a litres-per-kilometre estimate and then monetised based on current fuel prices, fuel excise, and the Goods and Services Tax (GST). These values and sources are listed in Table 3.13.

Table 3.5 Urban vehicle operating costs: fuel cost including taxes (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
Urban stop-start model fuel costs										
Cars (all types)										
Small car	23.56	20.23	18.56	17.56	16.89	16.41	16.05	15.78	15.55	15.37
Medium car	30.40	25.28	22.72	21.18	20.16	19.43	18.88	18.45	18.11	17.83
Large car	39.71	32.45	28.82	26.64	25.19	24.15	23.37	22.76	22.28	21.88
Utility vehicles										
Courier van utility	33.13	26.69	23.47	21.53	20.24	19.32	18.63	18.10	17.67	17.32
4WD petrol	40.76	33.75	30.24	28.14	26.74	25.73	24.98	24.40	23.93	23.55
Rigid trucks										
Light Rigid	47.63	42.64	40.14	38.65	37.65	36.94	36.40	35.98	35.65	35.38
Medium Rigid	74.16	68.78	66.09	64.47	63.40	62.63	62.05	61.60	61.24	60.95
Heavy Rigid	146.92	128.79	119.72	114.28	110.65	108.06	106.12	104.61	103.40	102.41
Bus - heavy bus	145.12	122.72	111.52	104.80	100.32	97.12	94.72	92.86	91.36	90.14
Articulated trucks										
4 axle	176.68	161.13	153.36	148.69	145.58	143.36	141.70	140.40	139.36	138.51
5 axle	191.24	174.05	165.45	160.30	156.86	154.40	152.56	151.13	149.98	149.05
6 axle	208.99	190.42	181.14	175.57	171.86	169.21	167.22	165.67	164.43	163.42
Combination vehicles										
Rigid+5 Axle Dog	245.87	224.98	214.54	208.27	204.10	201.11	198.88	197.13	195.74	194.60
B-Double	262.16	240.07	229.03	222.40	217.98	214.83	212.46	210.62	209.15	207.94
Twin steer+5 Axle	263.34	241.01	229.84	223.14	218.68	215.49	213.09	211.23	209.75	208.53
A-Double	301.34	276.82	264.56	257.20	252.30	248.80	246.17	244.13	242.49	241.15
B-Triple	313.86	288.59	275.95	268.37	263.31	259.70	256.99	254.89	253.20	251.82
A B combination	347.58	320.53	307.01	298.89	293.48	289.62	286.72	284.47	282.66	281.19
A-Triple	383.23	354.24	339.74	331.04	325.24	321.10	317.99	315.58	313.64	312.06
Double B-Double	395.78	366.05	351.19	342.27	336.32	332.08	328.89	326.41	324.43	322.81
Freeway model fuel costs										
Cars (all types)										
Small car	11.86	11.38	11.13	11.12	11.34	11.81	12.52	13.47	14.65	16.08
Medium car	14.61	13.96	13.57	13.46	13.62	14.06	14.77	15.75	17.01	18.54
Large car	18.55	17.76	17.27	17.09	17.22	17.66	18.41	19.46	20.82	22.49
Utility vehicles										
Courier van utility	15.53	14.54	13.94	13.71	13.85	14.37	15.27	16.54	18.19	20.22
4WD petrol	18.97	18.31	17.97	17.93	18.20	18.78	19.66	20.86	22.36	24.16
Rigid trucks										
Light Rigid	18.78	18.12	18.12	18.76	20.06	22.00	24.60	27.84	31.74	36.29
Medium Rigid	30.30	29.94	30.32	31.43	33.27	35.84	39.14	43.18	47.94	53.44
Heavy Rigid	56.40	54.47	54.16	55.49	58.44	63.01	69.22	77.04	86.50	97.58
Bus - heavy bus	53.57	51.42	50.45	50.66	52.04	54.61	58.36	63.28	69.39	76.67
Articulated trucks										
4 axle	71.51	69.70	70.04	72.54	77.19	84.00	92.96	104.08	117.36	132.78
5 axle	76.92	75.27	75.62	77.95	82.28	88.61	96.92	107.23	119.53	133.82
6 axle	84.31	82.85	83.38	85.91	90.42	96.93	105.43	115.93	128.42	142.89
Combination vehicles										
Rigid+5 Axle Dog	100.15	98.78	99.44	102.13	106.85	113.61	122.40	133.22	146.08	160.97
B-Double	107.02	105.74	106.50	109.29	114.11	120.96	129.85	140.77	153.73	168.72
Twin steer+5 Axle	107.47	106.24	107.05	109.89	114.76	121.66	130.60	141.57	154.57	169.61
A-Double	123.84	122.68	123.60	126.59	131.65	138.79	148.00	159.29	172.65	188.08
B-Triple	129.26	128.22	129.30	132.49	137.80	145.22	154.75	166.40	180.17	196.04
A B combination	143.77	142.85	144.08	147.46	153.00	160.70	170.55	182.55	196.71	213.02
A-Triple	159.20	158.52	160.08	163.87	169.90	178.17	188.67	201.41	216.38	233.60
Double B-Double	164.56	163.91	165.49	169.31	175.37	183.67	194.20	206.96	221.97	239.21

Source: Estimated by Economic Advisory, TfNSW based on ATAP PV2 (2016) Table 36, and Australian Institute of Petroleum (2023).

The full financial costs are presented in Table 3.6 and Table 3.7. The financial cost will include market costs, including taxes and subsidies in addition to the resource cost as outputs from the VOC models.

Table 3.6 ATAP Urban Stop-start Model VOC: Full financial cost (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
ATAP PV urban VOC model (Equation 1: stop-start)										
Cars (all types)										
Small car	87.59	65.87	55.01	48.49	44.15	41.04	38.71	36.90	35.46	34.27
Medium car	125.20	91.14	74.11	63.90	57.08	52.22	48.57	45.73	43.46	41.60
Large car	169.36	121.73	97.92	83.63	74.10	67.30	62.20	58.23	55.05	52.46
Utility vehicles										
Courier van utility	142.96	105.07	86.12	74.76	67.18	61.76	57.70	54.55	52.02	49.95
4WD petrol	150.99	113.69	95.04	83.85	76.39	71.07	67.07	63.96	61.47	59.44
Rigid trucks										
Light Rigid	188.55	146.32	125.21	112.54	104.10	98.07	93.54	90.02	87.21	84.90
Medium Rigid	254.86	193.49	162.80	144.39	132.12	123.35	116.78	111.66	107.57	104.22
Heavy Rigid	329.64	257.41	221.29	199.61	185.17	174.85	167.11	161.09	156.27	152.33
Bus - heavy bus	506.68	378.22	313.99	275.46	249.76	231.41	217.65	206.95	198.38	191.37
Articulated trucks										
4 axle	441.57	349.54	303.52	275.91	257.50	244.36	234.50	226.83	220.69	215.67
5 axle	484.62	382.48	331.41	300.77	280.34	265.75	254.81	246.29	239.48	233.91
6 axle	525.00	414.49	359.23	326.08	303.97	288.19	276.35	267.14	259.77	253.74
Combination vehicles										
Rigid+5 Axle Dog	550.87	446.77	394.72	363.48	342.66	327.79	316.64	307.96	301.02	295.34
B-Double	624.21	496.88	433.22	395.03	369.56	351.37	337.73	327.12	318.63	311.69
Twin steer+5 Axle	614.26	492.53	431.66	395.14	370.79	353.40	340.36	330.21	322.10	315.46
A-Double	754.67	597.52	518.95	471.81	440.38	417.93	401.09	388.00	377.52	368.95
B-Triple	881.35	685.67	587.82	529.12	489.98	462.02	441.06	424.75	411.70	401.03
A B combination	852.68	679.90	593.50	541.67	507.11	482.42	463.91	449.51	437.99	428.57
A-Triple	963.47	766.90	668.61	609.64	570.33	542.24	521.18	504.80	491.70	480.97
Double B-Double	968.00	775.47	679.21	621.45	582.95	555.44	534.81	518.77	505.94	495.43

Source: Estimated by Economic Advisory, TfNSW. Values for Car (all types) are indexed from June 2013 to January 2023 prices (ABS Series ID A2326616R). Values for commercial vehicles have been indexed from June 2013 prices to January 2023 prices (ABS Series ID A2314058K).

Table 3.7 ATAP Urban Freeway Model VOC: full financial cost (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
ATAP PV urban VOC model (Equation 2: Freeway model)										
Cars (all types)										
Small car	38.57	37.31	36.42	35.89	35.72	35.92	36.49	37.42	38.71	40.37
Medium car	51.74	49.84	48.38	47.35	46.75	46.59	46.86	47.57	48.70	50.28
Large car	68.12	65.64	63.65	62.17	61.20	60.72	60.75	61.28	62.31	63.85
Utility vehicles										
Courier van utility	60.78	58.69	57.15	56.16	55.72	55.83	56.50	57.71	59.48	61.80
4WD petrol	65.93	64.33	63.23	62.63	62.53	62.93	63.83	65.23	67.13	69.54
Rigid trucks										
Light Rigid	80.28	78.17	77.00	76.78	77.51	79.20	81.83	85.42	89.95	95.44
Medium Rigid	99.21	96.41	94.62	93.82	94.02	95.23	97.44	100.65	104.86	110.07
Heavy Rigid	130.30	125.26	122.29	121.40	122.58	125.83	131.16	138.55	148.03	159.57
Bus - heavy bus	193.93	186.86	181.56	178.04	176.29	176.33	178.14	181.72	187.09	194.23
Articulated trucks										
4 axle	176.46	170.23	166.80	166.17	168.35	173.33	181.11	191.70	205.09	221.29
5 axle	191.90	185.93	182.53	181.70	183.45	187.78	194.68	204.15	216.19	230.81
6 axle	207.41	201.35	197.88	196.97	198.64	202.88	209.70	219.09	231.06	245.60
Combination vehicles										
Rigid+5 Axle Dog	224.50	219.15	216.35	216.10	218.40	223.25	230.65	240.61	253.12	268.17
B-Double	248.11	241.70	237.94	236.82	238.36	242.54	249.37	258.84	270.96	285.73
Twin steer+5 Axle	246.70	240.73	237.38	236.64	238.51	243.00	250.11	259.83	272.17	287.12
A-Double	300.09	292.43	287.61	285.65	286.54	290.27	296.85	306.28	318.56	333.69
B-Triple	345.71	336.17	329.70	326.32	326.02	328.80	334.67	343.61	355.64	370.74
A B combination	343.12	334.90	329.74	327.63	328.58	332.60	339.67	349.80	362.99	379.24
A-Triple	388.83	379.37	373.17	370.25	370.59	374.20	381.09	391.24	404.66	421.35
Double B-Double	393.53	384.47	378.67	376.15	376.90	380.92	388.21	398.76	412.59	429.68

Source: Estimated by Economic Advisory, TfNSW. Values for Car (all types) are indexed from June 2013 to January 2023 prices (ABS Series ID A2326616R). Values for commercial vehicles have been indexed from June 2013 prices to January 2023 prices (ABS Series ID A2314058K).

3.1.2 TfNSW depreciation-adjusted VOC model

The depreciation adjusted VOC model for private vehicles uses the base formula from ATAP PV2 urban VOC model, with an additional depreciation adjustment:

Equation 3 Urban Stop-Start Model

$$c = A + \frac{B}{V} + \left(D \times \frac{60}{V}\right) + E$$

Equation 4 Freeway Model

$$c = C_0 + C_1V + C_2V^2 + D + E$$

Where:

- **c** represents VOCs (cents/km)
- **V** represents journey speed (km/h)
- **A**, **B**, $\mathbf{C_0}$, $\mathbf{C_1}$, and $\mathbf{C_2}$ are model coefficients
- **D** and **E** are adjustments to remove HDM-4 depreciation estimates, and to add the use-based component of depreciation back into the VOC model, respectively. Coefficient D is multiplied by $60/V$ for the stop-start model, removing an adjustment made in ATAP PV2 to account for reduced utilisation in lower journey speed environments.

Coefficients **A**, **B**, $\mathbf{C_0}$, $\mathbf{C_1}$, and $\mathbf{C_2}$ are the same for both the ATAP PV2 urban VOC model (Table 3.8) and the TfNSW depreciation-adjusted model. The usage of the tables in Section 3.1.2 is the same as the tables in Section 3.1.1.

Table 3.8 Coefficients for the TfNSW depreciation-adjusted Model

Vehicle Type	Stop-start		Free-flow			Depreciation	
	A	B	C_0	C_1	C_2	D	E
Car (all types)							
Small car	16.9442	1134.1444	34.8987	-0.1695	0.0014	-8.6245	1.9920
Medium car	17.1163	1779.7837	47.4156	-0.2369	0.0016	-18.0256	4.3165
Large car	19.5222	2487.3008	62.4729	-0.3005	0.0019	-25.7924	6.1765
Utility vehicles							
Courier van utility	23.1185	1968.8685	55.8429	-0.2669	0.0020	-12.1568	1.5183
4WD mid-size Petrol	28.4763	1797.7458	54.8715	-0.2083	0.0018	-19.4962	2.2253
Rigid trucks							
Light Rigid	49.2821	2239.3367	74.7278	-0.3599	0.0036	-15.1715	1.7658
Medium Rigid	51.9429	3278.5933	90.9330	-0.4355	0.0038	-31.6415	3.8860
Heavy Rigid	82.9258	3708.2697	119.3835	-0.8015	0.0077	-37.5272	4.3734
Bus - heavy bus	93.6570	6720.1713	180.9126	-0.9382	0.0068	-55.1103	6.3710
Articulated trucks							
4 axle	122.6929	4820.9106	161.9956	-1.0504	0.0104	-45.9215	5.2151
5 axle	132.2088	5351.3096	173.9460	-0.9865	0.0096	-50.6409	5.7509
6 axle	143.1765	5790.4085	186.6960	-0.9978	0.0096	-54.9013	6.2348
Combination vehicles							
Rigid + 5 Axle Dog	177.7930	5411.1339	197.5392	-0.9289	0.0094	-47.9342	5.4436
B-Double	178.4326	6662.1843	219.7499	-1.0486	0.0099	-62.6763	7.1178
Twin steer + 5 Axle	184.5335	6354.3144	217.5148	-1.0026	0.0097	-58.4091	6.6331
A-Double	208.9002	8257.7659	266.2669	-1.2085	0.0107	-79.1298	8.9863
B-Triple	216.7645	10350.4288	310.6713	-1.4331	0.0118	-102.9361	11.6898
A B combination	247.0964	9078.6728	302.7858	-1.3082	0.0116	-86.2383	9.7934
A-Triple	276.5859	10351.1114	343.9305	-1.4698	0.0125	-99.1728	11.2624
Double B-Double	289.5300	10121.0011	346.3338	-1.4336	0.0125	-62.6763	7.1178

Source: TfNSW Economic Advisory (2023) based on ATAP Guidelines PV2 Road Parameter Values (2016).
Note: Coefficients produce VOC estimates in January 2023 prices

Table 3.9 TfNSW depreciation-adjusted urban stop-start model VOC: Resource cost (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
TfNSW depreciation-adjusted VOC model (Equation 3: stop-start)										
Cars (all types)										
Small car	49.77	39.49	34.35	31.27	29.21	27.75	26.64	25.79	25.10	24.54
Medium car	56.35	44.71	38.89	35.40	33.07	31.41	30.16	29.19	28.42	27.78
Large car	72.69	57.02	49.19	44.49	41.36	39.12	37.45	36.14	35.10	34.24
Utility vehicles										
Courier van utility	86.61	65.95	55.62	49.43	45.29	42.34	40.13	38.41	37.03	35.90
4WD petrol	62.10	51.63	46.40	43.26	41.17	39.67	38.55	37.68	36.98	36.41
Rigid trucks										
Light Rigid	117.50	95.35	84.27	77.63	73.20	70.03	67.66	65.82	64.34	63.13
Medium Rigid	124.83	101.83	90.33	83.43	78.83	75.54	73.08	71.16	69.63	68.38
Heavy Rigid	160.13	135.85	123.72	116.43	111.58	108.11	105.51	103.48	101.87	100.54
Bus - heavy bus	270.71	213.81	185.37	168.30	156.92	148.79	142.70	137.96	134.16	131.06
Articulated trucks										
4 axle	231.19	196.76	179.55	169.22	162.33	157.42	153.73	150.86	148.56	146.69
5 axle	253.60	215.05	195.78	184.22	176.51	171.00	166.87	163.66	161.09	158.99
6 axle	274.23	232.62	211.82	199.34	191.02	185.07	180.62	177.15	174.37	172.11
Combination vehicles										
Rigid+5 Axle Dog	309.99	267.74	246.61	233.94	225.49	219.45	214.93	211.40	208.59	206.28
B-Double	330.63	282.27	258.09	243.58	233.91	227.00	221.82	217.79	214.57	211.93
Twin steer+5 Axle	333.65	286.16	262.41	248.16	238.66	231.88	226.79	222.83	219.66	217.07
A-Double	393.39	334.89	305.64	288.09	276.39	268.03	261.76	256.89	252.99	249.80
B-Triple	437.17	367.60	332.81	311.94	298.03	288.09	280.63	274.83	270.20	266.40
A B combination	452.11	387.04	354.50	334.98	321.96	312.67	305.69	300.27	295.93	292.38
A-Triple	507.89	434.54	397.87	375.86	361.19	350.72	342.86	336.75	331.86	327.86
Double B-Double	614.67	508.66	455.66	423.86	402.65	387.51	376.15	367.32	360.25	354.47

Source: Estimated by Economic Advisory, TfNSW. Estimates based on the coefficients in Table 3.8. Values are indexed to January 2023 prices

Table 3.10 TfNSW depreciation-adjusted urban freeway model VOC: Resource cost (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
TfNSW depreciation-adjusted VOC model (Equation 4: Freeway)										
Cars (all types)										
Small car	25.42	24.40	23.65	23.17	22.97	23.03	23.36	23.97	24.84	25.99
Medium car	29.62	28.06	26.83	25.92	25.34	25.08	25.15	25.54	26.25	27.29
Large car	37.60	35.55	33.87	32.57	31.65	31.10	30.94	31.16	31.75	32.72
Utility vehicles										
Courier van utility	40.68	39.02	37.78	36.94	36.50	36.47	36.85	37.63	38.82	40.42
4WD petrol	34.14	32.93	32.08	31.58	31.43	31.63	32.19	33.10	34.35	35.96
Rigid trucks										
Light Rigid	55.57	53.79	52.73	52.39	52.78	53.90	55.74	58.31	61.60	65.61
Medium Rigid	55.98	53.51	51.79	50.83	50.63	51.17	52.48	54.53	57.35	60.91
Heavy Rigid	73.27	69.10	66.47	65.38	65.82	67.80	71.32	76.37	82.97	91.10
Bus - heavy bus	116.14	110.16	105.55	102.31	100.43	99.91	100.76	102.97	106.54	111.48
Articulated trucks										
4 axle	104.46	99.18	95.99	94.89	95.87	98.95	104.11	111.37	120.71	132.14
5 axle	113.16	108.08	104.92	103.67	104.33	106.92	111.41	117.83	126.15	136.40
6 axle	121.90	116.71	113.44	112.08	112.63	115.10	119.48	125.78	134.00	144.13
Combination vehicles										
Rigid+5 Axle Dog	140.24	135.67	132.98	132.18	133.26	136.23	141.09	147.83	156.46	166.97
B-Double	147.17	141.61	138.03	136.42	136.79	139.13	143.44	149.72	157.98	168.21
Twin steer+5 Axle	149.57	144.41	141.19	139.91	140.57	143.18	147.74	154.24	162.68	173.06
A-Double	176.25	169.53	164.96	162.54	162.26	164.13	168.15	174.32	182.63	193.09
B-Triple	195.46	187.01	180.90	177.15	175.75	176.69	179.99	185.63	193.63	203.98
A B combination	204.82	197.54	192.58	189.95	189.63	191.64	195.97	202.62	211.59	222.88
A-Triple	231.62	223.16	217.19	213.72	212.75	214.27	218.29	224.80	233.81	245.31
Double B-Double	267.09	258.99	253.39	250.28	249.67	251.56	255.93	262.81	272.18	284.04

Source: Estimated by Economic Advisory, TfNSW. Values are indexed to January 2023 prices

Table 3.11 TfNSW Dep. Adj. Urban Stop-start Model VOC: Full financial cost (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
TfNSW depreciation-adjusted VOC model (Equation 3: stop-start)										
Cars (all types)										
Small car	61.32	49.09	42.97	39.30	36.85	35.10	33.79	32.77	31.95	31.29
Medium car	70.46	56.23	49.12	44.85	42.00	39.97	38.45	37.26	36.31	35.54
Large car	91.04	71.78	62.16	56.38	52.53	49.78	47.71	46.11	44.82	43.77
Utility vehicles										
Courier van utility	104.52	80.00	67.74	60.38	55.47	51.97	49.34	47.30	45.67	44.33
4WD petrol	79.69	66.22	59.48	55.44	52.75	50.82	49.38	48.26	47.36	46.62
Rigid trucks										
Light Rigid	140.43	114.89	102.12	94.46	89.35	85.70	82.97	80.84	79.14	77.74
Medium Rigid	154.72	128.15	114.87	106.90	101.59	97.79	94.95	92.73	90.96	89.51
Heavy Rigid	210.62	179.66	164.18	154.89	148.70	144.27	140.96	138.38	136.31	134.62
Bus - heavy bus	331.83	263.99	230.07	209.72	196.15	186.46	179.19	173.54	169.02	165.32
Articulated trucks										
4 axle	295.76	254.24	233.49	221.03	212.73	206.80	202.35	198.89	196.12	193.85
5 axle	323.83	277.40	254.18	240.25	230.96	224.33	219.35	215.48	212.39	209.85
6 axle	350.68	300.56	275.50	260.47	250.44	243.28	237.91	233.73	230.39	227.66
Combination vehicles										
Rigid+5 Axle Dog	398.68	347.30	321.61	306.20	295.92	288.58	283.08	278.80	275.37	272.57
B-Double	425.20	366.82	337.64	320.12	308.45	300.11	293.85	288.99	285.09	281.91
Twin steer+5 Axle	428.81	371.32	342.58	325.33	313.84	305.62	299.47	294.68	290.84	287.71
A-Double	503.43	433.32	398.27	377.24	363.22	353.21	345.70	339.85	335.18	331.36
B-Triple	554.52	472.07	430.84	406.10	389.61	377.83	368.99	362.12	356.63	352.13
A B combination	578.87	500.94	461.98	438.60	423.02	411.89	403.54	397.04	391.85	387.60
A-Triple	648.59	561.11	517.37	491.12	473.62	461.13	451.75	444.46	438.63	433.86
Double B-Double	769.00	645.41	583.62	546.55	521.83	504.18	490.94	480.64	472.40	465.66

