Transport for NSW

Technical Note on Calculating Road Vehicle Operating Costs

Version 2.0

This document applies to all agencies within the NSW Transport cluster

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 Background

This document provides a recommended approach for calculating road vehicle operating costs (VOC) for cost-benefit analysis (CBA) of NSW Transport cluster projects. It expands on the guidance provided in the *Transport for NSW Cost-Benefit Analysis Guide* (Guide) and the *Transport for NSW Economic Parameter Values* (EPV).

This is a detailed user guide with a presumed high level of knowledge of demand modelling and transport economics.

The calculation of VOC is a common source of error in transport CBA. Although it is estimated for most road and public transport projects, this benefit is not calculated in a consistent way across NSW Transport cluster CBAs. As VOC benefits can account for a significant proportion of the benefits estimated in CBA, inaccuracies in estimation approaches or techniques can have a material impact on the end results. This document provides an overview of common issues encountered when estimating the VOC benefit, and recommends approaches for overcoming them.

This document also contains interim guidance on the treatment of electric vehicle (EV) operating costs in CBA, as uptake and use of EVs in NSW is expected to grow over time. The increase in EV usage has impacts for projects which reduce vehicle operating costs, as EVs have lower operating costs than conventional petrol and diesel vehicles.

1.2 How to use this document

This document provides recommended approaches and parameter values to be used in the CBA of initiatives within the NSW Transport cluster that impact on road travel (either directly or indirectly). 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.

This document provides a framework for selecting the appropriate VOC approach and parameter values, based on the project type, location, and transport modelling approach being used.

Approaches and parameter values that are not covered in this document may still be used in CBA, but should be accompanied by evidence to support their validity. Best practice would involve calculating results with recommended and preferred parameters and explaining the difference.

1.3 Changes in Version 2.0

TfNSW has taken onboard feedback from project teams and CBA practitioners, as well as from other Infrastructure Australia (IA) and Australian Transport Assessment and Planning (ATAP) to further improve the VOC guidance.

This version makes changes to simplify the VOC guidance and to promote consistency of use across different Transport cluster projects. The changes made between the last version of the technical note and this version are detailed below:

Table 1 Changes to the Technical Note on Calculating Road VOC

#	Updates in Version 2.0
1	**Number of alternative approaches to estimate VOC** Simplification of approaches to estimating VOC. Previous versions of this paper provided 4 separate approaches to estimate vehicle operating costs impacts, while this paper presents only two approaches that are more suitable for most TfNSW projects
2	**When to use alternative approaches to estimate VOC** Clearer guidance on when to use each of the two recommended VOC approaches, so that project teams have more certainty of when to apply each approach
3	**Perceived Costs** Changes to perceived costs. Previous versions of this Technical Note provided perceived costs based on international studies of perceptions by users of different cost components. This version aligns to the TfNSW EPV (2022) and to consultation with national guidance bodies which uses a *fuel-only* perceived cost instead, noting that literature in this area is yet to be fully settled
4	**ATAP PV2 VOC model** The base ATAP PV2 (2016) VOC models have been added to the Technical Note. Caution should be taken when applying the ATAP PV2 VOC model to speeds of travel below 20km/h as this can produce unrealistically large economic benefits in cost-benefit analysis. Treatment of depreciation should be consistent within the CBA – this may mean projects which need to use both the urban and rural VOC models (such as regional bypass projects) will need to apply the ATAP PV2 VOC model
5	**Depreciation for private vehicle travel (cars)** ATAP T2 Cost Benefit Analysis notes that depreciation should be left out of CBA because the full cost of the asset to society is accounted for when the resources are consumed to create the asset (in this case, a vehicle) – and as such including depreciation would lead to double counting. For freight vehicles, however, time savings from higher speeds or shorter trip distances enable the trucks to be utilised more intensively, saving capital costs at a fleet level. The depreciation component captured in some VOC models can be used to assess this impact. However, when a private vehicle user saves time, their car will only spend more time parked. There is no way to utilise the vehicle more effectively, and no reduction in the total number of cars required, and therefore no saving in fleet capital costs. For this reason, the ATAP PV2 models should be avoided when calculating the VOC benefits for private vehicles.

Source: TfNSW Economic Advisory (2022)

1.4 Changes to come

ATAP continues to work on vehicle operating cost parameters and is expected to release updated VOC models in the future. When undertaking CBA, practitioners should confirm whether more recent ATAP guidance has been made available.

TfNSW welcomes feedback on the approaches outlined in this technical note. Comments or questions should be directed to EconomicAdvisory@transport.nsw.gov.au.

2 Background

2.1 What are vehicle operating costs?

The largest cost of undertaking a journey is usually the time given up to travel. However, travellers will also consider other financial and non-financial costs when they decide where and when they will travel.

The cost of operating motor vehicles is a major financial cost for drivers, experienced when filling up at the petrol pump, buying new tyres, or getting a vehicle serviced.

Vehicle operating costs (VOC) are the sum of these costs. These costs are influenced by road condition and environment, and the speed of travel. Expenditure items related to the vehicle itself are referred to as **VOC components.** Aspects of the road or highway that influence these costs are referred to as **VOC factors**. For example, *fuel* (a VOC component) is consumed at a higher rate per kilometre when there is a reduction in *speed*, or an increase in *gradient* (VOC factors). A selection of the major VOC components and factors are shown in **Table 2**.