Source: Estimated by Economic Advisory, TfNSW. Estimates based on the coefficients in Table 3.8. Values are indexed to January 2023 prices

Table 3.12 TfNSW Dep. Adj. Urban Freeway Model VOC: full financial cost (cents/km)

Vehicle type	Speed (km/h)									
	20	30	40	50	60	70	80	90	100	110
TfNSW depreciation-adjusted VOC model (Equation 4: Freeway model)										
Cars (all types)										
Small car	31.27	30.01	29.12	28.59	28.43	28.63	29.19	30.12	31.42	33.08
Medium car	36.66	34.76	33.30	32.27	31.67	31.51	31.78	32.49	33.62	35.20
Large car	46.54	44.06	42.08	40.60	39.62	39.14	39.17	39.70	40.74	42.27
Utility vehicles										
Courier van utility	49.08	46.99	45.44	44.45	44.02	44.13	44.80	46.01	47.78	50.10
4WD petrol	42.84	41.34	40.30	39.74	39.65	40.04	40.90	42.23	44.03	46.30
Rigid trucks										
Light Rigid	65.54	63.42	62.25	62.03	62.77	64.45	67.09	70.67	75.21	80.69
Medium Rigid	68.68	65.88	64.08	63.29	63.49	64.70	66.91	70.12	74.33	79.54
Heavy Rigid	93.83	88.79	85.83	84.93	86.11	89.36	94.69	102.09	111.56	123.10
Bus - heavy bus	140.32	133.24	127.95	124.43	122.68	122.71	124.52	128.11	133.47	140.61
Articulated trucks										
4 axle	131.68	125.45	122.02	121.39	123.57	128.55	136.34	146.92	160.31	176.51
5 axle	142.52	136.55	133.15	132.32	134.07	138.40	145.30	154.77	166.81	181.43
6 axle	153.87	147.82	144.34	143.44	145.11	149.35	156.17	165.56	177.53	192.07
Combination vehicles										
Rigid+5 Axle Dog	177.76	172.41	169.61	169.36	171.66	176.51	183.91	193.87	206.38	221.43
B-Double	186.99	180.58	176.82	175.71	177.24	181.42	188.25	197.73	209.85	224.62
Twin steer+5 Axle	189.75	183.78	180.42	179.68	181.56	186.05	193.15	202.88	215.21	230.17
A-Double	222.93	215.27	210.46	208.49	209.38	213.11	219.69	229.12	241.40	256.53
B-Triple	245.34	235.79	229.33	225.95	225.65	228.43	234.30	243.24	255.27	270.37
A B combination	259.03	250.81	245.65	243.54	244.50	248.51	255.58	265.71	278.90	295.15
A-Triple	292.13	282.67	276.47	273.54	273.89	277.50	284.38	294.54	307.96	324.65
Double B-Double	332.41	323.35	317.56	315.04	315.79	319.80	327.09	337.65	351.47	368.57

Source: Estimated by Economic Advisory, TfNSW. Estimates based on the coefficients in Table 3.8. Values are indexed to January 2023 prices

Fuel use parameters and VOC per stop on urban roads are provided in Table 3.13 and Table 3.14. **TfNSW recommends** using the values presented in Table 3.14 for projects that impact the number of vehicle stops rather than speed of travel. Additional VOC per stop maybe considered at intersections with dense traffic, or urban environment with high levels of congestions.

Table 3.13 Vehicle operating cost parameters for cars

Parameter	Value	Units
Fuel cost*	107.66	cents/L
VOC per km (excluding fuel and VOC for stops)**	20.22	cents/km
VOC per stop (excluding fuel)***	5.46	cents/stop
Fuel used per stop****	0.04	L
Fuel consumption*****	9.0 to 12.0	L/100 km
Fuel excise******	47.7	Cents/L

Source and note:
* Fuel cost is a resource cost and is based on Q4 2022 average petrol price excluding GST and fuel excise Terminal Gate Prices (TPG) (Australian Institute of Petroleum)
** VOC per km (excluding fuel and VOC per stop) estimated based on a medium car at 50km/hr using Table 12 and fuel consumption parameters provided by the 2015 (NGTSM Table 5.13).
*** VOC per stop (excluding fuel) calculated from Sydney Coordinated Adaptive Traffic System (SCATS) Computer Aided Traffic Engineering System (SCATES) model, indexed by private motoring (excluding automotive fuel) component of ABS CPI
**** Fuel used per stop based on SCATS values
***** Fuel consumption based on 2015 NGTSM, medium car
****** Fuel excise applicable from 1 February 2023

Table 3.14 Vehicle operating cost per stop

Vehicle	VOC/stop (excl. fuel) (cents)	Fuel consumption per stop (L)	Fuel cost (cents/L)	VOC/stop (incl. fuel) (cents)
Car	5.46	0.04	107.66	9.23
Light truck	12.61	0.22	137.12	43.37
Heavy truck	23.13	0.72	137.12	121.58

Source: Fuel consumption per stop is based on estimates of 0.42 stops per km (based on SCATES data). Fuel cost is a resource cost and is based on 2021 average fuel price TGP excluding GST and fuel excise (Australian Institute of Petroleum). Diesel fuel price used for Light and Heavy trucks (Australian Institute of Petroleum). Values indexed to January 2023 prices

3.1.3 Austroads VOC model – urban

The functional form of the Austroads VOC model for urban areas in given by Equation 5.

Equation 5 Austroads VOC model – urban

$$c = A + \frac{B}{V} + C * V + D * V^2$$

Where:

- **c** represents VOC (cents/km)
- **A**, **B**, **C**, and **D** are model coefficients
- **V** is the average link speed in km/h

Table 3.15 and Table 3.16 contain the model coefficients. These values are in June 2010 prices.

Table 3.15 Austroads VOC model urban: coefficients (freeway, all day)

Vehicle	A	B	C	D
Car	19.779	124.70	0.0501	-0.00015
LCV	42.830	266.67	-0.0031	-0.000110
HCV	118.542	3669.83	0.1076	0.000082

Source: Austroads 2012, value as at June 2010
Note: The coefficients include the value of freight time but excludes the value of personal time. The value of freight time refers to the value of time of the goods being transported, for example the value of freight time is higher when delivery is faster and therefore customers are willing to pay more for express post. Personal time refers to the value-of-time to the individual (commercial and private)
Coefficients are derived in data in June 2010 prices. To convert into current prices use ABS Series ID A2326616R for Cars; and ABS Series ID A2314058K for LCV and HCV + buses

Table 3.16 Austroads VOC model urban: coefficients (at-grade roads, all day)

Vehicle	A	B	C	D
Car	59.889	-27.96	-0.9768	0.005926
LCV	18.126	1286.3	0.3527	-0.002123
HCV	316.434	2835.72	4.2828	0.025487

Source: Austroads 2012, value as at June 2010
Note: The coefficients include the value of freight time but excludes the value of personal time. The value of freight time refers to the value of time of the goods being transported, for example the value of freight time is higher when delivery is faster and therefore customers are willing to pay more for express post. Personal time refers to the value-of-time to the individual (commercial and private)
Coefficients are derived in data in June 2010 prices. To convert into current prices use ABS Series ID A2326616R for cars; and ABS Series ID A2314058K for LCV and HCV + buses

3.2 Rural vehicle operating cost model

3.2.1 ATAP VOC model – rural

The functional form of the ATAP VOC model for rural areas is given by Equation 6.

Equation 6 ATAP VOC model – rural

$$VOC = Base\ VOC \times (k_1 + \frac{k_2}{V} + k_3V^2 + k_4IRI + k_5IRI^2 + k_6GVM)$$

Where:

- **VOC** = vehicle operating cost (cents/km)
- **Base VOC** = lowest VOC point in curve from raw HDM-4 output
- **V** = vehicle speed (km/hr)
- **IRI** = International Roughness Index (m/km)
- **GVM** = gross vehicle mass (tonnes)
- **k_1 to k_6** = model coefficients

The Base VOC and coefficient k1-k6 can be found in ATAP PV2 Road Parameter Values Appendix D. The estimated VOC using this model is as at June 2013 dollars, which should be indexed to the project base year using appropriate indexation described in Appendix D.

The International Roughness Index (IRI) is a scoring process for the roughness of the road surface. At low values the road surface is characterised as good or very good with little surface imperfections. A fair road is characterised with surface imperfections; poor roads with frequent minor depressions and very poor roads with frequent shallow depressions or deep shallow depressions (Table 3.17) (Gillespie, Paterson, & Sayers, 2002).

Table 3.17 Description of road surface conditions

Measure	Sealed road				
Pavement condition	Very Poor	Poor	Fair	Good	Very Good
International Roughness Index (IRI)	8+	6-7	4-5	3	0-2

Source: National Association of Australian State Road Authorities

The functional form of the rural ATAP fuel consumption model as presented in ATAP PV2 is described in Equation 7.

Equation 7 ATAP fuel consumption – rural

$$Fuel\ consumption = Base\ Fuel \times (k_1 + \frac{k_2}{V} + k_3V^2 + k_4IRI + k_5GVM)$$

Where:

- Fuel consumption is in L/km
- **Base Fuel** = lowest fuel consumption point in curve from raw HDM-4 output
- **V** = vehicle speed (km/hr)
- **IRI** = International Roughness Index (m/km)
- **GVM** = gross vehicle mass (tonnes)

- **k_1 to k_5** = model coefficients

The fuel consumption and coefficient k1-k6 can be found in ATAP PV2 Road Parameter Values Appendix E.

3.2.2 Rural Evaluation System model

REVS is the model used in economic appraisal of NSW rural road projects. The system is based on the National Association of Australian State Road Authorities Improved Model for Project Assessment and Costing (NIMPAC) road planning model[1]. The REVS model uses the economic parameters provided in Table 3.18.

The REVS is designed to be used on rural and outer urban roads because it assumes uninterrupted traffic flows. Nevertheless, it can be used on roads in towns where traffic flow is predominantly uninterrupted. The REVS is also designed to handle small networks of interacting roads, where an improvement to a single road can affect traffic conditions on the other roads in the network; in this situation a traffic survey would first be required to establish the redistribution of traffic. Stop/Give Way signs, traffic lights, pedestrian crossings and the like will reduce the applicability of REVS in an urban situation.

1 The National Association of Australian State Road Authorities is now Austroads.

Table 3.18 Rural Evaluation System model economic parameters

Parameters	Identifier	Units	Car	2x-4ty Truck	2x-6ty Truck	3 Axle Truck	4 Axle Truck	5 Axle Semi	6 Axle Semi	B-Double	B-Triple	Quad Group Semi
Road user cost parameters												
Petrol price	PETROL	cent/litre	107.7	107.7	107.7	107.7	107.7	107.7	107.7	107.7	107.7	107.7
Diesel price	DIESEL	cent/litre	137.1	137.1	137.1	137.1	137.1	137.1	137.1	137.1	137.1	137.1
Oil price	OIL	cent/litre	884	536	536	536	536	536	536	536	536	536
New tyre price	TYRE	$ per tyre	156	197	435	841	780	796	792	754	795	826
Retread tyre price	RETRED	$ per tyre	77	99	222	282	282	272	279	286	316	292
Repair and servicing cost	REPAIR	cents/km	8.0	8.5	12.2	17.8	24.3	28.2	28.9	33.6	44.8	32.9
New vehicle price	VEHCLE	$	28,303	32,458	92,954	210,731	286,709	318,201	346,632	400,809	653,358	373,353
Sales tax rate	TAX	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time depreciation rate	TIMDEP	%/ year	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distance depreciation rate	DISDEP	%/ 1000km	0.224	0.311	0.311	0.205	0.155	0.137	0.137	0.137	0.137	0.000
Time and crash parameters												
Commercial time value	COMMTIM	$/ hr/ person	63.09	32.97	34.62	43.04	54.26	59.62	61.58	74.75	89.20	89.20
Commercial vehicle occupancy	COMMOCC	Persons/ vehicle	1.3	1.0	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Weighted average crash cost	UACCST	$/ crash	Rural Urban	$354,626 $163,392								
Private car occupancy	PRIVOCC	Persons/ vehicle	1.7									
Private time value	PRIVTIM	cents/ hr/ person	19.45									

Source: Estimated by Economic Advisory, TfNSW. Values are indexed to January 2023 prices. The REVS model refers to its economic parameters inputs as the “SWIDE file”.

Table 3.19 provides the proportion of vehicles in urban and rural areas used to calculate the heavy VOCs.

Table 3.19 Mix of vehicles

Vehicle type	% Urban	% Regional	% Overall
Cars (all types)	77.40	71.35	76.06
Cars	77.40	71.35	76.06
Utility vehicles	16.58	15.84	16.41
Courier van utility	9.66	9.23	9.56
4WD Mid-Size Petrol	6.92	6.61	6.85
Rigid trucks	3.62	5.00	3.93
Light Rigid (previously LCV 2 axle-4tyre)	0.58	0.80	0.63
Medium Rigid (previously 2 axle-6 tyre)	1.00	1.38	1.09
Heavy Rigid (previously 3 axle)	2.04	2.82	2.21
Articulated trucks	0.76	3.07	1.27
4 axle	0.23	0.32	0.25
5 axle	0.07	0.39	0.14
6 axle	0.46	2.36	0.88
Combination vehicles	0.77	3.95	1.45
Rigid + 5 Axle Dog	0.01	0.06	0.02
B-Double	0.70	3.60	1.34
Twin steer + 5 Axle Dog	0.01	0.06	0.02
A-Double	0.01	0.06	0.02
B-Triple	0.01	0.04	0.01
A B combination	0.01	0.0	0.01
A-Triple	0.01	0.04	0.01
B-Double	0.01	0.05	0.02
Buses	0.86	0.77	0.84
Heavy Bus	0.86	0.77	0.84

Source: Estimated by Economic Advisory, TfNSW from ABS Survey of Motor Vehicle Use 2018

Additional information on freight vehicle types, average payloads, and distance travelled can be found at the following sources:

- The Traffic Volume Viewer website to identify relevant Permanent or Sample Classifiers, requests for freight data by Austroads heavy vehicle class can be sent to Network & Asset Intelligence
- The *Who Moves What Where* report, available on the National Transport Commission website
- ABS Category 2993.0 Road freight movements, 2014.

Table 3.20 contains commercial vehicle mixes for selected Traffic Volume Viewer Classifiers, sourced from Network & Asset Intelligence.

Table 3.20 Commercial vehicle class mix: selected Sydney Classifiers

Commercial vehicle class	Mobbs Lane, Mobbs Hill	Daines Parade, Beacon Hill	Newbridge Road, Milperra	New Beach Road, Rushcutters Bay
Rigid trucks	6.36%	6.67%	8.01%	5.34%
3. Two Axle Truck or Bus	5.41%	5.37%	6.56%	4.93%
4. Three Axle Truck or Bus	0.63%	0.84%	1.14%	0.28%
5. Four Axle Truck	0.32%	0.46%	0.32%	0.13%
Articulated trucks	1.54%	0.77%	2.08%	0.17%
6. Three Axle Articulated	0.14%	0.25%	0.26%	0.08%
7. Four Axle Articulated	0.06%	0.14%	0.21%	0.03%
8. Five Axle Articulated	0.12%	0.07%	0.32%	0.02%
9. Six Axle Articulated	0.99%	0.25%	1.13%	0.04%
10. B Double	0.23%	0.06%	0.14%	0.01%
11. Double Road Train	0.00%	0.00%	0.01%	0.00%
12. Triple Road Train	0.00%	0.00%	0.00%	0.00%

Source: Network & Asset Intelligence (2019)

4 Urban road congestion cost

The marginal congestion cost includes the impacts from:

- extra travel time
- increased travel time variability
- increased VOC due to higher fuel consumption
- poorer air quality, as vehicles on congested roads emit more harmful pollutants compared to free-flowing traffic conditions.

TfNSW recommends not including the marginal cost of congestion in a CBA if the economic benefits of road user travel time savings, reliability, urban vehicle operating costs, or environmental impacts have been separately assessed; to avoid double counting benefits.

TfNSW recommends the marginal congestion costs presented in Table 4.1 are to be used for the Greater Sydney Region. As the impacts of cars, freight vehicles and buses are different, VKT has been converted into Passenger Car Equivalent Units (PCU) kilometre travelled (PCU-km). Passenger Car Equivalent (PCE) factors of buses and trucks are presented in Table 4.1.

Table 4.1 Marginal road congestion cost in Sydney

Vehicle type	PCE factors	Marginal congestion cost in Sydney (cents/vkt)
Passenger vehicles & LCVs	1.00	50.69
Rigid trucks	3.00	152.07
Trailers	6.00	304.13
Articulated trucks	5.00	253.44
B doubles	8.00	405.51
Double road train	8.00	405.51
Triple road train	10.00	506.88
2 axle buses	2.00	101.38
3 axle buses	3.00	152.07

Source: Estimated by Economic Advisory, TfNSW. Values indexed from March 2006 prices to January 2023 prices (ABS Series ID A2325806K)

4.1 Passenger Car Equivalent (PCE) units

TfNSW recommends the use of the PCE factors in Table 4.2 which have been used to calculate the values in Table 4.1. The recommended values can be adjusted using the PCE range provided, considering:

- the terrain type
- the gradient of the road and the distance vehicles are traveling at that gradient (grade severity and length of grade)
- traffic mix.

These factors affect the performance of heavy vehicles and subsequently affect traffic flow. Table 4.2 also presents the findings from a literature review on PCE.

Table 4.2 Passenger car equivalency factors

Vehicle Type	NTC	ARRB		Mainroads Western Australia			USA	DfT UK	National Guidelines	TfNSW	
		Urban	Rural	Flat terrain	Rolling terrain	Mountainous terrain				Range	Recommended
Passenger vehicles & LCVs	1.0			1.0	1.3	2.0	1.0	1.0	0.99-1.12	1.0 - 2.0	1.0
Rigid trucks	2.0	4.9	1.4 - 7.9	1.2 - 2.0	1.7 - 5.0	3.0 - 8.0	1.5	1.9	1.23 - 1.56	1.2 - 8.0	3.0
Trailers	2.0 - 3.0	6.5 - 8.7	1.7 - 13.0				2.0			1.7 - 13.0	6.0
Articulated trucks	3.0			2.5	5.0	10.0		2.9	1.78 - 1.89	2.5 - 10.0	5.0
B doubles	4.0	8.8 - 22.3	1.9 - 15.6	4.0	10.0	16.0			2.22	1.9 - 16.0	8.0
Double road trains	4.0			4.0	10.0	16.0			2.75 - 2.90	4.0 - 16.0	8.0
Triple road trains	5.0	9.7 - 24.0	4.2 - 25.7	9.0	22.0	35.0			2.82 - 3.38	4.2 - 35.0	10.0
2 axle buses	1.0 - 2.0			1.2	1.7	3.0				1.0 - 3.0	2.0
3 axle buses	3.0			1.7	3.5	6.0			1.59	1.7 - 6.0	3.0

Source:
(1) NTC - National Transport Commission, Heavy vehicle charges - Report to the Standing Council of Transport and Infrastructure, February 2012
(2) ARRB - ARRB Consulting, Review of passenger car equivalency factors for heavy vehicles, October 2007
(3) Mainroads Western Australia - Mainroads Western Australia, Policy and guidelines for overtaking lanes, December 2011
(4) USA - US Highway Capacity Manual & Al-Kaisy, A. (2006) Passenger car equivalents for heavy vehicles at freeways and multilane highways: some critical issues, ITE Journal, March 2006
(5) DfT UK - UK Department for Transport, Transport Analysis Guidance (TAG)
(6) NGTSM update 2015

4.2 Additional information: urban road congestion cost

4.2.1 Marginal and average congestion cost

The marginal congestion cost is the incremental congestion delay an individual traveller imposes when entering traffic. The average congestion cost is the total congestion delay per VKT. The marginal congestion cost increases at a faster rate that the average congestion cost as the volume of traffic increases. By joining the congested traffic flow, the additional traveller adds to the congestion, and causes a small increase in the delay experienced by each of the other users.

Marginal cost varies at different levels of congestion. When congestion is low, marginal cost is close to average cost. When congestion is high, marginal cost is higher than average cost.

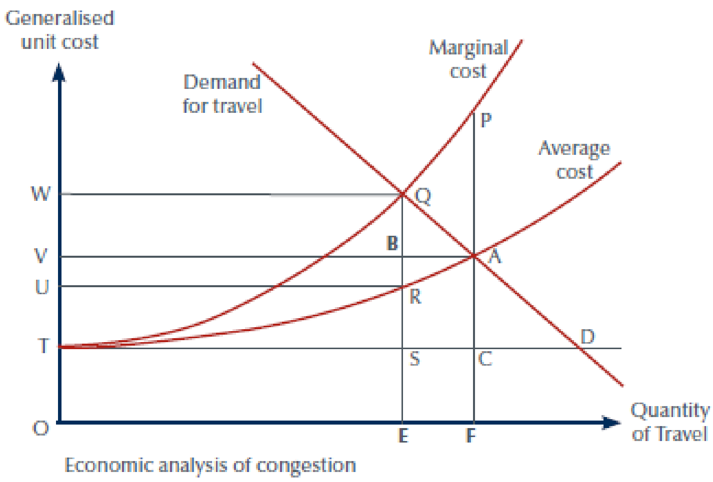


Figure 4.1 Average and marginal congestion costs
Source: BITRE (2007)

In Figure 4.1**,** the net increase in costs from the increased traffic congestion is therefore equal to area **VBRU** less area **BAQ**, which given the geometry of the marginal cost curve, is equal to area **PAQ**. Where:

1. **VBRU** is an increase in total travel costs for all existing users (due to the higher congestion at point A)
2. **BAQ** is an increase in consumer surplus amount for extra travellers (whose overall utility improves).

The congestion cost in Sydney was estimated by the Bureau of Infrastructure Transport and Regional Economics (BITRE) at $3.53 billion in 2005 and projected to increase to $7.76 billion in 2020.[2] An update to the BITRE report was released in 2016, which estimated the cost of congestion in Sydney as $6.12 billion as at 2015, and projected 2020 congestion costs of $9.63 billion, an increase on the 2005 forecast.[3] Indexed to January 2023 dollar values, Sydney cost by 2022 is

2 Estimating urban traffic and congestion cost trends for Australian cities, Bureau of Transport and Regional Economics, working paper No. 71, 2007
3 BITRE (2016) Estimating urban traffic and congestion cost trends in Australian cities. Working paper 74, Bureau of Infrastructure, Transport and Regional Economics. Values indexed from June 2010 to January 2023 prices (ABS Series ID A2325846C)

projected to be $11.93 billion. Table 4.3 presents 2016 BITRE estimates of the average social costs of congestion in Australian capital cities

Table 4.3 Average congestion costs: Sydney and Australian capital cities

Year	Sydney		Australian capital cities	
	Total congestion cost ($B)	Unit cost of congestion (cents/PCU km)	Total congestion cost ($B)	Unit cost of congestion (cents/PCU km)
Original estimate in 2010 prices				
2022	$8.74	16.30	$18.56	11.53
2023	$9.08	16.55	$19.77	11.97
2024	$9.40	16.75	$21.02	12.38
2025	$9.72	16.94	$22.36	12.81
Indexed to January 2023 prices				
2022	$11.93	22.26	$33.72	18.31
2023	$12.39	22.59	$35.25	18.66
2024	$12.83	22.87	$36.73	18.96
2025	$13.26	23.13	$38.18	19.24

Source: BITRE (2016) Estimating urban traffic and congestion cost trends for Australian cities, Working Paper No 74. Values indexed from June 2010 prices to January 2023 prices (ABS Series ID A2325846C) For consistency Australian CPI was applied to all values.

Estimating changes in congestion costs between two years can be used as a proxy for the marginal congestion cost.[4] This is done using the BITRE forecast of the social cost of congestion and projections of total metropolitan vehicle kilometres travelled in passenger car unit equivalents (PCU) from 1990-2020.[5]

Total metropolitan vehicle kilometres are represented in PCUs to account for the impact of differing vehicle class such as cars, light commercial vehicles, rigid trucks and articulated trucks.

The marginal social cost of congestion is calculated by dividing the change in the social cost of congestion between two consecutive years by the change in PCU kilometres travelled. This value is then indexed from 2005/06 prices to January 2023 prices using CPI (Sydney). The estimated marginal congestion cost is $0.42 per VKT in 2023 as shown in Table 4.5. This is a marginal value representing the social cost of congestion imposed by each additional passenger car to all other vehicles on the road.

Table 4.4 Marginal congestion cost by road type in Sydney

Road category	Marginal congestion cost (cents/vkt) in 1996 dollars	Marginal congestion cost (cents/vkt) indexed to January 2023
Freeways	13.00	25.40
CBD streets	62.00	121.13
Arterial roads (inner)	21.00	41.03
Arterial roads (outer)	7.00	13.68

Source: Traffic congestion and road user charges in Australian capital cities, Report 92, Bureau of Transport and Communications Economics, 1996. Values indexed from June 1996 prices to January 2023 prices (ABS Series ID A2325806K)

4 This method was originally developed by PwC Australia
5 BITRE (2007) Estimating urban traffic and congestion cost trends in Australian cities. Working paper 71, Bureau of Infrastructure, Transport and Regional Economics

Table 4.5 Marginal congestion cost over time, Sydney-wide

Cost	2020	2021	2022	2023	2024	2025
Social Cost ($billion)	8.04	8.40	8.74	9.08	9.40	9.72
Change in Social Cost ($billion)	0.41	0.37	0.33	0.34	0.32	0.32
Billion pcu-km	45.45	46.56	47.70	48.81	49.91	51.00
Change in pcu-km	1.07	1.11	1.14	1.11	1.10	1.09
MSC in 2005/06 dollar ($/pcu-km)	0.38	0.33	0.29	0.31	0.30	0.29
MSC in 2023 dollar ($/pcu-km)	0.52	0.45	0.40	0.42	0.40	0.40

Source: Economic Advisory, TfNSW. Values indexed from June 2010 prices to January 2023 prices (ABS Series ID A2325806K)

5 Road safety benefits

TfNSW recommends that road safety benefits be estimated based on the Inclusive Willingness-to-Pay (WTP) values in Table 5.2. Where detailed crash data is not available, the average crash costs by road type in Table 5.1 can be used to estimate the economic benefit.

Table 5.1 Average crash costs by road type, WTP values – urban

Road type	Average crash cost ($/mvkt)		
	All crashes	Bus crashes	Car crashes
Local/sub-arterial	99,039	159,673	98,916
Arterial	72,118	116,575	71,995
Freeway	22,475	36,183	22,475
Weighted average	81,010	130,777	80,886

Source: TfNSW estimate. Indexed from June 2014 prices to January 2023 prices (ABS Series ID A2325806K)

Detailed road safety analysis can be undertaken using the Road User Movement (RUM) codes, and Inclusive WTP costs. The Safer Roads team in the Centre for Road Safety maintains a model that calculates road safety benefits and costs for road infrastructure projects. The Safer Roads team also maintains the Crash Reduction Factor matrix that records the literature-based crash reduction or increase factors of individual road safety countermeasures, by RUM code.

5.1 Inclusive Willingness-to-Pay

The Inclusive WTP approach represents the individuals WTP to avoid death or injury; as well as the cost to society due to the crash, such as emergency costs. The WTP values are derived from a stated preference survey. The rationale for incorporating these additional costs is that individuals do not factor costs that are not incurred by the individual.

The Inclusive WTP approach is recommended by the Australian Government Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA) and has been adopted by ATAP. The values are a combination of WTP values with some additional vehicle, emergency, and other crash related costs.

Table 5.2 Costs per casualty and per crash – Inclusive WTP approach

Accident type	Urban	Rural	Average
Inclusive WTP costs per casualty			
Fatality	$8,388,230	$9,184,283	$8,757,819
Serious injury (injury requiring hospitalisation)	$505,028	$668,036	$561,892
Moderate injury (attendance at an emergency department)	$77,568	$99,429	$87,645
Minor injury (not requiring attendance at an emergency department or hospital)	$77,568	$99,429	$87,645
Unknown injury type	$222,161	$283,516	$244,731
Inclusive WTP costs per crash			
Fatal crash (at least one person killed)	$8,821,788	$10,441,335	$9,700,635
Serious injury crash (at least one person hospitalised, but no fatalities)	$575,299	$792,910	$650,677
Moderate injury crash (at least one person attended emergency, but no serious injuries or fatalities)	$96,516	$127,369	$110,316
Minor injury crash (at least one person received a minor injury, but no moderate / serious injuries or fatalities)	$88,701	$117,048	$101,041
Unknown injury type crash	$200,841	$275,230	$238,778
Property damage only	$11,778	$11,778	$11,778

Source: Values from the Economic Valuation of Safety Benefits, Serious Injuries, Final Report, PricewaterhouseCoopers (PWC) for Roads and Traffic Authority (now Roads & Maritime Services) and indexed from December 2007 to January 2023 (ABS Series ID A2325846C)
Notes: Unknown injury type crash is non-fatal casualty crash where injury severity is unknown

Definitions:

- A **fatality** occurs when a person dies within 30 days of a crash, from injuries due to the crash.
- A **fatal crash** is a road traffic crash on public roads in which at least one person in the crash dies within 30 days from injuries received in that crash.
- A **serious injury** is when a person is admitted to hospital as a result of a road traffic crash on public roads who does not die within 30 days as a result of those injuries.
- A **serious injury crash** is a road traffic crash on public roads in which at least one person was admitted to hospital as a result of the crash, and in which there were no fatalities as a result of that crash.
- A **moderate injury** is when a person attends an emergency department following a road traffic crash on public roads but is not subsequently admitted to hospital
- A **moderate injury crash** is a road traffic crash on public roads in which at least one person attends an emergency department following that crash but is not subsequently admitted to hospital. There were no serious injuries or fatalities from that crash.
- **Minor injury** occurs when a person injured from a road traffic crash on public roads that does not attend an emergency department and is not admitted to hospital.
- A **minor injury crash** is a road traffic crash on public roads in which at least one person injured from that crash does not attend an emergency department and is not admitted to hospital. There were no moderate injuries, serious injuries or fatalities from that crash.
- **Urban** refers to Sydney, Newcastle and Wollongong metropolitan areas, and town centres where the speed limit is up to and including 80km/h.
- **Rural** refers to areas outside the Sydney, Newcastle and Wollongong metropolitan areas, where the speed limit is more than 80km/h.

5.2 Crash rates

Crash rates for NSW roads were estimated by Austroads for a range of single and combined attributes. A selection of crash rate tables is included below, with more information available at the Austroads website.

Table 5.3 NSW Crash rates – single attribute

Attribute	100m VKT (5 years)	Fatal	Fatal crash rate	Injury	Injury crash rate	All crashes	Total crash rate
Carriageway							
Divided	905.88	339	0.37	17,386	19.19	24,990	27.59
Single	947.45	763	0.81	19,902	21.01	26,823	28.31
Environment							
Rural	791.00	625	0.79	9,518	12.03	21,657	27.38
Urban	1,194.65	642	0.54	34,446	28.83	82,964	69.45
Surface							
Asphalt concrete	1,151.24	623	0.54	32,097	27.88	77,699	67.49
Concrete	183.34	83	0.45	2,521	13.75	6,361	34.69
Spray seal	647.71	559	0.86	9,322	14.39	20,525	31.69
Unsealed	3.35	2	0.60	24	7.16	36	10.75

Source: Road Safety Engineering Risk Assessment Part 7: Crash Rates Database, AP-T152-10, Austroads 2010
Notes: Contact Economic Advisory for more detail on road class if required for a CBA

Table 5.4 NSW crash rates – rural and urban by carriageway

Attribute	100m VKT (5 years)	Fatal	Fatal crash rates	Injury	Injury crash rates	All crashes	Total crash rates
Rural by carriageway							
Divided	174.14	72	0.41	1,782	10.23	4,632	26.6
Single	616.86	553	0.9	7,736	12.54	17,025	27.6
Urban by carriageway							
Divided	755.21	335	0.44	18,982	25.13	46,715	61.86
Single	439.44	307	0.7	15,464	35.19	36,249	82.49

Source: Road Safety Engineering Risk Assessment Part 7: Crash Rates Database, AP-T152-10, Austroads 2010

5.3 Additional information: crash values

For additional information, the breakdown of the WTP values and the additional costs are provided in Table 5.5 and Table 5.6, respectively. The calculations for average crash costs also draw on the average number of persons killed and injured per crash, as presented in Source: NGTSM 2015.
*Values indexed from June 2013 prices to January 2023 prices (ABS Series ID A2328771A).
**Values indexed from June 3013 prices to January 2023 prices (ABS Series ID A2325846C).

Table 5.7.

Table 5.5 and Table 5.6 are not intended to be directly used in economic appraisals for road projects. The WTP values may be used in economic appraisal of maritime, railway and other initiatives where the inclusive costs are not applicable.

Table 5.5 Value per casualty and per crash – willingness to pay approach

Accident type	Urban	Rural	Average
WTP value per casualty			
Value of fatality risk prevention	$8,200,907	$8,996,960	$8,570,496
Value of serious injury risk prevention (requiring hospitalisation)	$295,849	$458,857	$352,713
Value of moderate injury risk prevention (attendance at emergency department)	$62,288	$84,149	$72,365
Value of minor injury prevention	$62,288	$84,149	$72,365
Value of unknown injury type prevention	$145,089	$206,444	$167,659
WTP value per crash			
Fatal crash (at least one person killed)	$8,551,130	$10,144,010	$9,411,821
Serious injury crash (at least one person hospitalised, but no fatalities)	$341,820	$549,720	$413,623
Moderate injury crash (at least one person attended emergency, but no serious injuries or fatalities)	$77,504	$107,796	$91,084
Minor injury crash (at least one person received a minor injury, but no moderate / serious injuries or fatalities)	$71,229	$99,061	$83,426

Source: Estimated by Economic Advisory, TfNSW. Values indexed from December 2007 prices to January 2023 prices (ABS Series ID A2325806K)

Table 5.6 Vehicle and general costs ($ per person) in inclusive WTP values

Cost category	Crash type			
	Fatality	Serious injury	Moderate/ Minor injury	Unknown injury
Vehicle costs				
Repairs*	$16,668	$13,929	$13,745	$13,803
Unavailability of vehicles*	$2,115	$1,876	$991	$1,273
Towing*	$497	$442	$233	$300
Total vehicle costs*	$19,281	$16,246	$14,969	$15,376
General costs				
Travel delays**	$93,498	$113,159	$148	$36,162
Insurance administration**	$59,915	$72,516	$94	$23,174
Police**	$12,054	$4,142	$62	$1,362
Property**	$1,942	$2,349	$4	$751
Fire**	$634	$767	$3	$246
Total general costs**	$168,042	$192,933	$310	$61,696
Total inclusive costs (vehicle plus general)	$187,323	$209,179	$15,279	$77,072

Source: NGTSM 2015.
*Values indexed from June 2013 prices to January 2023 prices (ABS Series ID A2328771A).
**Values indexed from June 3013 prices to January 2023 prices (ABS Series ID A2325846C).

Table 5.7 Average number of persons killed and injured in a crash

Crash type	Urban	Rural	Average
Fatal crash			
Average no. of persons killed per crash	1.03	1.10	1.08
Average no. of persons hospitalised per crash	0.32	0.39	0.37
Average no. of persons with moderate injury per crash	0.65	0.40	0.48
Average no. of persons with minor/other injury per crash	0.09	0.19	0.16
Serious injury crash			
Average no. of persons hospitalised per crash	1.10	1.14	1.11
Average no. of persons with moderate injury per crash	0.18	0.21	0.19
Average no. of persons with minor/other injury per crash	0.11	0.11	0.11
Moderate injury crash			
Average no. of persons with moderate injury per crash	1.11	1.16	1.13
Average no. of persons with minor/other injury per crash	0.13	0.12	0.13
Minor injury crash			
Average no. of persons with minor/other injury per crash	1.14	1.18	1.15

Source: Number of persons is estimated by Economic Advisory, TfNSW based on casualty and crash data provided by the Centre for Road Safety for urban and rural 2011 to 2015

5.3.1 The Human Capital approach to crash valuation

Although not recommended by TfNSW, the Human Capital approach is commonly used to value the impact of crashes. The Human Capital approach aggregates various identifiable costs, such as: loss of income, medical expenses, long term care, insurance cost, vehicle repair, property damage, travel delays and policing. The value of a statistical life or a fatality is the discounted present value of these costs over a period up to 40 years.

There are several limitations of the Human Capital approach. Firstly, public policy is designed to reduce the risk of crashes or injuries; however, the Human Capital approach concentrates on what has been lost, rather than prevented. Secondly, it includes lost productivity and income and therefore undervalues fatalities involving non-working individuals. Thirdly, it does not make allowance for pain and suffering. Due to these limitations, the contemporary trend of economic evaluation is to use the crash values derived from the WTP approach. Human Capital accident costs were originally estimated by the Bureau of Transport Economics (BTE 2000). These values were then updated by the NGTSM (Table 5.8). As noted above, the human capital approach is not the preferred method for calculating crash values.

Table 5.8 Crash cost per person – Human Capital approach

Cost components	Fatality	Serious injury	Other injury
Human costs*			
Ambulance	$705	$705	$383
Hospital in-patient	$3,810	$15,244	$77
Other medical	$2,824	$22,883	$111
Long-term care	$0	$173,154	$0
Labour in the** workplace	$930,594	$44,001	$0
Labour in the** household	$774,134	$36,689	$0
Quality of life**	$855,071	$91,739	$4,875
Insurance claims***	$23,533	$41,469	$2,479
Criminal prosecution***	$3,036	$878	$108
Correctional services***	$16,690	$0	$0
Workplace disruptions***	$15,840	$16,279	$1,055
Funeral***	$3,334	$0	$0
Coroner***	$1,094	$0	$0
Vehicle costs			
Repairs****	$16,668	$13,929	$13,745
Unavailability of vehicles****	$2,115	$1,876	$991
Towing****	$497	$442	$233
General costs			
Travel delays***	$93,498	$113,159	$148
Insurance administration***	$59,915	$72,516	$94
Police***	$12,054	$4,142	$62
Property***	$1,942	$2,349	$4
Fire***	$634	$767	$3
Total costs	$2,817,988	$652,221	$24,367

Source: NGTSM 2015
*Values are indexed from June 2013 prices to September 2021 prices (ABS Series ID A2331111C), indexed to January 2023 NSW Treasury forecasts
**Values are indexed from May 2013 AWE to November 2021 AWE (ABS Series ID A84998729F), indexed to January 2023 with NSW Treasury forecasts
***Values are indexed from June 2013 to January 2023 prices (ABS Series ID A2325846C)
****Values are indexed from June 2013 to January 2023 prices (ABS Series ID A2328771A)

Table 5.9 presents the cost per crash using a Human Capital approach, by location.

Table 5.9 Cost per crash – Human Capital approach

Crash type	Urban	Urban freeway	Rural
Fatal crash	$3,226,190	$3,314,421	$3,654,574
Serious / Other injury crash	$694,248	$730,083	$748,029

Source: NGTSM, Road Parameter Values (2015). Indexed from May 2013 AWE to November 2021 AWE (ABS Series ID A84998729F), indexed to January 2023 with NSW Treasury forecast

5.3.2 Literature review of a value of a statistical life

A literature review indicates that the value of a statistical life (VSL) ranges from around $2 million to $15 million in January 2023 prices (excluding the two lowest and two highest outliers).

Table 5.10 Values of statistical life from existing international literature

Studies	Value of Statistical Life ($M)	Approximate Value in current prices (AUD $M)
Andersson (2005), Sweden	USD1.3	$2.02
Krupnick et al (2000), Canada	USD1.3	$2.37
RTA (2009) Human Capital Cost	AUD1.69	$2.54
Transport Canada (2007)*	AUD2.21 in 2007	$3.29
Mrozek and Taylor (2001)	USD2.0	$3.44
Guria et al (1999), NZ*	USD2.1	$3.96
Jones-Lee (1994)	USD2.1	$4.43
Tsuge et al (2005), Japan	USD2.9	$4.51
Kneisner and Leith (1991), Australia	USD2.2	$4.84
UK Dept for Transport (2007)*	AUD3.39 in 2007	$5.05
Jones-Lee et at (1995), UK	USD2.7	$5.43
Jenkins et al (2001)	USD3.2	$5.50
NZ Ministry of Transport (2007)*	AUD3.95 in 2007	$5.88
US Federal Highway Administration (2007)*	AUD4.45 in 2007	$6.62
Desaigues and Rabl (1995), France	USD3.4	$6.83
Desvouges et al (1998)	USD3.6	$6.89
Johannesson et al (1997), Sweden	USD3.8	$7.33
Van den Burgh et al (1997), US and UK	USD3.9	$7.53
PWC (2008), Australia	AUD5.95m in 2008	$8.41
Gayer et al (2000), US	USD4.7	$8.59
Meng and Smith (1999), Canada	USD5.2	$9.81
Day (1999), US, Canada, UK	USD5.6	$10.57
Viscusi (1993)	median USD5.5	$11.78
Baranzini and Luzzi (2001), Switzerland	USD7.5	$12.89
Schwab-Christe (1995), Switzerland	USD7.5	$15.08
Miller et al (1997), Australia	median USD15.2	$29.34
ATAP Guidelines (2016), Australia	AUD7.53	$9.56
Median international literature value		$6.62

Source: Values indexed to January 2023 prices (ABS Series ID A2325806K). *Source: PWC (2008)

6 Environmental impacts

TfNSW recommends the use CO2 equivalent emission values in Table 6.1, Table 6.2 and Table 6.3 for quantifying climate change impacts in the core analysis.

TfNSW recommends the values in Table 6.4 for sensitivity tests related to carbon values. A minimum of four sensitivity tests for are recommended:

- Sensitivity 1: European Union Emissions Trading Scheme (EU ETS) low spot price. The values are escalated by 2.25 per cent per annum.
- Sensitivity 2: EU ETS high spot price. The values are escalated by 2.25 per cent per annum.
- Sensitivity 3: Intergovernmental Panel on Climate Change global marginal abatement cost (IPCC MACC). The values are escalated by 4.3 per cent from FY32 to FY51.
- Sensitivity 4: Zero carbon value (i.e., a scenario that effectively excludes carbon costs from analysis)

TfNSW recommends the use of the parameter values for other environmental externalities in Table 6.5 and Table 6.6 for passenger transport, and values in Table 6.7 and Table 6.8 for freight transport.