Table 2 Example of VOC Factors and Components

VOC components (Vehicle based contributory components)	VOC factors (Road based contributory factors)
Fuel	Gradient
Tyres	Speed
Oil	Curvature
Maintenance	Pavement roughness

Source: Sinha, K. C., & Labi, S. (2011). *Transportation decision making: Principles of project evaluation and programming*. John Wiley & Sons.

Transport projects or investments can create benefits for the NSW community by reducing these financial costs of travel. This can occur directly (e.g. when a motorway upgrade reduces the curvature and gradient of a road), and indirectly (e.g. when a rail project diverts users away from road, reducing traffic volumes and increasing the speed of travel for the remaining road users).

2.2 Challenges in estimating vehicle operating costs

Measuring benefits in transport CBA can be complex, especially given the variety of traffic modelling and forecasting tools used in CBA. Complexity arises in the calculation of VOC benefits because some traffic forecasting approaches predict changes in travel behaviour, and others assume no change in behaviour in the project case. Different **benefit equations** (functions used to estimate the economic benefit to the community) are required to capture the full costs and benefits to the community, based on which traffic forecasting approach is used.

In addition to this, there are multiple **VOC models** (functions used to estimate VOC on a per kilometre basis) published in State and National guidance documents. These models are used because VOC per kilometre changes with the speed of travel, as well as with pavement roughness, gradient, and road curvature. However, each model produces different estimates of VOC and the choice of model can materially influence the size of the benefit estimated in CBA. Whilst there is a significant amount of technical literature available on VOC calculation, it is not always clear what the underlying assumptions are for each VOC model.

Finally, additional complexity arises because the required **input data** (the change in speed and quantity of road travel) can be reported at different levels of aggregation. Some simple traffic forecasts only report changes in total vehicle kilometres travelled (VKT), whilst others report the change in VKT by speed, or road type. Rural or 'uninterrupted travel' VOC models also require information on the pavement roughness, slope, or curvature of road surfaces to accurately calculate VOC benefits.

Sections 2.2.1 to 2.2.3 outline these challenges in more detail.

2.2.1 The benefit equation

The benefit equation is used to estimate the economic impact of a project on the NSW community. The benefit equations most commonly used to estimate VOC benefits measure the benefit either as a change in resource costs, or as the sum of consumer surplus benefits and resource cost corrections.

The benefit equation is determined by the traffic forecasting approach used. For simple traffic forecasting approaches used in many road projects, the economic impact is equivalent to the reduction in the resource costs of travel (See **Equation 1**, p10). For example, a project that increases average speeds along a road would decrease fuel use, creating a benefit equal to the avoided fuel consumption.

For larger projects, this approach is not suitable because some travellers change their behaviour in response to the project. The change in behaviour can include drivers making longer trips (in distance terms) as a result of reduced congestion and higher speeds, or new users (who previously did not travel) taking advantage of improved travel conditions to make trips they previously did not. This would increase some user costs, but would be offset by the additional consumer surplus benefits they receive from travelling to their new destination.

The consumer surplus benefit is based on perceived travel costs, which differ from the resource cost of travel. In addition, new user benefits are apportioned using the 'rule of half', which is discussed in greater detail in the TfNSW Guide and the ATAP guidelines.

As a result, the benefit equation must account for both the changes in resource costs and perceived costs, as well as applying the rule of half. The specific equations used to estimate VOC benefits are described in greater detail in Section 3.

2.2.2 VOC models and parameters

VOC models are used to calculate the cost of travel on a per kilometre basis. Multiple VOC models are publicly available, such as those in the Austroads Guide to Project Evaluation or the Australian Transport Assessment and Planning (ATAP) Guidelines.

These VOC models cover either 'uninterrupted travel' or 'interrupted travel' and are often referred to as rural or urban VOC models, respectively. Interrupted travel is any travel where stopping at signalised or signed intersections occurs, whereas uninterrupted travel occurs on roads without signalised or signed intersections.

The available models produce different VOC estimates. Much of the discrepancy in the estimated cost results from how the model treats *depreciation* (capital and interest costs),[1] which results from assumptions about vehicle *utilisation* and whether depreciation is *time-based* or *use-based*.

Utilisation and depreciation in VOC models

Several different underlying assumptions regarding vehicle *utilisation* have been used when developing the VOC models currently in use in Australia. A vehicle may (for example) be assumed to make a constant number of trips per year, or be used for a constant number of hours, or driven for a constant number of kilometres.

If a vehicle is assumed to travel a constant number of hours per year, then any travel time saving would allow that vehicle to travel additional kilometres, spreading the capital cost of the car over a further distance travelled, and reducing the cost of depreciation when viewed on a per kilometre basis.[2] This would cause very high estimates of VOC per kilometre at low speeds, increasing exponentially as travel speeds approach zero. In reality, it is often unlikely that travel time savings will result in additional travel, particularly for commuting and education-based trips.