6.1 CO2 equivalent emissions and carbon values

6.1.1 Carbon values for passenger and freight transport

The NSW Government requires potential climate change impacts to be assessed in the CBA where the cost or benefit is likely to materially affect the NPV and BCR. The cost of (or the benefits of reduced) CO2 equivalent emissions should be estimated.

Table 6.1 presents the recommended carbon emission values. The carbon emissions value is increased by 2.25 per cent per annum for each year after FY2023. This escalation accounts for expected real increases in the cost of emissions. The values are based on EU ETS average market prices.

Table 6.1 Carbon emissions value per tonne for core analysis ($/tonne CO2-e)

Price ($)	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32
Carbon emissions value (NSW)	123	126	128	131	134	137	140	144	147	150

Source: Technical note to NSW Government Guide to Cost-Benefit Analysis TPG23-08 Carbon value in cost-benefit analysis 2023

Using the values in Table 6.1, the carbon emission values for passenger transport are estimated and presented in Table 6.2. Values for four financial years are presented. The interim years can be extrapolated using a straight-line method.

These values are applicable to both urban and rural environment since carbon emissions have a global impact. The table also includes estimates by passenger kilometres using the average load. These values may be used for initiatives that change volume of passengers on public transport vehicles or result in mode switch between different vehicle types. If a more accurate transport vehicle load is known, project specific values by passenger kilometres can be estimated.

Table 6.2 Carbon values of passenger transport (Cents/vkt)

	FY23	FY24	FY28	FY32
By vehicle kilometre travelled				
Motorcycle	1.29	1.32	1.44	1.58
Car	2.61	2.68	2.91	3.19
Minibus	3.80	3.89	4.23	4.63
Bus	12.06	12.35	13.43	14.71
Rail (Diesel)	27.74	28.42	30.90	33.83
Ferry	71.62	73.37	79.77	87.34
By passenger kilometres				
Motorcycle	1.23	1.26	1.37	1.50
Car	1.62	1.66	1.81	1.98
Minibus	0.76	0.78	0.85	0.93
Bus	0.63	0.64	0.70	0.77
Rail (Diesel)	0.47	0.48	0.53	0.58
Ferry	0.75	0.77	0.84	0.92

Source: Estimated by Economic Advisory based on ATAP PV5 2021 and NSW Government CBA Guide TPG23-08
Interim years can be extrapolated using a straight-line method. Values are in Jan 2023 prices (ABS Series ID A2325846C).

Light rail and urban electric rail cars do not directly generate CO2-e emissions. However, this does not mean these vehicles do not contribute to carbon emissions. The carbon impact of these vehicles is captured in the WTT (well-to-tank) emissions, which will be discussed later in this section.

Similar to passenger transport, the carbon emission values for freight transport are estimated and presented in Table 6.3. These values are applicable to both urban and rural environments.

Table 6.3 Carbon values of freight transport

	FY23	FY24	FY28	FY32
Cents per vehicle kilometre travelled				
LCV	3.80	3.89	4.23	4.63
HV	8.93	9.15	9.95	10.89
Rigid trucks	6.54	6.70	7.28	7.97
Articulated trucks	10.35	10.61	11.53	12.63
Freight trains	154.99	158.77	172.64	189.02
Dollars per 1000 tonne km				
LCV	54.84	56.18	61.08	66.88
HV	7.24	7.41	8.06	8.83
Rigid trucks	31.18	31.94	34.73	38.03
Articulated trucks	7.07	7.25	7.88	8.63
Freight trains	3.44	3.53	3.84	4.20

Source: Estimated by Economic Advisory based on ATAP PV5 2021 and NSW Government CBA Guide TPG23-08.
Interim years can be extrapolated using a straight-line method. Values are in Jan 2023 prices (ABS Series ID A2325846C).

6.1.2 Sensitivity tests for carbon values

To use the values in Table 6.4 in a sensitivity test, a factor representing the percentage increase or decrease from the core values in Table 6.1 can be applied to values presented in Table 6.2 and Table 6.3. Note that the IPCC MACC prices from FY32 – FY51 needs to be escalated by 4.3 per cent per annum.

Table 6.4 Carbon emissions value per tonne for CBA sensitivity analysis

Price ($)	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32
EU ETS low spot price	88	90	92	95	97	99	101	103	106	108
EU ETS high spot price	149	152	155	159	162	166	170	174	178	182
IPCC MACC estimate	163	163	163	163	163	163	163	163	163	170

Source: Technical note to NSW Government Guide to Cost-Benefit Analysis TPG23-08 Carbon value in cost-benefit analysis 2023

6.2 Air pollution and other environmental parameters

Externality unit costs for passenger and freight transport are presented in Table 6.5 to Table 6.8.

Table 6.5 Externality costs by passenger transport mode - Urban

Externality type	Motorcycle	Car	Minibus	Bus	Light rail	Rail	Ferry
Cents per vehicle kilometre travelled							
Air pollution	1.00	0.97	2.76	12.16	0.74	0.97	1084.81
WTT emissions and pollutions	0.52	0.61	0.78	2.95	118.69	258.23	25.47
Noise	8.03	0.76	0.97	5.39		69.37	
Soil and water	0.33	0.33	0.44	3.83		5.31	
Nature and landscape	0.07	0.17	0.17	0.40		9.61	
Urban effects	0.57	0.57	0.51	1.69		5.31	
Biodiversity	0.08	0.08	0.03	0.63		0.07	
Cents per passenger kilometre							
Air pollution	0.95	0.60	0.55	0.63	0.01	0.01	11.42
WTT emissions and pollutions	0.50	0.38	0.16	0.15	2.37	1.95	0.26
Noise	7.64	0.47	0.19	0.28		1.18	
Soil and water	0.31	0.21	0.09	0.40		0.09	
Nature and landscape	0.06	0.11	0.04	0.02		0.16	
Urban effects	0.55	0.36	0.10	0.18		0.09	
Biodiversity	0.08	0.04	0.01	0.07		0.00	

Source: Estimated by Economic Advisory based on ATAP PV5 2021 and NSW Government CBA Guide TPG23-08. Values are in Jan 2023 prices (ABS Series ID A2325846C).

Table 6.6 Externality costs by passenger transport mode – Rural

Externality type	Motorcycle	Car	Minibus	Bus	Light rail	Rail	Ferry
Cents per vehicle kilometre travelled							
Air pollution	0.01	0.01	0.03	0.12		0.40	1084.81
WTT emissions and pollutions	0.52	0.61	0.78	2.95		258.23	25.47
Noise	0.08	0.01	0.01	0.05		6.91	
Soil and water	0.03	0.03	0.00	0.04		0.07	
Nature and landscape	0.67	1.72	1.74	4.00		96.14	
Urban effects							
Biodiversity	0.00	0.00	0.00	0.00		0.00	
Cents per passenger kilometre							
Air pollution	0.01	0.01	0.01	0.01		0.01	11.42
WTT emissions and pollutions	0.50	0.38	0.16	0.15		1.95	0.26
Noise	0.08	0.00	0.00	0.00		0.12	
Soil and water	0.03	0.02	0.00	0.00		0.00	
Nature and landscape	0.64	1.07	0.35	0.21		1.63	
Urban effects							
Biodiversity	0.00	0.00	0.00	0.00		0.00	

Source: Estimated by Economic Advisory based on ATAP PV5 2021 and NSW Government CBA Guide TPG23-08. Values are in Jan 2023 prices (ABS Series ID A2325846C).

Table 6.7 Externality unit costs by freight transport - Urban

Externality type	LCV	HV	Rigid trucks	Articulated trucks	Freight trains
Cents per vehicle kilometre travelled					
Air pollution	2.76	7.99	7.93	12.97	260.31
WTT emissions and pollutions	0.78	2.47	1.09	1.73	60.54
Noise	0.97	5.00			171.54
Soil and water	0.44	3.49			59.83
Nature and landscape	0.17	0.47			21.53
Urban effects	0.51	2.59			35.90
Biodiversity	0.03	1.24			1.20
Dollars per 1000 tonne kilometres					
Air pollution	39.88	6.48	18.56	8.86	5.79
WTT emissions and pollutions	11.33	2.00	4.64	1.19	1.34
Noise	13.99	9.70			3.81
Soil and water	6.35	3.16			0.56
Nature and landscape	2.54	0.38			0.48
Urban effects	7.32	2.25			0.34
Biodiversity	0.49	1.12			0.01

Source: Estimated by Economic Advisory based on ATAP PV5 2021 and NSW Government CBA Guide TPG23-08. Values are in Jan 2023 prices (ABS Series ID A2325846C).

Table 6.8 Externality unit costs by freight transport - Rural

Externality type	LCV	HV	Rigid trucks	Articulated trucks	Freight trains
Cents per vehicle kilometre travelled					
Air pollution	0.03	0.80	3.89	5.84	2.60
WTT emissions and pollutions	0.78	2.47	0.98	1.60	60.54
Noise	0.01	0.05			17.15
Soil and water	0.00	1.24			1.20
Nature and landscape	1.74	4.66			215.26
Urban effects					
Biodiversity	0.00	3.60			23.93
Dollars per 1000 tonne kilometres					
Air pollution	0.40	0.65	18.56	3.99	0.06
WTT emissions and pollutions	11.33	2.00	4.64	1.09	1.34
Noise	0.14	0.09			0.38
Soil and water	0.01	1.12			0.01
Nature and landscape	25.36	3.78			4.78
Urban effects					
Biodiversity	0.00	3.27			0.23

Source: Estimated by Economic Advisory based on ATAP PV5 2021 and NSW Government CBA Guide TPG23-08. Values are in Jan 2023 prices (ABS Series ID A2325846C).

The average loads by freight vehicle type are in Table 6.9. A more extensive list of freight vehicle average payload can be found in Appendix C of the ATAP PV5 2021. The payload can be used in Equation 8 to convert the values in Table 6.7 and Table 6.8 between dollars per 1000 tonne kilometres and cents per vehicle kilometres travelled, for different types of vehicles.

Table 6.9 Average freight vehicle payloads

Vehicle Type	Average load per trip (kg)	Average load per trip (t)
Light commercial vehicles	359	0.359
Rigid trucks	5,879	5.879
Articulated trucks	23,451	23.451

Source: ABS, 9208.0 Table 26 Survey of Motor Vehicle Use, Australia, 2018 - NSW values

Equation 8 Freight externality unit conversion

$$Unit\ cost_{ev} = \frac{CT_e \times L_v}{10}$$

Where,

- **Unit Cost$_{ev}$** = the externality unit cost per vehicle type and environmental externality (c/km)
- **CT$_e$** = the cost in $ per 1000 tonne kilometres, by environmental externality
- **L$_v$** = the average payload per vehicle type

6.2.1 Air pollution

Air pollution is predominantly an urban issue. The parameter values given in Externality unit costs for passenger and freight transport are presented in Table 6.5 to Table 6.8.

Table 6.5 are a function of vehicle kilometres travelled (VKT), population distribution, and population density. As a rule of thumb, the parameter values for air pollution for a passenger car in a rural area is 1 per cent of the corresponding values in an urban area.

Air pollution is lower in free-flowing conditions than on congested roads. A project that improves an urban road may reduce road congestion and increase the average travel speed, which will reduce air pollution. Vehicle pollutions of carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NOx) and particles increase by 22 per cent, 33 per cent, 14 per cent and 13 per cent respectively when driving conditions change from free flowing (urban vehicle speed 25 km/h or above) to congested conditions (urban vehicle speed less than 25 km/h).

6.2.2 Noise pollution

Noise pollution is mostly an urban issue. The externality value is a function of population distribution and the location of the travelling vehicle. As a result, the rural noise unit cost in Table 6.6 and Table 6.8 are significantly lower than the urban values. For rural towns, the urban value is assumed. For urban freeways where there are noise barriers or no noise exposure to residential areas, the rural value is assumed.

6.2.3 Soil and water pollution

Soil and water pollution includes organic waste or persistent toxicants run-off from roads generated from vehicle use: engine oil leakage and disposal, road surface, particulate matter and other air pollutants from exhaust and tyre degradation. Concentrations of pollutants in urban land and waterways are significantly higher compared to rural areas.

6.2.4 Nature and landscape impacts

Nature and landscape impacts are driven by the infrastructure ‘footprint’. For example, habitat loss, loss of natural vegetation or reduction in visual amenity as infrastructure is constructed. Key impacts in rural areas are natural impacts, whilst key impacts in urban areas are mostly amenity/visual as the urban environment is already dominated by infrastructure. The impacts on nature and the landscape are assumed to be higher for rural areas, therefore the impact in urban locations is 10 per cent that for rural locations.

6.2.5 Urban barrier effects

Urban separation is only an externality in urban areas. This negative externality is due to time lost to pedestrians, lack of non-motorised transport provision, and visual intrusion.

6.2.6 Well-to-tank emissions (Upstream and downstream impacts)

Upstream and downstream costs refer to the indirect costs of transport including energy generation, vehicle production and maintenance and infrastructure construction and maintenance.

6.2.7 Other values for emissions

Table 6.10 presents parameter values of different types of emissions. This includes a carbon value from in 2023 prices. Note that carbon values require escalation under NSW Treasury's recommendation and values from Table 6.1 should be adopted in a CBA.

Table 6.10 Unit values for emissions (2023)

Emission	$/tonne
Carbon dioxide equivalent (CO2-e) - from NSW Government*	123.00
Carbon monoxide (CO)**	4.51
Oxides of nitrogen (Nox)**	2,852.48
Particulate matter (PM10)**	453,985.09
Total hydrocarbons (THC)**	1,429.24

Source:
*NSW Government CBA Guide TPG23-08
**Guide to Project Evaluation, Part 4, Project Evaluation Data, Austroads 2012.
Values are indexed to January 2023 prices (ABS Series ID A2325846C)

7 Active transport

Active transport refers to physical activity undertaken as a means of transport. The most popular forms of active transport are cycling and walking.

TfNSW recommended parameter values for active transport in Table 7.1. Values in Table 7.2 can be used for sensitivity tests.

Table 7.1 Active transport parameters

Costs / Benefits	Cycling ($/bicycle-km)	Walking ($/km)	Recipient
Total health benefits – ATAP	**2.20**	**4.39**	**Versus inactivity**
Health private benefits (morbidity and mortality)	1.48	2.95	Versus inactivity
Health system benefit	0.72	1.44	Versus inactivity
Congestion cost savings	0.45	0.45	Former car users
Vehicle operating cost savings	0.30	0.35	Former car users
Accident cost	0.24	0.12	Former car users
Air pollution	0.010	0.010	Former car users
WTT emissions and pollutions	0.006	0.006	Former car users
Noise	0.008	0.008	Former car users
Soil and water	0.003	0.003	Former car users
Nature and landscape	0.002	0.002	Former car users
Urban effects	0.006	0.006	Former car users
Biodiversity	0.001	0.001	Former car users
Roadway provision cost savings	0.07	0.07	Former car users
Parking cost savings	0.02	0.02	Former car users
Travel time cost*			

Source: Estimated by Economic Advisory, TfNSW. See notes below for details. Values are in January 2023 dollars (ABS Series ID A2325806K). ATAP M4
* TfNSW does not recommend quantifying a travel time cost or saving for active transport projects.

7.1 Health benefits

An increase in active transport reduces morbidity and mortality, however the health benefits are lower for more active people. Table 7.2 presents the range of health benefits estimated. The value from ATAP M4 should be used in the core analysis, whereas the values from TfNSW and NSW Ministry of Health should be used in sensitivity tests.

Table 7.2 Range of values of active transport health benefits ($/km)

References	Cycling	Walking
ATAP (Core analysis)	$2.20	$4.39
Transport for NSW (Sensitivity test: low)	$1.37	$2.06
NSW Ministry of Health (Sensitivity test: high)	$3.00	$6.70

Source: ATAP M4, TfNSW Economic Advisory, NSW Ministry of Health.

7.2 Congestion cost savings

This benefit is applicable only when the cycling or walking trip replaces a car trip. It is assumed that both cycling and walking impose no congestion cost compared to motor vehicles.

7.3 Vehicle operating cost savings [6]

This benefit is applicable only when cycling and walking replace car trips. It is a net savings calculated from VOC minus any operating cost for cycling. The operating cost of a bicycle is approximately $0.04/km. No operating cost is incurred from walking.

[6] Parameters from section 7.3, 7.6 and 7.7 are estimated by Economic Advisory, presented in 2015 prices

7.4 Accident cost

Cycling incurs greater accident costs compared to cars, as there are more cycling accidents than vehicle accidents per kilometre travelled. The accident costs per kilometre travelled for car, bus, cycling and walking are estimated in Table 7.3.

Table 7.3 Crash costs

Crash type	Car	Bus	Cycling	Walking
Average annual no. of crashes	20,683	384	629	1,216
Fatal	64	4	5	28
Injury	10,360	199	621	1,186
Property damage	10,259	181	2	2
Allocated crash cost ($M)	$1,353.67	$28.84	$57.13	$135.57
Million vehicle kilometres travelled (MVKT)	41,153	2,070	209	883
Average cost ($/VKT)	$0.03	$0.01	$0.27	$0.15

Source: Number of crashes based on RMS Road Safety crash statistics 2011-2015. Million vehicle kilometres travelled sourced from 2015/16 Household Travel Survey. Values are in March 2018 prices.

7.5 Environmental cost savings

The same values as Externality unit costs for passenger and freight transport are presented in Table 6.5 to Table 6.8.

Table 6.5 are used if the individual walking or cycling is no longer using a passenger car.

7.6 Roadway provision cost savings

Cycling and walking causes less wear-and-tear on roads and requires less space than other vehicles. Footpaths and cyclepaths cost less than roads. The roadway provision cost for cars is estimated by the annual roadway provision costs divided by total vehicle kilometres travelled totalling $0.07/km. The roadway provision cost for cycling (cycle lanes/paths) is approximately $0.03/km, which gives a cost saving of $0.04/km for cycling.

7.7 Parking cost savings

This benefit is applicable only when the cycling and walking trip replace a car trip with a parking cost. Travelling by car may incur parking costs which includes the costs associated with parking facility infrastructure (land) and maintenance. Parking costs vary depending on the location. In the Sydney CBD, metered parking costs can range from $4.40 to $7.60 per hour. While cycling requires provision of bicycle racks for parking, the cost is small compared to parking a car. The recommended parking cost savings when cycling / walking trips replace car trips is $0.01/km.

7.8 Travel time costs

TfNSW recommends no travel time cost or saving for cycling and walking. Cycling and walking is usually slower than a car or public transport which means that cycling and walking involve a net cost in travel time. However, the travel time is not a key factor for people choosing to walk/cycle. The decision to walk or cycle as a transport mode is often for leisure or to improve health.

8 Road damage cost

TfNSW recommends the road damage costs presented in Table 8.1 be used in CBA for calculating the benefits of diverting or reducing road traffic as a result of a project or initiative.

Table 8.1 Unit cost of road maintenance by vehicle types

Vehicle type	Unit costs (cents / vkt)
Cars and motorcycles	4.95
Rigid truck	6.19
Light rigid (LCV)	4.95
Medium rigid	11.39
Heavy rigid	17.10
Articulated trucks	21.12
4 or less axles	16.84
5 axles	18.71
6 or more axles	21.82
Combination vehicles	28.07
Rigid 3 axle plus trailer	18.58
Rigid 4 axle plus trailer	28.92
B-double	28.49
Double road train	32.07
B-triple	40.24
Buses	9.32
2 axle light bus	4.95
Rigid bus	11.54
Articulated bus 3 axle	13.17
Special purpose vehicles	15.53
Sub-total: Light Vehicles	4.95
Sub-total: Heavy Vehicles	17.04
Total: All Vehicles	5.75

Source: Estimated by Economic Advisory, TfNSW. Values are indexed from December 2011 prices to January 2023 prices (ABS Series ID A2325806K)
Note: 46% of total cost is for road repair & maintenance and 54% for road provision (construction)

8.1 Method

The unit cost of road damage was calculated using the process described below. This methodology is based on research by the National Transport Commission (NTC).

Step 1: Collect road expenditure data in NSW and group it into the following categories:

- road serving and operating
- road pavement and shoulder construction
- bridge maintenance and rehabilitation
- road rehabilitation
- road safety and traffic management
- asset extension and improvements
- other items including corporate services, enforcement of heavy vehicle regulations, vehicle registration, driver licensing and debt servicing.

Step 2: Estimate traffic related costs by excluding costs for:

- vehicle registration and driver licensing, which are not directly related to road traffic and its cost has been recovered from registration fees
- debt servicing, which is a funding mechanism and not directly related to road traffic
- local road access and community amenity, which is only partly related to road traffic with a proportion of costs have been collected from developers' contributions.

Step 3: Total traffic related costs can be separated into the following groups:

- Vehicle kilometre travelled (vkt): This part of the cost is equally distributed to vkt regardless of vehicle size, mass or axle weight.
- Passenger Car Equivalent (PCU) kilometres: This cost is distributed based on PCU thus large sized vehicles bear more costs than cars.
- Equivalent Standard Axle (ESA) kilometres: This cost is distributed based on damages caused by vehicle axle weight. Heavier vehicles reduce the serviceability in a much shorter time than light vehicles. It is assumed that damages caused by vehicles are related to the 4th power of their axle weight. The 4th power law describes the relationship between vehicle's axle weight and road damage.
- Average Gross Mass (AGM) kilometres: This cost is allocated based on gross mass of vehicles.
- Heavy vehicle kilometres travelled: This cost is related to enforcement of heavy vehicle regulations. The cost is distributed based on heavy vehicle vkt.
- Costs that cannot be allocated into any of the above groups are referred to as non-separable items, which are distributed based on vkt for all vehicles. Percentages of cost allocation are sourced from the latest NTC report (National Transport Commission, 2012).

Step 4: Allocate the cost across the following vehicle types:

- cars and motor cycles
- light commercial vehicles
- rigid trucks (2, 3 and 4 axles of different gross mass, with or without a trailer)
- articulated trucks (3, 4, 5 and 6 axles)
- B doubles
- road trains
- buses (2 and 3 axle rigid buses, 3 axle articulated buses)
- Special purpose vehicles (light and heavy)

Vehicle kilometres by vehicle types are sourced from ABS Survey of Motor Vehicle Use (SMVU) 2010. PCU and ESA by vehicle types are sourced from NTC and Average Gross Mass (AGM) is sourced from ARRB report (Vuong & Mathias, 2004).

Step 5: Estimate the unit costs by vehicle types resulting in the values presented in Table 8.1

9 Demand elasticity

TfNSW recommends the short-run demand elasticity values in Table 9.1. For long-run demand elasticity, twice the value of short-run elasticities should be used.

Table 9.1 Short-run elasticity

Attributes	Best estimate – demand response			Typical range
	Peak	Off peak	Overall	
Fares	-0.25	-0.50	-0.35	-0.2 to -0.6
Service level (frequency)	0.25	0.50	0.35	+0.2 to +0.5
In vehicle time	-0.30	-0.50	-0.40	-0.1 to -0.7

Source: NGTSM, Australian Transport Council, 2006.

9.1 Additional information

Elasticity is a measure of a variable's sensitivity to a change in another variable. In transport economics, it usually refers to the change in trips due to changes in the price of a fare or the total travel time. Direct elasticity measures the responsiveness of demand for a particular product to a change in its own price, whereas cross elasticity measures the responsiveness of demand to a change in the price of a substitute or complementary product.

Elasticities are often lower in the short run than in the long run. This is because some changes are not possible to make in a short amount of time. For example, if the train fare during off-peak times reduces, commuters may need time to change their work schedule to take advantage of the reduced price.

Table 9.2 summarises the direct and cross elasticities of public transport and car use. The ranges of the elasticity values are based on a literature review of transport elasticity particularly focusing on Sydney and Australia. The central values are based on a review undertaken by IPART which used the former rail weekly and bus travel ten (these have now been replaced by Opal) as the fare type.

Table 9.2 Cross elasticity of demand

Mode	Rail fare cost [5]		Bus fare cost[5]		Car operating cost (Petrol price)[5]		Public transport fare cost[4]		In veh. time[4]
	Range	Value	Range	Value	Range	Value	Range	Value	Value
Rail	-0.043 to -1.103 (2)	-0.250	0.004 to 0.500 (5,1)	0.004	0.009 to 0.190 (4,5)	0.009			
Bus	0.009 to 0.400 (5,1)	0.009	-0.040 to -0.822 (4,5)	-0.383	0.005 to 1.010 (4,5)	0.005			
Car	0.015 to 0.090 (5,1)	0.015	0.020 to 0.007(5,1)	0.007	-0.014 to -0.800 (5,1)	-0.014			-0.17
Public Transport					0.07 to 0.8 (3)		-0.100 to -0.600 (4)	-0.35	

Source: Compiled by Economic Advisory, TfNSW based on:
(1) Transport Elasticities Database, BITRE, 2009.
(2) CityRail Fare Elasticities, Booz & Co, 2008.
(3) Exploring the impacts of fuel price increases on public transport use in Melbourne, Currie & Phung, 2006.
(4) Survey of Public Transport Elasticities, Industry Commission, 1993.
(5) Estimation of Public Transport Fare Elasticities in the Sydney Region, IPART, 1996, Table 16, p. 25.

Sydney Trains estimated the demand elasticity values for train travel (Table 9.3). Compared with other studies, the elasticity for in-vehicle time and generalised journey time is high.

Table 9.3 Demand elasticity estimated by Sydney Trains

Crash type	Peak	Off peak	Overall
Fare (price)	-0.35	-0.42	-0.38
Rail in-vehicle time	-0.63	-0.74	-0.67
Service interval	-0.28	-0.32	-0.30
Generalised journey time	-1.00	-1.16	-1.07

Source: (Douglas Economics, 2008)

10 Public transport project expansion factors

Transport demand modelling is usually undertaken in 1 hour, 2 hour or 3.5 hour peak periods. The estimated levels of demand are then converted into annual numbers by applying expansion and annualisation factors.

TfNSW recommends calculating project-specific expansion factors where data is available. The values presented in Table 10.1 provide expansion factors appropriate for use in public transport projects when estimating specific benefit streams in a CBA in an urban area.

TfNSW requires that urban and rural road projects use project-specific expansion and annualisation factors rather than the factors presented in this section. The TfNSW Economic Advisory team can be contacted for assistance.

Table 10.1 Expansion factor by benefit category – urban

Attributes	Input unit	Expansion AM peak			Annualisation	Type
		1hr to weekday	2hr to weekday	3.5hr to weekday		
Trains*						
Travel time savings	hours	6.84	4.61	3.40	277	Volume
Train crowding**	hours	2.05	1.51	1.39	252	Cost
Station crowding**	hours	2.05	1.51	1.39	252	Cost
Station quality	trips	6.84	4.61	3.40	277	Volume
Vehicle quality	trips	6.84	4.61	3.40	277	Volume
Travel time reliability	hours			2.00	277	Volume
Buses***						
Travel time savings	hours	7.10	4.34	3.19	300	Volume
Bus crowding	hours			2.00	300	Cost
Stop crowding	hours			2.00	300	Cost
Stop and station quality	trips	7.10	4.34	3.19	300	Volume
Vehicle quality	trips	7.10	4.34	3.19	300	Volume
Travel time reliability	hours			2.00	300	Volume
Road****						
Travel time savings	hours	12.45	6.29	4.04	336	Cost
Vehicle operating costs / cost savings	vkt	12.45	6.29	4.04	336	Cost
Crash costs / cost savings	vkt	12.45	6.29	4.04	336	Cost
Environmental impacts	vkt	12.45	6.29	4.04	336	Cost
Travel time reliability	hours	12.45	6.29	4.04	336	Cost

Source: Detailed methodology is provided in Orthongthed et al (2013). Estimated by Economic Advisory, TfNSW, based on the following datasets:
*Trains: A compendium of CityRail travel statistics, 7th edition, June 2010.
**Crowding: Rail Opal Assignment Model (ROAM) data, methodology provided in Svanberg A.J. (2021).
***Buses: Sydney Buses boarding data by time of day and weekday of the year in 2010/11. Data were sourced from State Transit Authority (STA).
****Roads: Traffic volume data in 2011 provided by Roads and Maritime Services.
Notes: Crowding and reliability benefits are not generally quantified for off-peak time periods, hence use of a 1.0 expansion factor for the 3.5 hour to weekday period. 1hr and 2hr expansion factors should be calculated on a project-specific basis. These expansion factors are not suitable use in road projects, which require expansion factors to be calculated on a project-specific basis.

Using Table 10.1, for a Train travel time savings benefit measured for the 2hr AM peak in Sydney, a factor of 4.61 should be used to expand this to average weekday volumes. A factor of 277 is applied to annualise this figure for a full year.

10.1 Additional information: expansion factors

Table 10.1 represents the relevant cost expansion factor or volume expansion factor to use. Cost expansion factors are not always the same as volume expansion factors. Cost expansion factors take into account the impacts of congestion, vehicle operating costs, and environmental externalities generated by road use.

The cost expansion factors are lower than the volume expansion factors as the proportion of daily traffic cost is higher than the proportion of traffic volume in the peak periods, for urban areas. In the rural regions, the difference between cost and the volume expansion is smaller due to a more even distribution of traffic throughout the day

10.1.1 Volume expansion factors

Table 10.2 Volume expansion factors

	Roads	
	Sydney (1)	**Rural (2)**
From peak 1 hour to weekday	14.31 (AM Peak: 07:00 AM – 08:00 AM)	12.10 (15:00 PM – 16:00 PM)
From peak 2 hours to weekday	7.21 (AM Peak: 07:00 AM – 09:00 AM)	6.13 (15:00 PM – 17:00 PM)
From peak 3.5 hours to weekday	4.46 (AM Peak: 06:30 AM – 10:00 AM)	3.61 (14:30 PM – 18:00 PM)
From weekday to year	345	347
	Public transport	
	Train (Sydney) (3)	**Bus (Sydney) (4)**
From peak 1 hour to weekday	6.84 (AM Peak: 8:00 AM – 9:00 AM)	7.10 (AM Peak: 7:30 AM – 8:30 AM)
From peak 2 hours to weekday	4.61 (AM Peak: 7:30 AM – 9:30 AM)	4.34 (AM Peak: 7:00 AM – 9:00 AM)
From peak 3.5 hours to weekday	3.40 (AM Peak: 6:00 AM – 9:30 AM)	3.19 (AM Peak: 7:00 AM – 10:30 AM)
From weekday to year	277	300

Source: Estimated by Economic Advisory, TfNSW, based on the following datasets:
(1) Sydney roads: Traffic volume data in 2011 provided by Roads and Maritime Services. Expansion factors are based on traffic data at 7 tolled freeway stations, 22 arterial stations and 31 local road stations. Stations are selected for fairly representing traffic conditions in Sydney Inner, Middle and Outer rings.
(2) Rural roads: Traffic volume data in 2011 provided by Roads and Maritime Services. Expansion factors are based on traffic data at 65 arterial stations and 26 local road stations in Hunter, Northern, South West, Southern and Western regions.
(3) Trains (Sydney): Estimated by Sydney Metro from March 2017 Opal data.
(4) Buses (Sydney): Sydney Buses boarding data by time of day and weekday of the year in 2010/11. Data were sourced from State Transit Authority (STA).

The volume expansion factors in Table 10.3 have been converted from those in Table 10.2 to provide the volume expansion factors in Average Annual Daily Traffic (AADT).

Table 10.3 Volume expansion factors by Average Annual Daily Traffic

	Roads	
	Sydney	**Rural**
From peak 1 hour to average weekday (AADT)	13.53 (AM Peak: 07:00 AM – 08:00 AM)	11.50 (15:00 PM – 16:00 PM)
From peak 2 hours to average weekday (AADT)	6.81 (AM Peak: 07:00 AM – 09:00 AM)	5.83 (15:00 PM – 17:00 PM)
From peak 3.5 hours to average weekday (AADT)	4.22 (AM Peak: 06:30 AM – 10:00 AM)	3.43 (14:30 PM – 18:00 PM)
From average weekday to year	365	365

Source: Estimated by Economic Advisory, TfNSW

10.1.2 Cost expansion factors

Cost expansion factors in Table 10.4 have been estimated using RMS data from 2011/12. The traffic cost is composed of travel time cost, vehicle operating cost, accident cost and environmental cost. The value of travel time during business hours is greater compared to the peak period due to a higher proportion of business vehicles.

The traffic volume data provided did not differentiate between vehicle types. The cost expansion and volume expansion factors are assumed to be the same for public transport modes (rail, bus and ferry). However, additional crowding costs can be included for peak hours in project appraisals.

Table 10.4 Cost expansion factors: road traffic

	Roads (ADT)	
	Sydney (1)	**Rural (2)**
From peak 1 hour to weekday	12.45 AM Peak: 08:00 AM – 09:00 AM	10.81 16:00 PM – 17:00 PM
From peak 2 hours to weekday	6.29 AM Peak: 07:00 AM – 09:00 AM	5.51 15:00 PM – 17:00 PM
From peak 3.5 hours to weekday	4.04 AM Peak: 06:30 AM – 10:00 AM	3.32 14:30 PM – 18:00 PM
From weekday to year	336	349
	Roads (AADT)	
	Sydney (1)	**Rural (2)**
From peak 1 hour to average day (AADT)	12.56 AM Peak: 08:00 AM – 09:00 AM	10.92 16:00 PM – 17:00 PM
From peak 2 hours to average day (AADT)	6.34 AM Peak: 07:00 AM – 09:00 AM	5.56 15:00 PM – 17:00 PM
From peak 3.5 hours to average day (AADT)	4.07 AM Peak: 06:30 AM – 10:00 AM	3.34 14:30 PM – 18:00 PM
From average day to year	336	350

Source: Detailed methodology is provided in Orthongthed et al (2013). Estimated by Economic Advisory, TfNSW, based on the following datasets:
(1) Sydney: Traffic volume data in 2011 provided by Roads and Maritime Services for each hour and direction. Breakdown of traffic volume by vehicle type was not available. Expansion factors are based on traffic data at 5 tolled freeway stations, 4 arterial stations and 5 local road stations. Stations are selected for fairly representing traffic conditions in Sydney Inner, Middle and Outer rings.
(2) Rural: Traffic volume data in 2011 provided by Roads and Maritime Services for each hour and direction. Expansion factors are based on traffic data at 26 arterial stations and 10 local road stations in Hunter, Northern, South West, Southern and Western regions.

11 Public transport

11.1 Public transport crowding

TfNSW recommended multipliers for train crowding presented in Table 11.1. These parameters can be used to evaluate transport projects that change on-board crowding. For example, projects that increasing service frequency, introducing new services, or building new links. These multipliers convert time spent in a crowded situation into equivalent IVT minutes. For example, sitting on a crowded train is valued at 1.01 to 1.05 times uncrowded on-board train time.

Table 11.1 Train crowding multipliers

Category	TfNSW multiplier	National Guidelines multiplier
Crowded seat	1.01 - 105	1.21
Standing	1.04 - 1.87	1.65
Crush standing	2.04 - 2.52	2.11

Source: TfNSW multipliers sourced from Douglas & Jones (2016). ATAP (2018)

Detailed crowding multipliers by mode are included in Table 11.2 by percentage of seated capacity. Because of the difference in the amount of standing area per seat between public transport vehicles, crowding multipliers scale at different rates for each vehicle type.

Table 11.2 Detailed heavy rail, light rail, metro and bus crowding multipliers

Heavy Rail		Light Rail and Metro		Bus	
% Seated capacity	Multiplier	% Seated capacity	Multiplier	% Seated capacity	Multiplier
80% - 90%	1.01	80% - 90%	1.01	80% - 90%	1.01
90% - 100%	1.02	90% - 100%	1.02	90% - 100%	1.05
100% - 110%	1.05	100% - 110%	1.04	100% - 110%	1.10
110% - 120%	1.09	110% - 120%	1.06	110% - 120%	1.16
120% - 130%	1.15	120% - 130%	1.09	120% - 130%	1.24
130% - 140%	1.21	130% - 140%	1.12	130% - 140%	1.32
140% - 150%	1.29	140% - 150%	1.15	140% - 150%	1.41
150% - 160%	1.38	150% - 160%	1.18	150% - 160%	1.52
160% - 170%	1.48	160% - 170%	1.21	Over 160%*	2.04 – 2.52
170% - 180%	1.60	170% - 180%	1.25		
180% - 190%	1.72	180% - 190%	1.29		
190% - 200%	1.86	190% - 200%	1.33		
Over 200%*	2.04 - 2.52	200% - 210%	1.37		
		210% - 220%	1.46		
		220% - 230%			
		230% - 240%	1.55		
		240% - 250%			
		250% - 260%	1.65		
		260% - 270%			
		270% - 280%	1.76		
		280% - 290%			
		290% - 300%	1.87		
		Over 300%*	2.04 - 2.52		

Source: Douglas & Jones (2016) * Crush capacity for each vehicle type

Crowding multipliers have not been estimated for the single-deck trains used by Sydney Metro. For single-deck trains, **TfNSW recommends** using light rail crowding multipliers.

Transport demand models used in NSW do not constrain public transport demand to the capacity of the service. This results in patronage above crush capacity in some cases. **TfNSW recommends** that one of the following approaches is used where modelled crowding exceeds the crush capacity threshold:

- Extrapolate the existing crowding function for levels of crowding above the crush capacity threshold
- Apply the maximum crowding factor to all travel occurring over the crush capacity threshold
- Estimate displacement of trips to other travel times or modes using an alternative model, such as the Enhanced Train Crowding Model (ETCM) or another appropriate methodology.

11.2 Station crowding

TfNSW recommends the multipliers for station crowding in Table 11.3. Four levels of station crowding are used:

- low crowding (Crowding level A: max density of 0.31 persons per square metre (psm))
- medium crowding (Crowding level B:max density of 0.43 psm to level C: max density 0.71 psm)
- high crowding (Crowding level D: max density of 1.08 psm to level E: max density of 2.13 psm).
- very high crowding (Crowding level F: max density of 3.6 psm).

The multipliers in Table 11.3 convert waiting and walking in a crowded station into on board train time. For example, one minute waiting time in a very highly crowded station is equivalent to 3.66 minutes on-board train time. These multipliers can be used to evaluate projects that impact station crowding (e.g., station upgrades, increasing service frequency or introducing new services).

Table 11.3 Station crowding multipliers

National Guidelines	Station crowding level					
	Low	Medium		High		Very High
Fruin classification	A	B	C	D	E	F
Waiting	1.00	1.00	1.00	1.02	1.55	3.66
Walking	1.00	1.00	1.00	1.00	1.10	2.77

Source: ATAP (2018)

11.3 Value of bus stop and station quality attributes

TfNSW recommends the values for bus stop and station quality attributes in Table 66. Public transport projects often involve the construction or improvement of bus stop and rail station attributes such as seating, information, cleanliness and lighting. Valuation of these attributes is often conducted using In Vehicle Time (IVT) minutes which convert peoples' willingness-to-pay for the improvement in the attribute to equivalent time spent travelling on board the bus, train or light rail.

Table 11.4 presents the IVT minute values from a 2013 stated preference and quality rating survey on bus, light rail and rail services conducted by Douglas Economics, as well as the converted dollar value. The values represent a service quality improvement from a customer rating of 40 per cent to 80 per cent (using a scale where 0 per cent corresponds to "very poor" and 100 per cent to "very good"). The 2013 survey showed that the average stop/station rating was 65 per cent, 79 cent cent, 62 per cent for bus, light rail and rail respectively with an overall rating of 67% for all modes.

To apply these values in an economic appraisal, the rating in the base case (denoted as A in the equation below) and the project case (denoted as B) for a particular mode must first be estimated. The economic benefit can then be estimated as:

Equation 9 Value of stop / station quality

$$\boldsymbol{Stop\ quality\ benefit = (entries + transfers + \ exits) \times uplift \times \frac{(B - A)}{40\%}}$$

Where:

- **Entries** = stop / station entries
- **Exits** = stop / station exits
- Uplift = the attribute dollar value in Table 11.4
- **A** = the quality rating (out of 100%) in the base case
- **B** = the quality rating (out of 100%) in the project case

The analysis can be done at an individual attribute level or overall rating level dependent on information availability.

Table 11.4 Value of bus stop / station quality attributes

Attribute	Sydney 2013 survey					
	IVT minutes			Dollar value of stop/station quality ($)		
	Bus	Light rail	Rail	Bus	Light rail	Rail
Weather protection	0.95	0.53	0.35	0.31	0.17	0.11
Seating	0.69	0.60	0.46	0.22	0.19	0.15
Information	0.86	0.72	0.37	0.28	0.23	0.12
Lighting	0.40	0.53	0.37	0.13	0.17	0.12
Cleanliness & graffiti	0.55	1.30	0.61	0.18	0.42	0.20
Ticket purchase	0.23	0.57	0.60	0.07	0.18	0.19
Platform Surface			0.57			0.18
Platform On/Off			0.40			0.13
Toilet Availability & Cleanliness			0.09			0.03
Staff			0.24			0.08
Retail Facilities			0.11			0.04
Car access facilities			0.08			0.03
Bus access facilities			0.07			0.02
Attribute sum	3.7	4.3	4.3	1.20	1.39	1.39
Overall rating	3.0	3.2	3.4	0.97	1.04	1.10

Source: Douglas Economics (2014) Passenger service quality values for bus, LRT and rail in inner Sydney, report to Bureau of Transport Statistics, TfNSW, August 2014
Note: The values in the represent the quality improvement from a rating score of 40% to 80%. The value of each attribute can be used if the individual attributes are known. Otherwise, the 'overall rating' value can be used for a 'package' of improvements or if the individual attribute is unknown

11.4 Value of vehicle quality attributes

TfNSW recommends the values for vehicle quality attributes in Table 11.5. It shows the value of vehicle quality attributes such as improvements to outside appearance, seat availability and heating & air-conditioning in terms of IVT minutes and dollar value. The average vehicle rating was 57 percent, 71 per cent, 62 per cent for bus, light rail and rail respectively with an overall rating of

63 per cent for all modes in the 2013 survey. The economic benefit can be calculated using the method below:

Equation 10 Value of vehicle quality

$$\boldsymbol{Vehicle\ quality\ benefit} = \boldsymbol{boardings} \times \boldsymbol{uplift} \times \frac{(\boldsymbol{B} - \boldsymbol{A})}{\mathbf{40\%}}$$

Where:

- **Boardings** = vehicle entries
- Uplift = the attribute dollar value in Table 11.5
- **A** = the quality rating (out of 100%) in the base case
- **B** = the quality rating (out of 100%) in the project case

Table 11.5 Value of vehicle quality attributes

Attribute	Sydney 2013 survey							
	IVT minutes				Dollar value of vehicle quality ($)			
	Bus	Light Rail	Rail	All	Bus	Light Rail	Rail	All
Outside appearance	0.18	0.50	0.70	0.47	0.06	0.16	0.23	0.15
Ease of on/off	0.20	0.41	0.17	0.27	0.06	0.13	0.06	0.09
Seat availability & comfort	0.33	0.31	0.52	0.37	0.11	0.10	0.17	0.12
Space for personal belongings	0.01	0.14	0.07	0.04	0.00	0.05	0.02	0.01
Smoothness & quietness of ride	0.35	0.43	0.24	0.38	0.11	0.14	0.08	0.12
Heating & air-conditioning	0.29	0.31	0.53	0.38	0.09	0.10	0.17	0.12
Lighting	0.14	0.27	0.24	0.21	0.05	0.09	0.08	0.07
Inside cleanliness & graffiti	0.44	0.19	0.34	0.37	0.14	0.06	0.11	0.12
On-board information & announcements	0.14	0.11	0.36	0.22	0.05	0.04	0.12	0.07
Ability to use computer & internet	0.03	0.00	0.10	0.01	0.01	0.00	0.03	0.00
Bus driver/on-board train staff	0.42	0.49	0.00	0.50	0.14	0.16	0.00	0.16
Environment: noise & emissions	0.28	0.42	0.29	0.37	0.09	0.14	0.09	0.12
Attribute sum	2.8	3.6	3.6	3.6	0.91	1.16	1.15	1.16
Overall rating	2.2	2.2	2.8	2.5	0.71	0.71	0.91	0.81

Source: Douglas Economics (2014) Passenger service quality values for bus, LRT and rail in inner Sydney, report to Bureau of Transport Statistics, TfNSW, August 2014. Prices have been indexed to January 2023 prices (ABS Series ID A84994877K)
Note: The values in the Table represent the quality improvement from a rating score of 40% to 80%. The value of each attribute can be used if the individual attributes are known. Otherwise, the 'overall rating' value can be used for a 'package' of improvements or if the individual attribute is unknown. A trip time of 25 minutes is assumed.