VOC models also rely on underlying assumptions about whether *depreciation* is based on kilometres travelled, or vehicle age, or a combination of both. Depreciation that occurs based on how old a vehicle is, regardless of how much it has been used, is referred to as *time-based* depreciation. Generally, no transport project will influence this kind of depreciation and it should not be used to estimate benefits in CBA. *Use-based* depreciation covers the decrease in value that results from use of a vehicle, and is generally measured on a per-kilometre basis. Research on vehicle depreciation suggests that depreciation is only 15-30 per cent use-based, with the remainder time-based.[3] This would suggest that changes in traffic or road conditions can only partially influence depreciation by changing the number of vehicle kilometres travelled.

In response to concerns raised by Infrastructure Australia regarding the depreciation approach used in the ATAP Urban VOC model,[4] TfNSW has developed a depreciation-adjusted VOC model for use in transport appraisals.

VOC models estimate resource costs, which differ from the perceived VOC costs that are also required in some CBAs, depending on the traffic forecasting approach. Research on perceived VOC is limited, and approaches are mostly based on intuitive or theoretical assumptions. Three approaches are commonly used in practice:

1. *Perceived costs equal a subset of resource costs, plus taxes and subsidies.* This approach is an intuitive assumption supported by some research,[5] and suggests that travellers perceive fuel costs (including fuel excise), but misperceive other costs where the cost is incurred infrequently and

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[1] The term 'depreciation' here refers to the reduction in the real value of an asset over time, sometimes referred to as 'capital and interest costs'. It does not refer to the financial concept of depreciation, which is not used in CBA

[2] This is discussed in detail in the Infrastructure Australia Assessment Framework (2018) p104

[3] See, for example, Bennet and Dunn (1990) *Depreciation of Motor Vehicles in New Zealand*, p18

[4] ATAP (2016) PV2 *Road Parameter Values*

[5] See Bray and Tisato (1997) or Shiftan and Bekhor (2002)

separately from travel decision making, such as tyre and maintenance costs. This approach is supported by ATAP M2.

2. *Perceived costs equal average fuel cost per kilometre, plus taxes and subsidies.* This approach is the 'behavioural cost' used in demand models in NSW, and is used to forecast behaviour changes as a result of a project or initiative. This approach differs from the others in that the perceived VOC is assumed to be fixed at a constant rate per kilometre, regardless of the speed of travel.
3. *Perceived costs equal resource costs, plus taxes and subsidies.* This approach is based on economic theory and assumes that travellers correctly perceive costs, including any taxes or subsidies such as fuel excise that contribute to the financial cost of travel. Taxes and subsidies are excluded from resource cost estimates because they are transfers to and from government, and not true resource costs.

TfNSW recommends the use of either the first or second of these approaches, and reports recommended parameter values in the TfNSW EPV (2022).

2.2.3 Input data

Travel forecasting methods do not always produce the right inputs to estimate VOC, or produce a range of different inputs. This requires CBA practitioners to select one of several alternative sets of input data, leading to inconsistencies between projects. The selection of input data will have a material impact on the results of the CBA, in some cases more than the choice of benefit equation or VOC model. Most projects require input data that accurately estimates changes in vehicle kilometres travelled (VKT) as well as the speed of travel across impacted roads.[6]

More accurate estimates of VOC, on larger projects that use strategic modelling, require detailed input data which reports the speed, distance, and number of trips for individual 'origin destination' (OD) pairs of Travel Zones. Travel Zones are the smallest geographic regions for which population and employment data are available, and are used to predict travel across a region. This type of input data is more complex and time consuming to analyse, but estimates VOC benefits with greater accuracy and can be used with all projects that use OD pairs.

Appendix A VOC input data provides more information on the limitations associated with different types of input data.

[6] For some very simple CBA approaches (used with low cost, low risk project such as upgrades to a low traffic intersection) VOC may be estimated based on changes in VKT, but not changes in speed. These approaches are not covered in this guide.

3 Recommended VOC benefit equation

The VOC approaches detailed in this section are designed to be used in CBA for NSW Transport cluster projects. Additional considerations for commercial vehicles, electric vehicles, and autonomous vehicles are included in Sections 4 through 7.

CBA practitioners should use one of the following VOC benefit equations:

- **Change in resource costs:** the change in resource costs approach should be used for road and public transport projects that do not include induced demand[7].
- **Detailed VOC benefit:** A detailed VOC benefit should be estimated on projects that include induced demand – this is generally the case for major (Tier 1 or Tier 2) road and motorway projects, as well as on most public transport projects

Project teams can contact TfNSW Economic Advisory for further clarification on when to apply these benefit calculations.

3.1 Change in resource costs

Measuring the change in resource costs is appropriate for use with traffic models, or for demand models that use a 'Fixed Matrix'. Traffic and Fixed Matrix models allow for travellers to change their choice or route (often referred to as re-assigned or diverted traffic) because of a project, but do not model other behaviour changes such as switching destination, mode, or time of travel. Models such as VISSIM and SIDRA, which are used frequently on Transport cluster projects, often fall into this category.

This approach relies on the use of a change in resource cost equation (discussed in **Error! Reference source not found.**), depreciation-adjusted resource costs (discussed in Section 4), and aggregated input data (discussed in Appendix A).

This approach detailed in this user guide is appropriate for use in urban environments where speed of travel is the relevant consideration for calculating VOC. Rural projects where pavement roughness, curvature or gradient is a relevant consideration can use this approach with the adjustments outlined in section 3.1.1, below.

The simplified VOC approach uses Equation 1:

Equation 1 Change in resource costs

$$\boldsymbol{VOC\ benefit = Q_1 AC_1 - Q_2 AC_2}$$

Source: Australia Transport Council (2006)

Where:

- **AC** is the resource VOC, in dollars per kilometre, based on the speed of travel, based on the speed of travel per kilometre (***S***)
- **Q** is the quantity of travel, in *vehicle kilometres travelled* (VKT)

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[7] This generally covers road projects below $1 billion. These typically use modelling approaches like SIDRA, AIMSUN or VISSIM

- Subscript **1** and **2** represent the base case and project case, respectively.

As there is no change in travel behaviour, perceived costs are not used in Approach 1.

This approach can use either VKT reported for individual transport links or road sections (along with the speeds for those links or road sections), or VKT data by 'speed bracket'. Sometimes, a traffic model for a small modelling region will report all travel for a network of similar roads by vehicle type only, as shown in **Table 3**. An example of speed bracket data is shown in **Table 4**, along with the resource cost of travel for each different speed bracket.

Table 3 Example of link or road section input data for cars (VISSIM)

Base Case	Base Case VKT (Q_1) Vehicle kilometres travelled	Base Case Speed (S_1) In kilometres per hour	Resource Cost (AC_1) Cents per kilometre travelled	Total Cost
Car	15,692	19.3	$0.46	$7,242.11
LCV	3,479	19.3	$1.48	$5,160.91
HCV	270	18.8	$2.15	$581.51
Bus	124	17.2	$0.49	$61.32
Total				**$13,045.85**
Project Case	Project Case VKT (Q_2) Vehicle kilometres travelled	Project Case VKT (Q_2) Vehicle kilometres travelled	Resource Cost (AC_2) Cents per kilometre travelled	Total Cost
Car	15,669	21.9	$0.43	$6,714.96
LCV	3,474	21.9	$1.40	$4,848.10
HCV	268	22.9	$1.91	$512.41
Bus	121	17.2	$0.49	$59.83
Total				**$12,135.31**
Incremental benefit				
Incremental Economic Benefit				**$910.54**

Source: TfNSW Economic Advisory (2022) Prices are in December 2021 dollars. Resource costs in Table 3 are calculated using TfNSW depreciation-adjusted parameter values.

Table 4 Example of aggregate 'speed bracket' input data for cars (PTPM)

Speed Bracket (*s*) km / hour	Base Case VKT (Q_1) Vehicle kilometres travelled	Project Case VKT (Q_2) Vehicle kilometres travelled	Assumed Speed (**S**) per kilometre travelled	Resource Cost (**AC**) Cents per kilometre travelled (1)	Incremental Economic Benefit
< 10	143,829	143,182	5	125.91 (45.60)	$81,461
10-20	1,118,457	1,119,020	15	54.52 (45.60)	-$30,697
20-30	2,952,160	2,948,214	25	40.24	$158,786
30-40	3,724,987	3,721,073	35	34.13	$133,586
40-50	3,068,046	3,073,125	45	30.72	-$156,046
50-60	2,164,978	2,170,559	55	28.56	-$159,388
60-70	1,634,770	1,632,808	65	27.06	$53,101
70-80	346,299	345,473	75	25.97	$21,448
80-90	625,449	625,450	85	25.13	-$25
90-100	427,882	427,952	95	24.46	-$1,712
Total	**16,206,856**	**16,206,856**			**$100,513**

Source: TfNSW Economic Advisory (2022) Prices are in December 2021 dollars. (1) Values in brackets should be used to sensitivity test VOC costs with a cap at the 20km per hour values, as per ATAP guidelines.

This input data provides a summary of how a project or initiative has impacted speed of travel across the transport network. Changes in average journey times from the project are reflected by changes in the VKT aggregated to each speed bracket.

3.1.1 Adjustment for rural projects

Rural projects where pavement roughness, gradient, or curvature are a relevant factor should use the uninterrupted flow model as presented in Transport and Infrastructure Council (2016) *Australian Transport Assessment and Planning (ATAP) Road Parameter Values PV2*, rather than the depreciation-adjusted parameter values.

Certain traffic forecasting models used in rural projects, such as TRARR,[8] produce VOC estimates calculated from individual link data. This kind of input data can be used instead of speed bracket data when sourced from calibrated and validated traffic models.

VOC models shouldn't be mixed in CBA

On some projects, there may be situations where both urban and rural conditions exist, or where one part of the road network needs to assess a change in gradient, curvature, or roughness. Where this is the case, the project should use ATAP PV2 VOC models, so that the treatment of depreciation is consistent across the CBA.

3.2 Detailed VOC benefit

A detailed VOC benefit should be estimated on major (Tier 1 or Tier 2) road and motorway projects, as well as on major (Tier 1 or Tier 2) public transport projects - particularly those that use the Sydney Travel Model (STM) or Public Transport Project Model (PTPM)

This approach is required to capture both the private benefits to road users from VOC changes, and the changes in social costs for all NSW residents. This approach uses the equation for calculating the full increase in social welfare[9] for existing and induced traffic from ATAP T2 *Cost Benefit Analysis*.