11.5 Value of quality attributes when switching modes

Travellers that switch mode may benefit from access to a service which is perceived as being of higher quality than the one previously used.

Two 'types' of preference have been estimated: quality and 'intrinsic'. Intrinsic preference is the residual preference after subtracting 'quality' differences. **TfNSW recommends** the 'intrinsic mode preference' values in Table 11.7 be used to estimate the additional benefit for travellers switching from bus to LRT and heavy rail. **TfNSW does not recommend** estimating a vehicle quality benefit for users switching from car to public transport.

Table 11.6 Modal preference per trip

Attribute	Estimated modal preference per 25 minute trip		
	IVT minutes		
	Bus to LRT	Bus to Rail	Rail to LRT
Quality modal preference	2.10	0.10	2.00
Intrinsic modal preference	2.80	2.50	0.30
Gross modal preference	4.90	2.60	2.30

Source: Developing a Suite of Demand Parameters for Inner Sydney Public Transport, Douglas & Jones, November 2016, ATRF. Table 11 (pg.17).

Table 11.7 Modal preference per hour of travel

Attribute	Estimated modal preference per hour of travel		
	IVT minutes		
	Bus to LRT	Bus to Rail	Rail to LRT
Quality modal preference	5.04	0.24	4.80
Intrinsic modal preference	6.72	6.00	0.72
Gross modal preference	11.76	6.24	5.52

Source: Developing a Suite of Demand Parameters for Inner Sydney Public Transport, Douglas & Jones, November 2016, ATRF.

11.6 Travel time reliability

When travel times are unreliable, travellers will include buffer times on their journey. **TfNSW recommends** additional buffer time built into a journey (because of travel time variability) be treated **equally as costly as** the time spent travelling.

Travel time reliability is defined as the consistency and dependability of travel times for a given trip. It can also be thought of as the variability in journey times. Statistical range measures provide information on the range of travel time variability that transport users' experience. One of these is the use of the standard deviation statistic.

Travel time reliability can be assessed using the buffer time, which is an additional time allowance a traveller includes due to trip variability. For example, a travel route has an average travel time of 60 minutes and standard deviation of 10 minutes. Assuming a normal distribution, if a trip-maker needs 95 per cent confidence to arrive at the destination on time, the departure time would need to be 20 minutes earlier (two standard deviations). However, the actual travel time is mostly likely to be 60 minutes in that the trip-maker will arrive 20 minutes earlier, which attracts additional waiting time cost.

The valuation of travel time reliability attempts to value the buffer time that the travellers have budgeted before departure. It is worth noting that, in this framework, the values of travel time reliability do not include other logistic costs such as worker's cost at warehouses waiting for loading or unloading freight vehicles.

Travel time reliability depends on many factors including road capacity, traffic accidents, road work, weather, traffic controls, special events and traffic fluctuations. This means that the travel time reliability, as measured by standard deviation, is constantly changing.

Table 11.8 summarises various studies of the value of travel time variability. Empirical evidence indicate that the valuation of travel time reliability varies. The relativity of the value of travel time variability to the value of in-vehicle travel time ranges from 0.10 to 3.23. TfNSW recommends that the reliability ratio is equal to 1. That is, the value of travel time reliability should be set at the same value as in-vehicle travel time.

Table 11.8 Value of travel time reliability

Study	Mode	Country	Reliability factor
Hollander (2006)	Bus	UK	0.10
Bhat and Sardesai (2006)	Multi-modes	US	0.27
Brownstone and Small (2005)	Car	US	0.40
Hensher (2001)	Car	NZ	0.57
Lam and Small (2011)	Car	US	0.66
Small et all (2005)	Car	US	0.91
Batley and Ibnez (2009)	Rail	UK	2.06
Small et al. (1999)	Car	US	3.23
Reliability ratio recommended by TfNSW	Multi-modes		1.00

Source: TfNSW Economic Advisory (2022)

11.7 Social inclusion benefits of public transport provision

When a new public transport service is introduced to an area and there is no existing other modes of public transport, social inclusion benefits may be estimated and presented in the CBA sensitivity analysis.

Social inclusion benefits are estimated at $20.38 per return trip (Stanley 2022).

Social inclusion benefits should be strictly applied to the following trips only:

- New trips from the areas of higher exclusion risk.
- Trips that would require a lift giver.
- Trips would have been taken by taxi.

The details of methodology can be found in Stanley (2022).

12 Asset life and residual value

12.1 Asset Life

TfNSW recommends the economic life of assets presented in Table 12.1. **TfNSW recommends** that residual value is calculated using the straight-line depreciation method.

Often information is available on the useful life of assets in TfNSW financial statements. However, these values will relate to each entity's accounting treatment for depreciation purposes and may or may not be suitable for use in an economic appraisal.

Table 12.1 Economic life of assets

Asset class	Economic life (years)
Network infrastructure	
Rail extensions, busways	70
Earthworks	50-150
Bridges - concrete	120
Bridges - timber	40
tunnels	100
Culverts	100-120
Rail track	50-100
Turnouts	15-50
Ballast	60
Sleepers – concrete	50
Sleepers - timber	20
Road pavements – concrete	60-80
Road pavement – asphalt	30-40
Bus priority schemes	20
Nodal infrastructures	
Stations – rail/light rail	50
Bus stops	20
Ferry wharves	40
Interchanges, commuter parking facilities	50
System infrastructure	
Deports, buildings (miscellaneous)	40-50
Plant and equipment (miscellaneous)	12
Control centres (IT systems, excl. buildings)	5
Rail signals and communications	20
Fleet and rolling stock	
Bus	15
Rollingstock	35

Source: ATAP (2018), TfNSW

Some assets have an economic life that is shorter than the appraisal period. Where this is the case, the costs of the replacement of that asset should be included in the CBA in the final year of the asset's economic life.

12.2 Residual value

Residual value refers to the components of the project that have significant life remaining at the end of the appraisal period. TfNSW recommends that residual value is calculated using the straight-line depreciation method:

Equation 11 Straight line depreciation

$$\boldsymbol{Residual\ value = K \times \frac{(Asset\ life - Appraisal\ period)}{Asset\ life}}$$

Where:

- **K** = the capital cost
- **Asset life** = useful life / economic life of the asset

- **Appraisal period** = the appraisal period used for the CBA

The residual value is treated as accruing in the final year of the appraisal for the purposes of discounting.

The full capital cost should be included when calculating the residual value, including labour, materials, plant, equipment, and other fees or management costs. Only including physical components (such as infrastructure or raw materials) will understate the residual value of the asset People with a disability

13 People with a disability

Lifts improve train station accessibility for people with a disability. Parameter values for the installation of a lift are:

- $0.80 for passengers without a disability
- $3.72 for passengers that have mobility challenges. Passengers that have mobility challenges may include elderly people, those with heavy luggage, bicycles and strollers
- $4.85 for passengers using a wheelchair.

Table 13.1 Benefits of rail station lift to passengers

	People without a disability ($ / train trip)	Mobility challenged (mild disabilities) ($ / train trip)	People using a wheelchair ($ / train trip)
Sydney Station Survey 1997	$0.80	$3.12	
UK survey 2009	$0.08	$1.00	$1.81
UK survey 2007	$0.67	$4.11	
Sydney Observation Survey		$4.32	$4.85
Recommended value (based on SP survey of Sydney Trains)	$0.80	$3.72	$4.85

Sources:
(1) Sydney surveys from Douglas (2011) Estimating the user benefit of rail station lift, ATRF 2011
(2) UK survey 2009 from Duckenfield et al (2010) Measuring the benefits of the access for all programme, European Transport Conference 2010
(3) UK survey 2007 from Maynard, A, (2007) Monetising the benefits of disabled access in transport appraisal, 2007 Conference Transport Canada
December 2011 prices indexed to January 2023 prices (ABS Series ID A2325806K)

14 Option value

Option value refers to an individual's willingness-to-pay (WTP) to have the option of another mode of transport, even if they may not use it. For example, a car driver benefits from having the option of a bus service available in case the car unexpectedly breaks down.

There is limited research into the monetary values of options in NSW. As a result, **TfNSW recommends** that option values are only included as a benefit as part of sensitivity testing. Table 14.1 provides indicative monetary values for option values based on a UK study.

The following factors need to be considered when estimating option value:

- The catchment area: this should consider the number of households that are likely to be affected by the project. A catchment area of 2km is appropriate for minor stations while a catchment of 5km is suggested for main stations.
- Alternative transport solutions in the area: if a train service is added to an area where public transport does not exist in the Base Case, the full option value is used. If there is already an existing bus service, the option value is lower and is the difference between the train and bus option values.

Table 14.1 Option value ($ / household per annum)

New Service Type	Option value only ($ / household per annum)	Option value and Non-use value*($ / household per annum)	Value of mixed mode package($ / household per annum)
Introduce train service where no public transport exists	$337	$562	
Introduce bus service where no public transport exists	$184	$307	
Introduce both bus and train service where no public transport exists	$337	$562	$869
Introduce train service where bus exists	$152	$255	

Source: UK DfT 2012, Transport Analysis Guidelines. Values converted to AUD from GBP (average 2010 exchange rate) then indexed from December 2010 to January 2023 prices (ABS Series ID A2325806K)
Notes: *Non-use value refers to the value placed on the existence of a service regardless of any possibility of future use of the individual

15 Cost estimation

A robust CBA needs comprehensive and accurate cost estimates that are able to be easily and clearly traced, replicated and updated. These expenses are generally estimated by a quantity surveyor, construction economist, or cost manager.

The standard for cost estimation can be found in the Cost Estimation Guidance by the Australian Government Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA). For large projects, especially those seeking federal funding, DITRDCA's cost estimation guidance should be followed and requires highly accurate estimates, including probabilistic cost estimation and itemised costing from first principles.

15.1 Difference between costings in a financial appraisal and a cost benefit analysis

The cost estimates used in a CBA differ from the cost estimates used in a financial appraisal. CBA uses real costs, discounted to present values using the social discount rate. Financial appraisals tend to report costs in nominal dollars and may use a different discount rate to the CBA.

Resource costs are used in a CBA and do not include taxes and subsidies. Taxes and subsidies are transfer payments due to government policy decision and do not impact the underlying level of benefits and costs of an initiative to the NSW community, rather they impact how these benefits and costs are shared by the NSW community.

Cost escalation is also treated differently in a CBA. Prices in a CBA are generally in real terms, that is, no escalation takes place. Escalation should not be included unless the prices of specific inputs or outputs are expected to move at a rate significantly different from the general inflation rate, that is if prices of project components move at a different rate.

15.1.1 Level of accuracy

The NSW Government recommends the use of probabilistic modelling approaches to be informed by actual experience of project managers, service delivery officers, legal or other experts who can identify and place a value on salient risks.

In practice, the accuracy of project estimates should increase during the decision-making process in keeping with available information about the project options. At the planning stage, estimates are likely to be less accurate than final out-turn costs. While early estimates may not be as accurate as final cost, planning estimates are generally accurate in relative terms so they provide a reasonable basis for the ranking and initial screening of options.

The cost of gaining greater accuracy should also be considered. For early stage investigations and unfunded transport projects the amounts spent on accurate cost estimations should be enough to support an informed choice and not necessarily be definitive.

TfNSW recommends that P50 cost should be used in core economic appraisal and P90 cost should be included in the sensitivity test. For some high value high risk projects where there is a high degree of likelihood of cost overrun, a Project Team can use P90 cost in core economic appraisal and P50 cost in sensitivity test. If P90 cost is used in the core BCR estimate, the Project Team should discuss with Economic Advisory and present necessary narratives in economic appraisal and business case reports. The project risk profile, life cycle phase, delivery strategy and the expertise available to the project team also need to be considered in deciding on the accuracy of cost estimates.

Cost estimates in a CBA should be clear in stating the level of coverage, completeness and accuracy involved, with particular care exercised in the public release of cost estimates that are preliminary or likely to be revised.

15.2 Indicative operation and maintenance costs

Operation and maintenance costs are expenses associated with the maintenance and administration of the project or initiative on a day-to-day basis, after it is built. The figures from Table 15.1 to Table 15.10 should only be used strategically. For example, they can be used to calculate the cost of network wide changes, where indicative costs are needed. For the majority of projects, Section 15 does not provide adequate consideration of project-specific factors to be used in cost estimation.

15.2.1 Heavy rail

Operating and maintenance cost parameter values for suburban and intercity trains are presented in Table 15.1. Although average costs are presented it is noted that rollingstock maintenance, presentation and cleaning costs are higher for suburban trains compared to intercity trains; while power, traction and crew costs are lower for suburban trains

Marginal costs are often more relevant in an economic evaluation because comparisons are between the base case and the project case. Marginal cost can be estimated by removing fixed costs. For example, rollingstock presentation and cleaning are often fixed costs because they incur independently of the number of kilometres travelled. High level benchmark station maintenance and operating costs are included in Table 15.2.

Table 15.1 Train operating and maintenance costs

Cost description	$ per car km	
	Average cost	Marginal cost
Power/traction	$0.29	$0.29
Rollingstock routine maintenance	$0.40	$0.40
Rollingstock presentation / cleaning*	$0.19	
Rollingstock major periodic maintenance*	$1.11	
Infrastructure routine maintenance	$1.11	$1.11
Infrastructure major periodic maintenance*	$1.75	
Crew	$1.47	$1.47
Total recurrent costs	$6.33	$3.28

Source: Railcorp Operating and Maintenance cost analysis, June 2015.
*These items are not marginal costs.
Crew costs are indexed from June 2015 to January 2023 wages (ABS Series ID A2599999R). All other costs are indexed from June 2015 prices to January 2023 prices (ABS Series ID A2325806K)

Table 15.2 Station operating and maintenance costs

Cost description	$m / year	
	Surface station	Underground station
Station operating and maintenance (range)	$0.73 ($0.71 – $0.91)	$1.21 ($1.21 - $1.81)

Source: Railcorp Operating and Maintenance cost analysis, June 2015. Values indexed to January 2023 prices (ABS Series ID A2325806K)
Note: Values are indicative, they should only be used strategically.

15.2.2 Rail freight

Table 15.3 presents indicative values. The values are suitable for economic analysis as they exclude tax.

Freight rail operating costs can vary widely depending on a range of factors. Some of the factors that may affect below rail operating costs include tonnage carried, axle loads, line speed, age and type of infrastructure and rolling stock characteristics. The factors that may affect above rail costs include type of rolling stock, condition of asset, level of usage, gradient, curvature, speed limits, axle load, payload and number of wagons.

Given the wide variability in freight rail operations the costs are provided in a range (i.e. low, medium and high). The below rail fixed maintenance costs are provided as annualised average costs for the coal network and the interstate freight network.

Users should exercise judgment when choosing the most appropriate value noting the following on the items provided in Table 15.3:

- **Items 1a and 1b:** are the fixed costs of track maintenance for the coal and inter-state network. They cover the costs of track maintenance over three distinct phases:
  - immediately after construction – inspection and routine maintenance
  - after 5 years – inspection and routine maintenance, regular rail regrinding and resurfacing
  - after 10 years - Major Periodic Maintenance.
- **Item 3:** Rail track variable maintenance costs vary with the volume of the load carried. These costs include grinding, ballast cleaning etc.
- **Item 4:** Major periodic maintenance (MPM) covers re-sleepering and laying ballast. They are typically incurred every 10 year. However, heavy usage may result in more frequent MPM.
- **Item 5:** This is the cost of new rolling stock including locomotives and wagons purchased. The economic life of rolling stock is assumed to be 35 years.
- **Item 6:** refit costs are the cost of refitting locomotives and wagons depending on usage. Assume these occur every 10 years for locomotives and 15 years for wagons. It should be noted that locomotive and wagon refit costs can vary significantly between 15 per cent and 50 per cent of the cost of a new unit.
- **Items 7 and 8:** If no refurbishment or half-life fit out costs are available, use costs in Items 7 and 8. Alternatively, Items 7b and 8b are per km values which may be used if detailed maintenance costs are not available. **To avoid double counting, if items 7 and 8 are used, item 6 should be excluded.**
- **Item 9:** To estimate fuel costs multiply the fuel consumption rate in Item 9 with the resource price of fuel (market wholesale price for diesel fuel less 10 per cent GST and excise taxes). This will provide the fuel cost per locomotive km. Fuel cost will vary significantly with load, terrain and distance travelled.
- **Item 10:** provides the hourly cost of a two person crew which can be used to estimate crew costs for each trip or over one year making assumptions about working hours and working conditions.

Table 15.3 Freight operating and maintenance costs – above and below rail

	Cost component	Low	Medium	High
Below Rail Costs	Item 1a – rail track fixed maintenance cost by volume ($ / track km) – Coal network			
	1 – 10 million ton per annum (mtpa)	$12,796	$19,194	$31,989
	10 – 30 mtpa	$19,194	$31,989	$51,183
	30 mtpa and above	$25,591	$31,989	$63,978
	Item 1b – rail track fixed maintenance cost by volume ($ / track km) – Inter-state network			
	Inter-state network	$24,312	$29,430	$40,946
	Item 2 – network control and corporate overheads ($ / track km)*	$7.68	$11.52	$15.35
	Item 3 – rail track variable maintenance costs ($ / '000 gtk)	$1.38	$2.56	$3.84
	Item 4 – major periodic maintenance ($ / track km) – assume every 5 or 10 years based on usage	$12,796	$31,989	$63,978
Above Rail Costs	Rolling stock – upfront capex			
	Item 5a – locomotive ($m per DC 3000 hp locomotive)	$4.86	$4.99	$5.12
	Item 5b – locomotive ($m per AC 4500 hp locomotive)	$6.14	$6.27	$6.40
	Item 5c – wagon ($ per wagon)	$102,366	$153,548	$204,731
	Re-fit costs			
	Item 6a – DC 3000 hp locomotive ($m)	$1.54	$1.66	$1.79
	Item 6b – AC locomotive ($m)	$1.92	$2.05	$2.18
	Item 6c – wagon re-fit cost ($ per wagon)	$10,237	$38,387	$102,366
	Rolling stock – Maintenance costs (annualised average costs)			
	Item 7a – locomotive maintenance ($ per loco per year), assuming 250,000km per year operations, and including scheduled, unscheduled, wheels, component change out (CCO) and maintenance facility charge	$447,849	$511,828	$575,806
	Item 7b – locomotive maintenance ($ per locomotive km)		$2.24	
	Item 8a – wagon maintenance ($ per wagon per year), assuming 250,000km per year operations, and including scheduled, unscheduled, wheels, component change out (CCO) and maintenance facility charge	$15,995	$19,194	$23,992
	Item 8b – wagon maintenance ($ per km per wagon)	$0.06	$0.08	$0.10
	Fuel and crew costs			
	Item 9 – fuel consumption (L / locomotive km)	3 (Flat or empty train)	5 (Loaded train or Mixed terrain)	8 (Hilly or bulk coal or steel)
	Item 10 – crewing cost (standard 2 person crew per hour)	$312	$36	$412

Source: Infrastructure Advisory Services (2013). Values have been indexed to January 2023 prices (ABS Series ID A2325806K). Values for Crewing cost have been indexed from December 2012 to January 2023 wages (ABS Series ID A2599999R)

Note: Values are indicative, they should only be used strategically.

15.2.3 Light rail

Table 15.4 presents the operating and maintenance cost parameters for light rail, with cost breakdown by track, station and train.

Table 15.4 Operating and maintenance costs – light rail

Cost item	Cost	Unit
Light rail vehicle	$3.8m to $5.5m	$m / per light rail vehicle
Track maintenance cost		
Fixed: track and right of way	13,981	$ / track km
Fixed: electric overhead	13,107	$ / track km
Variable: track and right of way	0.70	$ / train km
Variable: signals & communications	14.05	$ / train km
Variable: electric overhead	0.17	$ / train km
Station		
Station staff	27.97	$ / train hour
Station maintenance	17,476.63	$ / station per year
Train		
Driver	52.44	$ / train hour
Maintenance	1.57	$ / train hour
Customer services and ticketing	26.91	$ / train hour
Cleaning	15,729.74	$ / train-year
Materials and overheads	68,318.00	$ / train-year

Source: North West Transport Link Economic Appraisal by Douglas Economics (Jan 2006). Values have been indexed from December 2005 to January 2023 (ABS Series ID A84994877K)
Note: Values are indicative, they should only be used strategically.

15.2.4 Transitway and Metrobus

Table 15.5 presents the operating and maintenance parameters for Metrobus and Transitway buses.

Table 15.5 Operating costs – buses

Cost item	Unit cost	Unit type
Total non-labour costs	$1.90	$ / bus km
Labour cost	$61.44	$ / bus hour

Source: TfNSW analysis. Values have been indexed from March 2015 prices to January 2023 prices (ABS Series ID A2325806K)
Notes:
(1) Cost per revenue and dedicated school bus kilometre is an average of Sydney Transit Authority (STA) figures for a standard bus. Cost cover all running costs of a service variation excluding labour for a weekday between hours of 0559 and 2359. Dead running costs has been loaded to revenue and school bus kilometres by a factor of 1.259.
(2) Values are indicative, they should only be used strategically.