The benefit equation is shown in **Equation 2**:

Equation 2 Increase in social welfare using OD data

$$\boldsymbol{VOC\ benefit = 0.5 \times \left(P_{1ij} + P_{2ij}\right)\left(Q_{2ij} - Q_{1ij}\right)}$$
$$\boldsymbol{- \left(AC_{2ij}Q_{2ij} - AC_{1ij}Q_{1ij}\right)}$$

Source: ATAP (2016)

Where:

- **P** is the perceived VOC, in dollars per trip
- **AC** is the resource VOC, in dollars per trip
- **Q** is the quantity of travel in trips
- subscript $\boldsymbol{i}$ and $\boldsymbol{j}$ refer to the origin travel zone and destination travel zone, respectively

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8 TRAffic on Rural Roads

9 Equivalent to the increase in willingness-to-pay minus the increase in social costs, or the increase in consumer surplus plus a resource cost correction

- subscript **1** and **2** represent the base case and project case, respectively.

When applying formulas to origin-destination data, the rule-of-half is applied to new kilometres travelled, and the perceived cost and resource cost per trip will change between the base case and project case based on any changes in the average trip characteristics (such as average distance or speed) for each OD pair.

CBA practitioners should note that the first half of the benefit equation (change in willingness to pay) requires the calculation to be undertaken with origin-destination (OD) data, so that new and continuing users can be identified:

Equation 3 Increase in willingness to pay (WTP)

$$\boldsymbol{Increase\ in\ WTP = 0.5 \times \left(P_{1ij} + P_{2ij}\right)\left(Q_{2ij} - Q_{1ij}\right)}$$

Source: ATAP (2016)

The second part of the equation is the same as the *Change in resource cost* approach discussed in Section 3.1 above, and can be estimated from any link, OD, or network summary (speed bracket) data as available from the demand or traffic model. For instance, the approach shown in Table 4 can be used to estimate the increase in social cost from PTPM outputs:

Equation 4 Increase in social cost (resource costs)

$$\boldsymbol{Increase\ in\ social\ cost = -(AC_2Q_2 - AC_1Q_1)}$$

Source: ATAP (2016)

4 Recommended VOC Models

For urban project CBAs, interrupted flow VOC models reflect the change in operating costs with speed (in kilometres per hour) and the difference between driving in free-flow or stop-start traffic. Three VOC models are available for use in TfNSW appraisals, being:

- The ATAP PV2 urban VOC model
- The ATAP PV2 rural VOC model
- The TfNSW depreciation adjusted urban VOC model

Using models that include depreciation (such as the ATAP PV2 urban and rural VOC models) is not recommended for private vehicles, as explained in Section 2.2.2. and below:

Depreciation and private vehicles

ATAP T2 Cost Benefit Analysis notes that depreciation should be left out of CBA because the full cost of the asset to society is accounted for when the resources are consumed to create the asset (in this case, a vehicle) – and as such including depreciation would lead to double counting.[10]

For freight vehicles, however, time savings from higher speeds or shorter trip distances enable the trucks to be utilised more intensively, saving capital costs at a fleet level. The depreciation component captured in some VOC models can be used to assess this impact.

However, when a private vehicle user saves time, their car will only spend more time parked. There is no way to utilise the vehicle more effectively, and no reduction in the total number of cars required, and therefore no saving in fleet capital costs. For this reason, the ATAP PV2 models should be avoided when calculating the VOC benefits for private vehicles.

When choosing which VOC model to use on a project, practitioners should note that for urban projects:

- The TfNSW depreciation-adjusted VOC model is the most appropriate model for estimating VOC benefits for private vehicles (cars)
- VOC benefits for freight vehicles (utility, trucks, and combination vehicles) can be assessed with either the TfNSW depreciation-adjusted VOC model or the ATAP PV2 urban VOC model,

and that for rural projects:

- The ATAP PV2 rural model should be used, and if both urban and rural conditions are present, the project should use ATAP PV2 VOC models, so that the treatment of depreciation is consistent across the CBA.

Projects requiring federal funding may need to use the VOC model documented in the *Austroads Guide to Project Evaluation Part 4* (2012), often referred to as the Austroads 2012 VOC model, for sensitivity testing. This model is discussed in the TfNSW EPV (2022) and in Infrastructure Australia (2022).

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10 ATAP T2 Cost Benefit Analysis (2018), p18

4.1 ATAP PV2 Interrupted flow (urban) VOC model

The base ATAP PV2 urban VOC model can be used to assess the VOC benefit for urban road and public transport projects.

If using this model, it is important to take care where the minimum speed of travel input into the VOC model is below 20km per hour, as this has the potential to create overstated benefits in CBA. In most cases, it will be appropriate to cap the speed of travel inputs at 20km/h when using the ATAP PV2 model.

VOC differs by vehicle type, with lower costs per kilometre for newer, smaller vehicles, and higher costs for older, heavier vehicles. The VOC values in this document are presented for 20 separate vehicle classes as defined by Austroads.[11]

Equation 5 VOC model for private vehicles, stop-start model

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

Source: TfNSW Economic Advisory (2020); Formerly TfNSW Evaluation & Assurance

Equation 6 VOC model for private vehicles, free flow model

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

Source: TfNSW Economic Advisory (2020); Formerly TfNSW Evaluation & Assurance

Where:

- **c** represents VOC (cents/km)
- **V** represents journey speed (km/h)
- **A**, **B**, $\mathbf{C_0}$, $\mathbf{C_1}$, and $\mathbf{C_2}$, are model coefficients, as listed in Table 5 below.

The **D** and **E** parameters listed in Table 5 are used in the TfNSW depreciation adjusted VOC model and do not need to be considered when using the base ATAP PV2 urban VOC model

4.2 ATAP PV2 uninterrupted flow (rural) VOC model

The ATAP uninterrupted flow VOC model can be used to assess the VOC benefit for rural road projects and where gradient, roughness and curvature are being influenced by the project in question. The uninterrupted flow model can also be used to assess the change in VOC where there is a change in average freight payload.[12] Note that the uninterrupted flow model produces resource costs, not perceived costs.

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[11] Commonly referred to as Austroads '20 bin' classifications, and detailed in Austroads (2018) Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals, Appendix B

[12] Rural VOC parameters assume an average freight payload of 75% capacity. Policies or projects that change this average payload may have an impact on VOC, which can be estimated using the ATAP uninterrupted flow VOC model.

CBA practitioners can use the uninterrupted flow model as presented in Transport and Infrastructure Council (2016) *Australian Transport Assessment and Planning (ATAP) Road Parameter Values PV2*.

If using this model, it is important to take care where the minimum speed of travel input into the VOC model is below 20km per hour, as this has the potential to create overstated benefits in CBA. In most cases, it will be appropriate to cap the speed of travel inputs at 20km/h when using the ATAP PV2 model.

4.3 TfNSW depreciation adjusted VOC model

The depreciation-adjusted VOC model uses the base formula from ATAP (2016), with an additional depreciation adjustment.

Because the TfNSW model adjusts for depreciation impacts at low speeds, CBA practitioners do not need to apply the 20km per hour speed cap when using this model, as is needed with the base ATAP (2016) VOC model

VOC differs by vehicle type, with lower costs per kilometre for newer, smaller vehicles, and higher costs for older, heavier vehicles. The VOC values in this document are presented for 20 separate vehicle classes as defined by Austroads.[13]

Equation 7 VOC model for private vehicles, stop-start model

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

Source: TfNSW Economic Advisory (2020); Formerly TfNSW Evaluation & Assurance

Equation 8 VOC model for private vehicles, free flow model

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

Source: TfNSW Economic Advisory (2020); Formerly TfNSW Evaluation & Assurance

Where:

- **c** represents VOC (cents/km)
- **V** represents journey speed (km/h)
- **A**, **B**, **C_0**, **C_1**, and **C_2**, are model coefficients, as listed in Table 5 below.
- **D** and **E** are adjustments to remove depreciation (both capital and interest costs), 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.

[13] Commonly referred to as Austroads '20 bin' classifications, and detailed in Austroads (2018) Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals, Appendix B

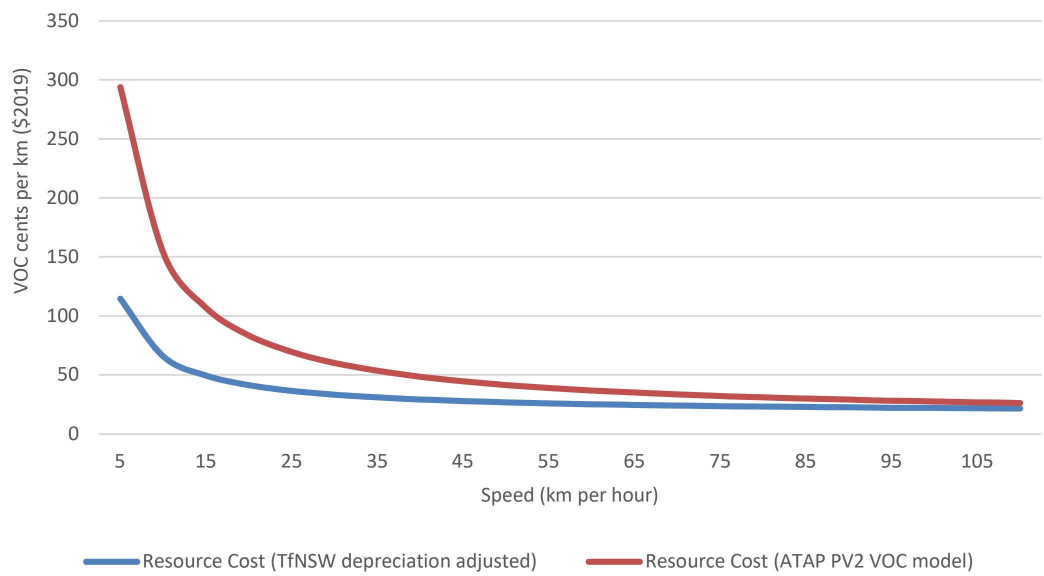
Table 5 VOC model coefficients (cents/km, 2022 prices)