15.2.5 Bus depots

Table 15.6 Operating and capital costs – bus depots

Cost item	Unit cost	Unit
Depot operating costs		
Employee related	39,203	$ / bus lot
Other operating costs	2,050	$ / bus lot
Maintenance costs	1,907	$ / bus lot
Administration	2,763	$ / bus lot
Rent		
Imputed rent	6,060 – 24,241	$ / bus lot
Bus		
Road repair and maintenance	0.04	$ / bus km
Crash cost	0.01	$ / bus km
Road congestion	1.01	$ / bus km
Air pollution	0.43	$ / bus km
GHG emissions	0.18	$ / bus km
Noise	0.03	$ / bus km
Water pollution	0.06	$ / bus km
Nature and landscape	0.00	$ / bus km
Urban separation	0.03	$ / bus km
Upstream and downstream	0.26	$ / bus km
Bus cost by type		
Category 1	74,094	$ / bus
Category 2	135,840	$ / bus
Category 3	419,868	$ / bus
Category 4	456,915	$ / bus
Articulated bus	852,085 to 926,179	$ / bus
Double deck bus	852,085	$ / bus

Source: Estimated by Economic Advisory, TfNSW
Notes:
(1) Imputed rent depends largely on land value and location.
(2) Refer to Table 26 for Road congestion and Table 37 for environmental costs (e.g. air pollution, GHG emissions etc).
(3) Road repair and maintenance costs account for 46% of total repair, maintenance and provision cost – refer to Table 68
(4) Bus categories 1,2,3 and 4 correspond to 13 to 18 passengers, 19 to 24 passengers, 25 to 41 passengers and 42+ passengers respectively
Values are indicative they are not appropriate for use in the costing of a final business case
* Values have been indexed from June 2016 prices to January 2023 prices (ABS Series ID A2325806K)
** Values have been indexed from June 2014 prices to January 2023 prices (ABS Series ID A2325806K)

15.2.6 Ferry services

Table 15.7 presents the costs of ferry services, vessels and wharves. The ferry fleet includes different vessel types that have different capacities and operating costs.

presents a list of operating and capital costs in a bus depot proposal.

Table 15.6 Operating and capital costs – bus depots

Cost item	Unit cost	Unit
Depot operating costs		
Employee related	39,203	$ / bus lot
Other operating costs	2,050	$ / bus lot
Maintenance costs	1,907	$ / bus lot
Administration	2,763	$ / bus lot
Rent		
Imputed rent	6,060 – 24,241	$ / bus lot
Bus		
Road repair and maintenance	0.04	$ / bus km
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Air pollution	0.43	$ / bus km
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Category 4	456,915	$ / bus
Articulated bus	852,085 to 926,179	$ / bus
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Source: Estimated by Economic Advisory, TfNSW
Notes:
(1) Imputed rent depends largely on land value and location.
(2) Refer to Table 26 for Road congestion and Table 37 for environmental costs (e.g. air pollution, GHG emissions etc).
(3) Road repair and maintenance costs account for 46% of total repair, maintenance and provision cost – refer to Table 68
(4) Bus categories 1,2,3 and 4 correspond to 13 to 18 passengers, 19 to 24 passengers, 25 to 41 passengers and 42+ passengers respectively
Values are indicative they are not appropriate for use in the costing of a final business case
* Values have been indexed from June 2016 prices to January 2023 prices (ABS Series ID A2325806K)
** Values have been indexed from June 2014 prices to January 2023 prices (ABS Series ID A2325806K)

15.2.7 Ferry services

Table 15.7 presents the costs of ferry services, vessels and wharves. The ferry fleet includes different vessel types that have different capacities and operating costs.

Table 15.7 Operating and capital costs – ferry services

Cost item	Cost	Unit type
Vessel costs		
River Cat ferry	$6,100,000	per vessel
Manly class	$30,499,000	per vessel
Wharf costs		
Ferry wharf (commuter upgrade)	$7,320,000	per wharf
Ferry wharf (recreational) upgrade	$1,830,000	per wharf
New ferry wharf	$8,540,000	per wharf
Boat ramp upgrade	$488,000	per ramp
Operating costs		
Harbour rate (Parramatta and Inner harbour)	$1,024	per service hour
Freshwater rate	$1,343	per service hour

Source: Estimated by Economic Advisory, TfNSW based on costings supplied to NSW Treasury in 2015. Values have been indexed from March 2015 prices to January 2023 prices (ABS Series ID A2325806K)
Note: Values are indicative they are not appropriate for use in the costing of a final business case

15.2.8 Local infrastructure costs

Table 15.8 represents the median cost of delivering the infrastructure item and should be used as a guide.

Table 15.8 Infrastructure benchmark costs

Infrastructure type	Detail description	Benchmark base cost ($ / unit)	Unit
New sub-arterial road	New 3 lane flexible pavement road	11,191	m
	New 4 lane flexible pavement road	12,995	m
Sub-arterial road widening	Flexible pavement	7,929	m
	Rigid pavement	8,154	m
New rural road	New 2 lane, flexible pavement road	2,948	m
Rural road widening	Widening flexible pavement by 1 lane	4,486	m
Guide posts/safety barriers/pedestrian fencing	Metal guide posts	70 - 130	each
	Guardrail safety barriers	260 - 428	m
	Steel pedestrian fencing	927 - 1621	m
Traffic calming on 2 lane road	Flat top road hump	39,213	each
	Concrete road hump	10,467	each
New concrete footpath adjacent to traffic lane	1.2m wide footpath	287	m
	2.2m wide footpath	692	m
	2.5m wide footpath	849	m
Removal of old footpath and replace with new	1.2m wide footpath	324	m
	2.2m wide footpath	722	m
	2.5m wide footpath	876	m
Unsignalised intersection	"T" intersection	22,483	each
	4 way intersection	37,729	each
Signalised intersection	"T" intersection	277,899	each
	4 way intersection	330,970	each
Roundabout	4 leg roundabout with 2 approach lanes-greenfield	43,569	each
	4 leg roundabout with 2 approach lanes-brownfield (existing traffic)	127,052	each
	4 leg roundabout and pavement with 2 approach lanes-greenfield	419,505	each
Pedestrian crossing	Spanning 2 lanes including pedestrian refuge	6,970	each
Bus stop	Including enclosure, seating and signage	22,238	each
Street Lighting	Including post with 4.5m outreach- 10.5m high	12,775	each
	Including post with 4.5m outreach- 12m high	19,511	each
On road cycleway	2.2m wide lane without kerb separation	297	m
	2.2m wide lane with kerb separation	377	m
Pedestrian underpass	Under rail line	194,103	m
Road pavement resurfacing	Milling and filling of road pavement	123	m2
Cycleway facilities	Stainless steel bicycle racks	1,423	each
Pedestrian/cycle overpass with anti-throw screens and covered walkway	Pedestrian Bridge	38,493	m
	Cycle overbridge	40,594	m
Single lane, on road cycleway, surface treatment and signage	Without kerb separation	297	m
	With kerb separation	377	m
Carpark	At grade carpark	7,999	space
	Multi-storey	43,219	space

Source: IPART Report on Local Infrastructure Benchmark Costs, Final Report, April 2014. Values indexed from June 2013 prices to January 2023 prices (ABS Series ID A2325806K) Note: Values are indicative they should only be used strategically.

Table 15.9 Infrastructure reference costs

Infrastructure type	Detail description	Benchmark base cost ($ / unit)	Unit
Road bridge over railway, waterway or grade separation	Single span bridge 9.4m wide X 19m (lower bound)	1,224,627	each
	Single span bridge 25m wide X 34m (upper bound) with ramps	8,215,911	each
Intersection state / local road	Intersection with perpendicular junction, widening for turning, profiling & removal of 1.2m width asphalt carriageway for local road tie-in, traffic mitigation measures, 100mm asphalt paving, rework at pavement interface, signage.	76,198	each
	Above plus acceleration-deceleration lane off and on, stormwater pipe	400,715	each
Additional cost for road maintenance attributed to mining activity	Lower bound (10% acceleration)	14,094	km
	Upper Bound (30% acceleration)	54,363	km

Source: IPART Report on Local Infrastructure Benchmark Costs, Final Report, April 2014. Values indexed from June 2013 prices to January 2023 prices (ABS Series ID A2325806K)
Note: Values are indicative, they should only be used strategically.

15.2.9 Average fare by mode

Table 15.10 Fare by public transport mode ($/trip)provides the average fares train, bus, ferry and light rail; estimated from Opal data.

Table 15.10 Fare by public transport mode ($/trip)

Card type	Train	Bus	Ferry	Light rail
Adult	$4.30	$2.29	$4.30	$1.64
Child / Youth	$2.13	$1.19	$2.13	$1.00
Concession	$2.28	$1.16	$2.28	$0.82
Senior	$0.83	$0.80	$0.83	$0.47
Weighted Average	$2.69	$1.85	$3.57	$1.37

Source: Data provided by TfNSW Customer Services. Based on Opal trip data only from September quarter 2016 to June quarter 2017. Increased for yearly Opal price increases to July 2022. Notes: GST on ticket price is excluded. Values are indicative, they should only be used strategically.

16 Placemaking

Placemaking and precinct benefits capture the impacts from improvements to places and open space. Types of impacts may include:

- User benefits – benefits users derive from directly interacting or experiencing a place. This may include active travel benefits, and amenity benefits of place and precinct.
- Environmental benefits – reflects environmental externality impacts such as a reduction in greenhouse gas emissions, urban cooling, air quality, noise reduction and retaining biodiversity.
- Social benefits – includes a range of wider benefits associated with places such as culture and heritage values, social inclusion, and social outcome.

When assessing placemaking and precinct benefits, it is important to recognise that some benefits may already be captured in other benefit streams (e.g., active transport, environmental externalities) and that some benefits are project specific and require specialised expertise to accurately assess (e.g., heritage value).

16.1 Amenity Benefit of Transport Precincts

16.1.1 VASP + PERS

The VASP + PERS approach uses the Transport for NSW VASP (Value Assessment System for Place) tool in combination with PERS (Pedestrian Environmental Review System) economic parameter values to monetise urban amenity benefits.

A VASP assessment can be used to evaluate changes in the public realm. The VASP approach is based on an assessment of the following attributes:

- Moving in the space
- Interpreting the space
- Personal safety
- Feeling comfortable
- Sense of place
- Opportunity for activity

In the VASP approach, the above attributes will be assessed using a grading system on a scale of -3 to +3 (seven units) for the base case and the project case options. Qualified urban designers or specialists in the relevant fields, with experience in transport infrastructure projects and independent to the project under the evaluation, should undertake a VASP assessment. The difference between the base case and the project options represents a quality improvement of the place or the precinct. This can then be monetised using the PERS economic parameter values presented in Table 16.1 and Table 16.2.

16.1.2 PERS economic parameter values

The PERS is designed to assess the quality of the pedestrian environment. Originally developed in the UK, updated PERS economic parameter values have been developed for station precincts within NSW (Sydney Metro 2023).

Two PERS methods are available for assessing the amenity benefits of transport precincts. One method is based on the number of visitors to a precinct, while the other is based on the number of households within a precinct catchment. The visitation method is preferred, while the catchment approach is acceptable if data limitations prevent the visitation method from being used.

16.1.2.1 Visitation method

Table 16.1 presents the PERS economics parameter values for the visitation method. The economic benefits of attribute quality improvement is estimated on a per unit basis, so a change in score from -2 to -1 would be valued the same as a change from 2 to 3. The amenity benefit of transport precincts can then be estimated by multiplying the units of improvement from a VASP assessment by the PERS economic parameter value.

Table 16.1 PERS economic parameter value per unit of quality improvement – visitation method

Place theme	Transport user ($/trip)	Non-transport user ($/visit)
Moving in the space	$0.063	$0.036
Interpreting the space	$0.059	$0.023
Personal safety	$0.081	$0.094
Feeling comfortable	$0.086	$0.044
Sense of place	$0.031	$0.000
Opportunity for activity	$0.073	$0.038

Source: TfNSW (2022), Sydney Metro (2023). Values are in June 2023 prices.

Under the visitation method, the PERS economic parameter values are available for public transport (PT) users and non-PT users of rail station, metro station and/or multi-modal interchange precincts. PT users are defined as customers that have used the precinct to get on or off a transport service, while non-PT users are customers that have come to the precinct for other purposes without onboarding to a transport service.

16.1.2.2 Catchment method

Table 16.2 presented the PERS economic parameter values for the catchment method. The catchment method is based on estimates of the number of households impacted by a precinct. While the size of a precinct catchment may vary depending on specific characteristics (e.g., station size, transport accessibility or proximity to other stations), a catchment area of 1.2 km network distance can be used as a baseline. Census data from the Australian Bureau of Statistics can be used to estimate the number of households within the catchment of a precinct.

Table 16.2 presents PERS economic parameter values for the catchment method. Values are available for both public transport users and non-public transport users. To differentiate between two transport users, the percentage of non-public transport households within the catchment can be derived from the Sydney Household Travel Survey (HTS) or other available data based on the precinct location.

Table 16.2 PERS economic parameter value per unit of quality improvement – catchment method

Place theme	Public transport users (household $/year)	Non-public transport users (household $/year)
Moving in the space	$20.28	$4.80
Interpreting the space	$19.20	$3.12
Personal safety	$26.40	$12.72
Feeling comfortable	$27.72	$6.00
Sense of place	$10.20	$0.00
Opportunity for activity	$23.76	$5.16

Source: TfNSW (2022), Sydney Metro (2023). Values are in June 2023 prices.

16.1.2.3 Calculations

The amenity benefits at transport precincts can be estimated using Equation 12:

Equation 12 Amenity benefits at transport precincts

$$\boldsymbol{Amenity\ benefit} = \boldsymbol{D} * \boldsymbol{R_i}\ (\boldsymbol{Project\ Case} - \boldsymbol{Base\ Case}) * \boldsymbol{V_i}$$

Where:

- **D** = demand, measured by the number of trips or households in the catchments
- $\boldsymbol{R_i}$ = Quality rating by VASP attributes
- $\boldsymbol{V_i}$ = Value by attributes (Table 16.1 or Table 16.2)

The calculation steps are outlined below:

Step 1: Estimate the number of trips (visitation method) or households (catchment method) for the transport precincts to be assessed. The number of trips can be sourced from strategic travel demand model, TfNSW train station entries and exits counts and project-specific traffic survey.

Step 2: Assess the changes in the quality of precinct attributes in accordance with the VASP framework.

Step 3: Apply the economic parameter values provided in Table 16.1 or Table 16.2

16.2 Amenity benefits of walking

TfNSW has adopted a Movement and Place framework that requires a balanced approach in assessing both movement and placemaking economic benefits in business case development. TfNSW Economic Parameter Vales (EPV) provides a range of economic benefits for both cycling and walking in terms of individual health benefit, cost savings for car use (vehicle running cost and parking cost) and environmental externalities). TfNSW is delivering projects of Healthy Streets that provide a walking friendly transport infrastructure.

The amenity benefits for healthy streets should be captured in the economic appraisal if data and appraisal framework permit. **Two approaches are recommended for assessing amenity benefits of walking environment. One approach uses the Walking Environment Quality Rating, and the other uses the Walking Environment Attribute Valuation. For a specific project, only one approach should be used dependent on information available.**

16.2.1 Estimating amenity benefit from Walk Environment Quality Rating Approach

The amenity benefit of walk infrastructure can be estimated using a walk environment rating approach by following the 6-step procedure in the worked example below.

Step 1: Decide the base case walk environment rating on 0-100 scale where 0 representing poor and 100 representing the best. It is suggested that the rating should be undertaken by 3-5 urban designers and planners independent to the project team to reduce the subjectivity. The rating should be based on the following attributes of the route:

- Route view- streetscape & landscape
- Green and peaceful
- Lively and interesting
- Healthy
- Pedestrian friendly
- Weather protection
- Feeling of personal security - Day
- Personal security - Night

Step 2: Repeat Step 1 and decide the project case walk environment rating.

Step 3: Calculate the weighted average ratings in the base case and the project case using Table 16.1 as a template.

Table 16.3 Worked example of an assessment of changes in walking environment attributes

Waking Route Attribute	Base Case Attribute Rating	Project Case Attribute Rating	Changes in Rating from the Base Case	Attribute weighting
Route view - streetscape & landscape	50%	80%	30%	24%
Green and peaceful of route	60%	70%	10%	9%
Lively and interesting	60%	70%	10%	8%
Healthy	50%	75%	25%	15%
Pedestrians friendly route	50%	70%	20%	15%
Weather Protection	30%	60%	30%	5%
Feeling personal security - Day	50%	70%	20%	19%
Personal security - Night	30%	60%	30%	5%
Overall rating (weighted average)	**53%**	**77%**	**24%**	

Step 4: Find the Equivalent Walk Time Factor (EWTF) either from Equation 12 or from the Figure 16.1 for the weighted average ratings in the base case and project case.

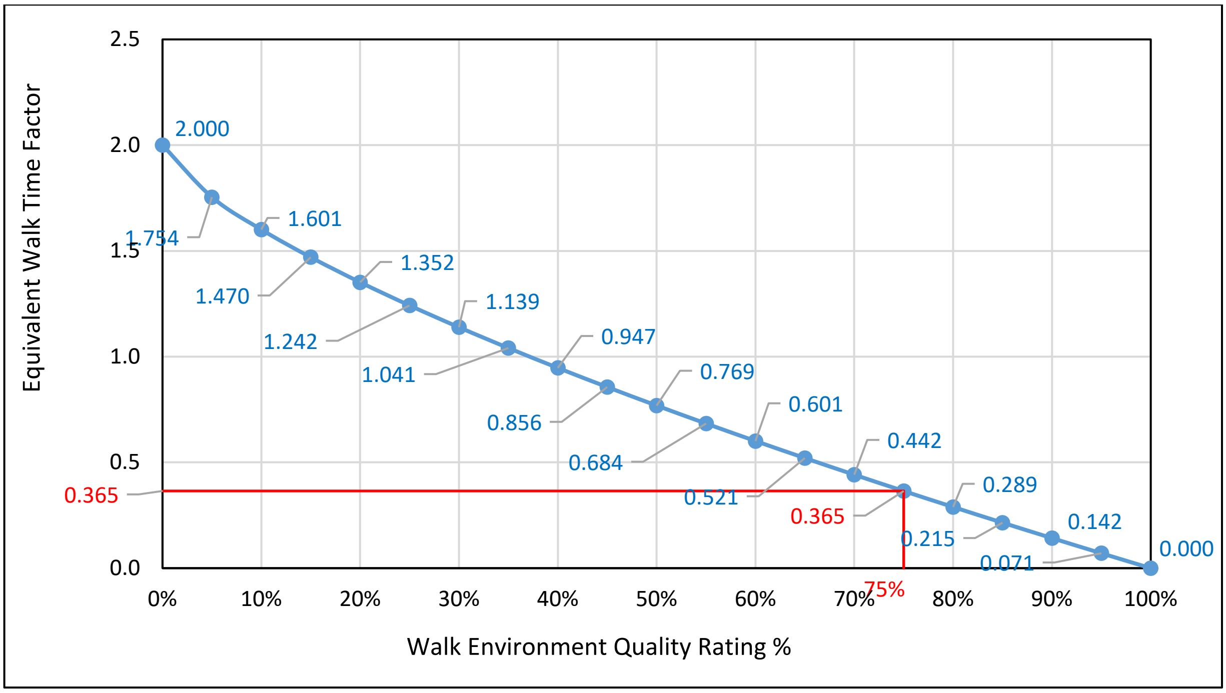
Equation 13 Equivalent Walk Time Factor

$$\boldsymbol{EWTF = 2 - 2 \times WQ^{0.7}}$$

Where:

- **EWTF** = Equivalent Walk Time Factor
- **WQ** = walk environmental quality rating (expressed as a proportion)

Figure 16.1 Equivalent Walk Time Factor with Walk Environmental Quality Rating



Source: Neil Douglas (2022) Valuing the Walk Environment

The example is a base case rating of 53%, and project case rating of 77%, a 24% change. From either Equation 12 or Figure 16.1:

- For the base case rating of 53%, the base case EWTF is 0.72
- For the project case option rating is 77%, the project case EWTF is 0.33.

Step 5: Determine the patronage, walk time and evaluation parameter values such as value of walk time. Estimate induced patronage if any.

- In the example, pedestrian patronage is 1 million trips per annum.
- The induced walking trips are estimated using the elasticity of demand with respect to walking environment rating. The recommended elasticity is 0.78 (Douglas, Jones and Whatley (2022).

  The induced patronage

  = 1,000,000 trips x 0.78 x 24% = 187,200 trips per annum.

- The average walk time on the project section is 30 minutes.
- Value of walk time is 1.5 times private travel time, based on standard practice of valuing walk time at 50% higher than in-vehicle time, this example adopts $28.5 per hour (in 2022 prices).

Step 6: Estimate the amenity benefit of walk environment from the base case to the project case.

Amenity benefit for existing trips

= Patronage x Walk Time x (Base Case EWTF – Project EWTF) x Value of walk time

= 1,000,000 trips x 0.5 hours x (0.72 -0.33) x $28.5

= $5,557,500 per annum.

Amenity benefit for induced walking trips (using rule-of-a-half)

= Induced patronage x Walk Time x (Base Case EWTF – Project EWTF) x Value of walk time / 2

= 187,200 trips x 0.5 hours x (0.72 -0.33) x $28.5 / 2

= $520,182 per annum.

The total amenity benefits for existing and induced walking trips are

$5,557,500 + $520,182 = $6,077,682 per annum.