Vehicle Type	Stop-start model		Free flow model			Depreciation	
	A	B	C_0	C_1	C_2	D	E
Cars							
Small Car	14.2405	953.1777	29.3302	-0.1425	0.0011	-8.0155	1.8513
Medium Car	14.3852	1495.7973	39.8499	-0.1991	0.0014	-16.7527	4.0117
Large Car	16.4072	2090.4214	52.5046	-0.2525	0.0016	-23.9710	5.7403
Utility vehicles							
Courier Van-Utility	18.7113	1593.5314	45.1973	-0.2160	0.0016	-10.7722	1.3454
4WD Mid-Size Petrol	24.7146	1560.2677	47.6231	-0.1809	0.0015	-17.7113	2.0216
Rigid trucks							
Light Rigid	38.6249	1755.0844	58.5681	-0.2821	0.0028	-13.4435	1.5647
Medium Rigid	40.7104	2569.6038	71.2689	-0.3413	0.0030	-28.0377	3.4434
Heavy Rigid	64.9932	2906.3635	93.5671	-0.6282	0.0060	-33.2530	3.8753
Heavy Bus	75.8026	5439.0653	146.4242	-0.7593	0.0055	-48.8335	5.6454
Articulated trucks							
Articulated 4 Axle	96.1608	3778.3979	126.9644	-0.8232	0.0082	-40.6913	4.6211
Articulated 5 Axle	103.6189	4194.0992	136.3305	-0.7732	0.0075	-44.8731	5.0959
Articulated 6 Axle	112.2149	4538.2438	146.3234	-0.7821	0.0075	-48.6483	5.5247
Combination vehicles							
Rigid + 5 Axle Dog	139.3456	4240.9865	154.8217	-0.7280	0.0074	-42.4747	4.8236
B-Double	139.8469	5221.4997	172.2294	-0.8219	0.0077	-55.5378	6.3071
Twin steer + 5 Axle	144.6285	4980.2060	170.4777	-0.7858	0.0076	-51.7566	5.8776
A-Double	163.7259	6472.0398	208.6872	-0.9472	0.0084	-70.1173	7.9628
B-Triple	169.8896	8112.1684	243.4892	-1.1232	0.0092	-91.2122	10.3584
A B combination	193.6623	7115.4272	237.3089	-1.0253	0.0091	-76.4162	8.6780
A-Triple	216.7748	8112.7034	269.5562	-1.1519	0.0098	-87.8775	9.9797
Double B-Double	226.9197	7932.3540	271.4398	-1.1236	0.0098	-55.5378	6.3071

Source: TfNSW Economic Advisory (2022) based on ATAP (2016). Coefficients produce VOC estimates in December 2021 prices

This adjustment changes the relationship between speed and VOC per km for private vehicles and has a significant impact at speeds below 30 kilometres per hour, as shown in **Figure 1**.

Figure 1 VOC with and without depreciation (medium car, stop start model)



Source: TfNSW Economic Advisory (2020); Formerly TfNSW Evaluation & Assurance

4.4 Perceived VOC parameters

Perceived costs are the sum of monetary and non-monetary travel costs that are considered by travellers in making transport decisions. The perceived vehicle operating cost differs from the resource cost because:

- travellers consider taxes and subsidies, such as GST, fuel excise and rebates, which are transfers to and from the government and not economic costs
- travellers do not perceive, or misperceive, some costs when making travel decisions, such as the impacts of additional travel on maintenance, engine oil, and tyre costs
- travel costs may be paid for by other parties, so the perceived vehicle operating cost is zero for some travellers
- some travellers may incorrectly allocate other costs as part of the marginal cost of travel, for instance, insurance costs
- some travellers may not perceive that VOC are higher during congested conditions, and lower when travelling at high speeds. Travellers may instead perceive VOC as a constant cost per kilometre.

Perceived VOC parameters are reported in the TfNSW *Economic Parameter Values*.

5 Consideration of commercial vehicles

VOC parameters are available for 20 separate vehicle classes, as classified by Austroads (see **Table 10**, p29). However, most traffic and transport models do not produce data for all of the vehicle classes covered in the ATAP model, and instead report travel at broader Light Commercial Vehicle (LCV) and Heavy Commercial Vehicle (HCV) aggregations.

When applying the ATAP VOC model to traffic and transport models, it is not appropriate to select an indicative LCV or HCV vehicle from the different classes used in ATAP (2016). Instead, **P**arameters can be calculated for all vehicle classes, and then a weighted average cost per kilometre by speed be derived for LCVs and HCVs. TfNSW makes available an urban VOC and rural VOC tool which can be used to calculate the recommended weighted average cost per kilometre for commercial vehicles. The tool can be found here.

Table 6 provides the proportion of vehicles in urban and rural areas used to calculate the weighted average VOCs. Where possible, data on heavy vehicle use in the project area should be sourced from TfNSW Economic Advisory, or TfNSW Network & Asset Intelligence.