16.2.2 Estimating amenity benefit from Attribute Valuation Approach

The amenity benefit of walking infrastructure can also be estimated using the attribute valuation approach. It should be noted that the amenity benefit can be estimated from either the Walk Environment Rating Approach or from Walk Environment Attribute Valuation Approach. The two approaches are measuring the same benefit which is not additive. **For a specific project, only one approach should be used dependent on information available.**

Table 16.4 Value of Walk Environmental Attributes Cents per Minute

Walk Environment Attributes		Attribute Levels	Value of Walk Attribute (Original Study)			Economic Parameter Value ($/hour)
			Range (cents per minute)	Mean (cents per minute)	Confidence Level	
1	Walk Setting **versus suburb**	Suburb = Base	-4.5 to +1.5		High	
		City	-3 to +2	-0.8	Med	-$0.53
		Park	0.5 to 3.5	1.7	Med	$1.12
2	Road Traffic **versus Moderate**	Busy Traffic	-4.5 to -2	-3	High	-$1.97
		Light Traffic	0 to 1.5	0.8	Low	$0.53
		Pedestrianized	0 to 3	1.7	Med	$1.12
3	Pedestrian Crowding **versus a reasonable number**	Crowded	-6 to -3	-4.5	High	-$2.96
		Few Pedestrians	0 to 2	0.8	Low	$0.53
		No Pedestrians	-2.5 to 0	-1.3	Low	-$0.86
		Cycle/Scooters on Pavement	-4.5 to -2	-3.2	Med	-$2.10
4	Road Crossing **versus Wait at Junction**	Overpass	0 to 3	1.2	Med	$0.79
		Underpass	-1.5 to +1.5	0.6	Low	$0.39
		Pedestrian Crossing	0 to 2	0.8	Low	$0.53
5	Wide **vs standard**, continuous **vs kerb at crossings,** uneven **vs smooth**	Wide	0.5 to 3.5	2.1	Med	$1.38
		No Kerb	0 to 1.3	0.4	Low	$0.26
		Uneven	-5.5 to -2.5	-3.4	Med	-$2.24
6	Trees **versus No Trees** & Grass Strip **vs no Grass Strip**	Lots of Trees	1.5 to 5.5	3.3	High	$2.17
		Some Trees	0.5 to 3	1.7	Med	$1.12
		Grass Strip	0 to 1	0.4	Low	$0.26
7	Litter / Graffiti **versus Tidy / Graffiti free**	Litter	-3.5 to -0.5	-1.3	Med	-$0.86
		Graffiti	-3 to 0.5	-1.7	Med	-$1.12
8	Seats & Clear Signing versus No Seats & Unclear Signing	Seats	0.5 to 2.5	1.7	Med	$1.12
		Clear Signing	0.5 to 3.5	1.7	Med	$1.12
9	Art / Security Cameras **versus no provision**	Art	-0.5 to 3	0.8	Low	$0.53
		Sec Cameras	-0.5 to 2	0.8	Low	$0.53
10	Night-time **versus Daytime taking account brightness of lighting**	Park - Bright Lighting	-8.5 to -4	-6	High	-$3.95
		Sub/City - Bright Lighting	-3 to -0.5	-1.7	High	-$1.12
		Sub/City - Dim Lighting	-4.5 to -2	-3	High	-$1.97
11	Pavement Quality	Decorative paving **versus asphalt**	-1 to +3.5	1.7	Low	$1.12
12	Provision of Footpath	Basic footpath **versus none**	12 to 44	27	Low	$17.76

Source: (1) Neil Douglas (2022) Valuing the Walk Environment; (2) Douglas, Jones and Whatley (2022) Valuing the walk environment, Australasian Transport Research Forum 2022 Proceedings, 28-30 September, Adelaide, Australia. Values are in January 2023 prices (ABS Series ID A2325806K).

Table 16.2 presents 12 walk environment attributes (Column 2). Each attribute has a base setting that alternative settings are compared with. The attribute levels (Column 3) are defined by the relativity between the base and alternative settings. Value of walk environment (cents per walk minute) was estimated in Douglas (2022) for a range (Column 4), mean (Column 5) and confidence level (Column 6). The mean value of walk environment is converted to dollar per walk hour (Column 7) for economic appraisal application.

Some illustrative Interpretations of Table 16.2 are provided below for a few attributes:

- Attribute 3 – Pedestrian Crowding. Compared to “a reasonable pedestrian number”, alternative scenarios, “Crowded”, “No Pedestrians” and “Cycle/Scooters on Pavement”, generate negative values. The scenario “Few Pedestrians” generates a positive value. This can be interpreted that, pedestrians like a walking environment of a few other walkers, but dislike crowding (including due to COVID-19 risks) and dislike situations with no other pedestrian at all for personal security concerns.
- Attribute 4 – Road Crossing. Compared to “wait at junction/intersection (base setting), three alternative settings, “Overpass”, “Underpass” and “Pedestrian Crossing”, will all generate positive values thus economic benefit. The “Overpass” is the most favourite road crossing from pedestrian perspective.
- Attribute 9 – Night-time. Compared to daytime, all night-time settings generate negative values (likely due to security concerns). “Bright Lighting” is better than “Dim Lighting” in suburb and city. In a park, pedestrians attach a high negative value even with “Bright Lighting”.

The following 6-step procedure illustrates how economic benefit can be estimated from one or more attribute changes from a base case to a project case in an economic appraisal.

Step 1: Define a walk environment using the attributes listed in Table 16.2.

Step 2: For each attribute, decide the appropriate attribute level at the base case and the project case.

- In this worked example, the travel demand is 1 million trips per annum. Each pedestrian needs 5 minutes to cross a busy road.
- Base case: Pedestrian level crossing. Each pedestrian needs 5 minutes to cross a busy road.
- Project case: Overpass. Each pedestrian needs 5 minutes to cross the road via a pedestrian overpass.

Step 3: Look for the equivalent economic value for the attribute level. From section 4 of Table 16.2:

- In the base case, the parameter value is $0.48 per hour/ pedestrian.
- In the project case, the parameter value is $0.72 per hour/ pedestrian.

Step 4: Estimate economic benefit from the base case to the project case.

Amenity benefit for existing trips

= Patronage x Walk Time x (Project Case Parameter Value – Base Case Parameter Value) x Value of walk time

= 1,000,000 trips x (5/60) hours x ($0.72 – 0.48) x $28.5

= $570,000 per annum.

Step 5: If the project case changes other attributes, repeat steps 1-5 to estimate amenity benefit for changes of each attribute.

Step 6: Sum amenity benefits for all attributes.

A 1 Other methods of valuing travel time

TfNSW recommends the VTT times in Section 2. The following is additional information.

A 1.1 Transport demand modelling – value of travel time used to model travel behaviour

TfNSW undertook the Value of Travel Time Study in 2015-2016 (Table A1. 1). This study used stated preference surveys to estimate the VTT for several modes of travel.

The values in Table 84 are used in transport demand models rather than economic evaluations. Transport demand models use different values of time for different segments of the NSW community to estimate their travel behaviour. For example, transport demand models differentiate travellers by behavioural characteristics, such as income (with higher income earners assumed to have a higher value of time), trip purpose, and time of day.

Table A1. 1 Value of travel time by mode – TfNSW 2015-16 survey

Mode	Mode share %	Personal income ($000 p.a.)	Value of travel time ($/hr)	
			Non income standardised	Income standardised
Car	85.40	74	18.51	18.20
Train	6.70	53	16.13	18.11
Bus	7.40	45	9.24	12.01
Ferry	0.40	83	17.95	16.64
Light Rail	0.10	75	24.72	24.19
Public transport	14.60	50	12.74	15.01
All	100.00	71	17.68	17.74

Source: Service Quality Values of Rail Transport in Sydney, Report to Railcorp by Douglas Economics, August 2015 Values indexed from November 2013 AWE to January 2023 AWE (ABS Series ID A84994877K)

When valuing the benefit of travel time savings within a CBA, the purpose of the value is to inform decisions on resource allocation. This differs from the transport modeller's objective of predicting behaviour. For this reason, the VTT savings is assumed to be consistent across modes and segments of the community. If a higher VTT was used for road travel compared to public transport, resource allocation would preference road projects, all else being equal. Similarly, if a higher VTT was used for higher income earners, transport initiatives in high socioeconomic areas would be preferred over lower socioeconomic areas, all else being equal.

A 1.2 Value of travel time - Austroads method

The TfNSW recommended VTT is in line with the ATAP values and based on the Austroads method. The Austroads method of calculating the VTT follows the willingness-to-pay (WTP) approach and is linked to people's productivity and earnings. Austroads recommended the following valuation principles:

- Private travel time is valued at 40 per cent of the seasonally adjusted full time Average Weekly Earnings (AWE) for Australia, assuming a 38-hour working week. This rate is applicable for travel modes of private car, motorcycle, bicycle, walking and public transport for commuting and recreational trip purposes.
- Business travel time is valued at 128 per cent of the seasonally adjusted full time AWE for Australia, applicable for all business trips. This is because businesses pay tax as well as wages. It is assumed that time spent travelling for business purposes is unproductive and therefore foregone working time (Austroads, 2012).

Below are some reasons for the lower VTT for private travel compared to business travel:

- The traveller's WTP is based on after-tax income.
- A worker's after-tax income is shared by household members. The WTP is then related to household disposable income and the number of persons in the household.
- For most people, the marginal disutility of travel is lower than that of work. In Sydney, the average work trip duration is 35 minutes (one way), and the daily travel time per capita is 79 minutes (Bureau of Transport Statistics, TfNSW, 2013). Most people seem to enjoy a certain amount of personal travel, about 30 minutes per day, and dislike travelling more than 90 minutes per day (Mokhtarian & Salomon, 2001). The benefit of small reductions in travel time, say from 34 minutes to 30 minutes, would be marginal or negligible for many people.

In general, however, the VTT reflects the willingness of travellers to trade time for money. Willingness to pay depends on additional factors including the value and urgency attached to the journey purpose and comfort of the trip. Therefore, VTT values are arguably better determined from revealed preference and stated preference data.

A 1.3 Value of travel time Sydney Trains method

In 2010, Sydney Trains (formerly RailCorp) engaged Douglas Economics to update the value of rail travel time used in economic evaluations. This study was updated in 2013. The values were estimated by stated preference market research that asked passengers to choose between two hypothetical rail journeys varying in travel time, fare and departure time. The overall value of on-board train time was estimated at $14.75 per hour with a peak value of $15.27 and an off-peak value of $14.33, as shown in Table A1. 2. Table A1. 3 compares the VTT from the Sydney Trains survey and that recommended by ATAP.

Table A1. 2 Value of on-board train time ($/hr)

Time period	Short	Medium	Long	All	Overall
	<25 min	26 – 29 min	>60 min		
Peak	15.58	17.08	13.33	15.27	14.75
Off peak	15.13	13.84	14.18	14.33	

Source: Service Quality Values for Sydney Rail, Report to Railcorp by Douglas Economics, October 2016 Values indexed from November 2016 AWE to January 2023 AWE (ABS Series ID A84994877K)

Table A1. 3 Value of on-board train time comparisons

Source	Value of time ($/hr)	Difference from ATAP value (%)
Sydney Trains concession fare	9.74	-49.91%
Sydney Trains non-concession fare	20.10	3.36%
Sydney Trains overall	17.31	-10.98%
ATAP - private trips	19.45	

Source: Service Quality Values of Rail Transport in Sydney, Report to Railcorp by Douglas Economics, August 2015 values indexed to January 2023 AWE ((ABS Series ID A84994877K)

The difference between the Sydney Trains and ATAP values can be explained by the following factors:

- The ATAP value is anchored at 40 per cent of AWE, while the Sydney Trains value is based on stated preference surveys of train users. The value of stated preference surveys can be affected by many factors such as sampling, income, trip purpose and general consumer sentiments at the time of the survey.
- Various surveys on the VTT have indicated that the VTT for public transport is lower than car travel. Abrantes and Wardman (2010), having undertaken meta-analysis of UK values of travel time of 1749 valuations in 226 studies from 1980 to 2008, reported that the value of

bus users was 35 per cent below that of car users, and the value of time of rail users was 15 per cent below car travel. Bus users tend to have lower VTT in stated preference surveys. However, bus travel is less comfortable than car travel, suggesting bus users are willing-to-pay a higher cost to cut bus travel time.

- The lower VTT for train users can be largely attributed to the lower value of private leisure. Based on the 2014/15 Household Travel Survey undertaken by Bureau of Transport Statistics, business trips represent 6 per cent of total train trips on weekdays, or 5 per cent in the 3-hour morning peak (6:30AM – 9:00AM) on weekdays

A 2 Vehicle classification

A number of vehicle classification systems are used in this document and by other state and federal guidance documents. This section provides an overview of the different vehicle types and a concordance between classifications. More detail can be found on the Austroads website.

Table A2. 1 Vehicle Classifications

Demand Category*		Vehicle class	Vehicle name / category
Light Vehicle (LV)	Car	1	Small Car Medium Car Large Car
	Light Commercial Vehicle (LCV)		Courier Van-Utility / Light Commercial Vehicle** 4WD Petrol
	N/A***	2	Trailer Caravan
Heavy Vehicle (HV)	Rigid	3	Light Rigid
		4	Medium Rigid
		5	Heavy Rigid
	Articulated	6	Three Axle Articulated
		7	Four Axle Articulated
		8	Five Axle Articulated
		9	Six Axle Articulated
		10	B Double Heavy Truck + Trailer
		11	Double Road Train Medium Articulated + Trailer
		12	Triple Road Train Heavy Truck + three trailers

Source: TfNSW Economic Advisory, based on Austroads (2018) Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals, Appendix B Austroads

* These categories are used by demand models such as PTPM and STM

** Light Commercial Vehicle as per Austroads AP-R264-05 (2005a); Courier Van-Utility as per ARRB RC2062 (2002) for Austroads.

*** Trailers and caravans are generally not separately modelled in strategic demand models

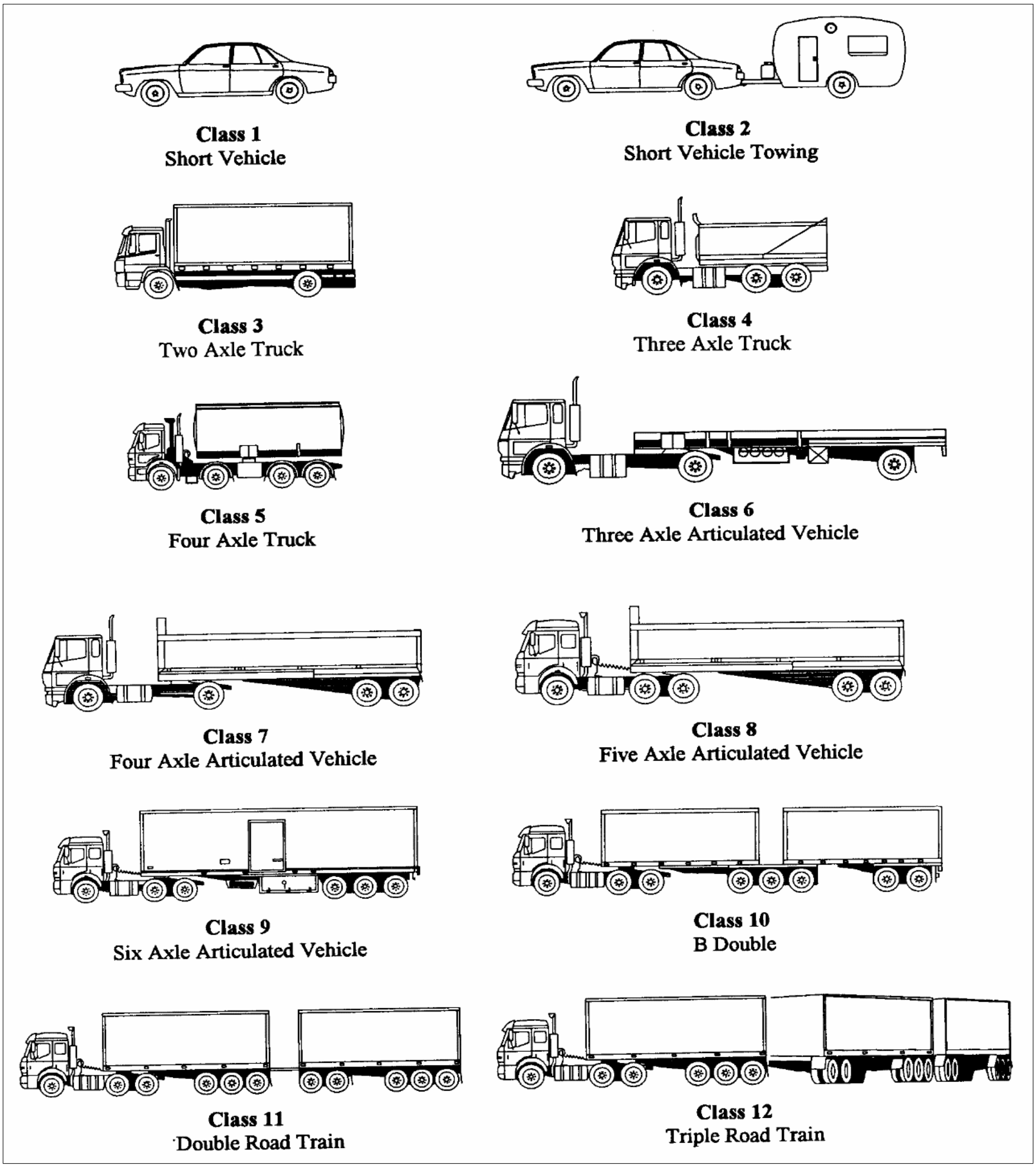


Figure A2. 1 Austroads typical configurations

Source: Austroads (2018) Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals, Appendix B Austroads

A 3 Parameters for use with strategic demand models

Table A3. 1 provides parameter values for use with PTPM's economic output module.

Table A3. 1 Parameters for use with PTPM – C1

Row number	PTPM Output	Unit	Period	Economic parameter
Public Transport Travel Time Savings				
Row 290	Commute	hours (Δ)	3.5h AM	$19.45
Row 291	Business	hours (Δ)	3.5h AM	$63.09
Row 292	Education	hours (Δ)	3.5h AM	$19.45
Row 293	Other	hours (Δ)	3.5h AM	$19.45
Road User Travel Time Savings (1)				
Row 497	VHT - Car continuous	hours (Δ)	2h AM	$39.25
Row 498	VHT - Car new (incl. ROH)	hours (Δ)	2h AM	$39.25
Urban road congestion (4)				
Row 487	Total	km	2h AM	$0.5069
Road Safety Benefit				
Row 487	Total	km	2h AM	$0.0809
Environmental Externalities				
Row 477	< 10 kph	km	2h AM	$0.1513
Row 478	10-20 kph	km	2h AM	$0.1513
Row 479	20-30 kph	km	2h AM	$0.1513
Row 480	30-40 kph	km	2h AM	$0.1513
Row 481	40-50 kph	km	2h AM	$0.1513
Row 482	50-60 kph	km	2h AM	$0.1424
Row 483	60-70 kph	km	2h AM	$0.1424
Row 484	70-80 kph	km	2h AM	$0.1424
Row 485	80-90 kph	km	2h AM	$0.1424
Row 486	90-100 kph	km	2h AM	$0.1424
Active Transport Health Externalities				
Row 149	Walk time (access, egress and interchange)	hours	3.5h AM	$0.4125
Road Damage Costs				
Row 487	Total	km	2h AM	$0.0495

Source: Economic Advisory, TfNSW (2022)
(1) Private / Business purpose split calculated from 2012/13 NSW Household Travel Survey
(2) ATAP 2016 VOC model results for 'Medium Car' used for resource costs, January 2023 prices.
(3) Flat perceived costs from PTPM used – for further information on calculating VOC benefits, refer to Transport for NSW Technical Note on Vehicle Operating Costs (2019)
(4) Not to be calculated in combination with road user travel time savings and vehicle operating costs

A 4 Key indices

Table A4. 1 Key indices for back-casting and forecasting

Indices	Actuals						Forecast			
	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
CPI Sydney	111.08	113.35	115.23	116.43	118.18	122.80	130.54	136.02	139.76	143.25
CPI Private Motoring	97.23	100.00	102.33	102.33	103.33	116.48	123.81	129.01	132.56	135.87
CPI Maintenance & Repair	105.43	106.55	108.70	111.70	113.28	119.20	126.71	132.03	135.66	139.05
CPI Motor vehicles	95.15	93.48	93.65	95.55	100.25	106.35	113.05	117.80	121.04	124.06
AWE NSW ($)	1540.80	1596.00	1643.10	1714.55	1758.10	1758.10	1819.63	1878.77	1939.83	1998.03
PPI road freight	106.53	108.60	111.60	113.38	112.63	118.45	125.91	131.20	134.81	138.18
Petrol cost excl taxes (cent/L)	61.28	69.83	76.12	67.69	58.80	96.63	107.66	112.19	115.27	118.15
Diesel cost excl taxes (cent/L)	59.67	70.14	82.81	71.91	57.38	99.13	137.12	142.88	146.81	150.48

Sources: Estimated by Economic Advisory, TfNSW.
(1) ABS Series ID A2325806K. CPI forecast from TfNSW Economic Advisory based on RBA Statement on Monetary Policy;
(2) ABS Series ID A2326616R. Assume growth by CPI forecast from (1).
(3) ABS Series ID A2328771A. Assume growth by CPI forecast from (1).
(4) ABS Series ID A2328591T. Assume growth by CPI forecast from (1).
(5) ABS Series ID A84994877K. Assume growth by NSW wage price index from NSW Treasury Budget Paper 1.
(6) ABS Series ID A2314058K. Assume growth by CPI forecast from (1).
(7) Average of actual Sydney monthly fuel prices from AIP TGP. Assume growth by CPI forecast from (1).
Note: Escalated to January 2023 prices

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