Table 6 Mix of vehicles

Vehicle type	% Urban	% Regional	% Overall	Annual VKT
Cars (all types)				
Cars	77.40	71.35	76.06	23,000
Utility vehicles				
Courier van utility	9.66	9.23	9.56	23,000
4WD Mid-Size Petrol	6.92	6.61	6.85	23,000
Rigid trucks				
Light Rigid	0.58	0.80	0.63	30,000
Medium Rigid	1.00	1.38	1.09	40,000
Heavy Rigid	2.04	2.82	2.21	86,000
Articulated trucks				
Articulated 4 Axle	0.23	0.32	0.25	86,000
Articulated 5 Axle	0.07	0.39	0.14	86,000
Articulated 6 Axle	0.46	2.36	0.88	86,000
Combination vehicles				
Rigid + 5 Axle Dog	0.01	0.06	0.02	86,000
B-Double	0.70	3.60	1.34	86,000
Twin steer + 5 Axle Dog	0.01	0.06	0.02	86,000
A-Double	0.01	0.06	0.02	86,000
B-Triple	0.01	0.04	0.01	86,000
A B combination	0.01	0.01	0.01	86,000
A-Triple	0.01	0.04	0.01	86,000
Double B-Double	0.00	0.00	0.00	86,000
Buses				
Heavy Bus	0.86	0.77	0.84	70,000

Source: Estimated by Economic Advisory, TfNSW from ABS Survey of Motor Vehicle Use 2018. See Appendix B for more information on vehicle type classification

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

- The RMS Traffic Volume Viewer to identify relevant Permanent or Sample Classifiers. Requests for freight data by Austroads heavy vehicle class can be sent to RMS Network & Asset Intelligence.
- ABS Category 2993.0 Road freight movements, 2014.

6 Consideration of electric vehicles

There are currently relatively few EVs in NSW. The NSW light passenger vehicle fleet of 2.95 million vehicles includes 1,700 battery EVs and 28,000 petrol-electric hybrid vehicles, as at September 2018. However, as the cost to purchase EVs decreases, and charging infrastructure becomes more widespread, uptake and use of EVs is expected to increase over time. NSW's Electric and Hybrid Vehicle Plan provides additional information on the impacts of EV uptake in NSW, including the Government's approach to preparing for the transition to hybrid and electric vehicle technologies.

The increase in EV usage has impacts for CBAs including where the benefits of reductions in VOC are forecast over long periods of time (up to 50 years from the beginning of project operations in some cases). EVs have lower operating costs than conventional petrol and diesel vehicles, which requires offsetting the expected future benefits of VOC savings.

This section outlines interim approaches and parameter values for estimating VOC impacts from electric vehicles, for use in policy development and CBA. Research on the impacts of speed, road surface roughness, and road curvature on EV operating costs have not yet been undertaken in sufficient detail to estimate operating costs with the same precision as conventional fuel vehicles. Several underlying assumptions are used to estimate the EV parameter values below, which may not be accurate in practice. In particular:

- that servicing, maintenance and tyre costs are the same for EVs as for conventional fuel vehicles, on a per-kilometre basis
- that energy consumption for EVs does not vary with speed of travel.

As such, the parameters presented in this section should be treated as preliminary values subject to future development and updates.

Table 7 provides energy consumption per kilometre in Australian conditions, for different vehicle classes.[14] Two vehicle classes are included in the below table: Class-E sedans, which currently represent around 15-20% of new car sales, and Class-B sedans, which represent approximately 35-40% of new car sales in Australia. Energy use for plug-in hybrid EVs and battery-electric EVs are shown as these are expected to be the most common EV types in the immediate future.

Table 7 Conventional and electric vehicle energy consumption

Vehicle Class	Vehicle	Energy use	
		Fuel (L/ 100 km)	Electricity (kWh/km)
Class-E medium (*e.g. Ford Falcon*)	Conventional Vehicle (CV)	12.5	-
	Plug-in hybrid electric vehicle (PHEV)	1.4	0.17
	Battery electric vehicle (BEV)	-	0.18
Class-B small (*e.g. Ford Fiesta*)	Conventional Vehicle (CV)	4.5	-
	Battery electric vehicle (BEV)	-	0.12

Source: Sharma et al (2012) *Conventional, hybrid and electric vehicles for Australian driving conditions – Part 1: Technical and financial analysis*, Table 3

The fuel and electricity cost assumptions in **Table 8** have been used to convert the energy consumption values into perceived and resource costs per kilometre.

[14] Sharma et al (2012) *Conventional, hybrid and electric vehicles for Australian driving conditions – Part 1: Technical and financial analysis*

Table 8 Fuel and electricity costs per unit in NSW

Cost component (2018)	Cost per unit	
Fuel cost components (1)	Petrol (cents/L)	Diesel (cents/L)
Fuel resource cost	160.0	183.9
Fuel excise	22.1	22.1
GST	18.2	20.6
Total	**200.3**	**226.6**
Resource Cost (AC)	**160.0**	**183.9**
Perceived Cost (P)	**200.3**	**226.6**
Electricity cost components (2)	Electricity (cents/kWh)	
Electricity resource costs	23.8	
Environmental tariffs and schemes	1.5	
GST	2.5	
Total	**27.8**	
Resource Costs (AC)	**23.8**	
Perceived Costs (P)	**27.8**	

Source:
(1) Australian Institute of Petroleum (2022) *Terminal Gate Prices*, prices as at June 2022
*Note excise is temporarily reduced by 50% as per 2022-2023 Federal Budget
(2) Australian Competition and Consumer Commission (2018) *Restoring electricity affordability and Australia's competitive advantage: Retail Electricity Pricing Inquiry*, prices as at December 2021 per ABS A2328101R
*Note temporal difference between data due to index availability in ABS A2328101R

Average costs per kilometre for fuel and electricity, by vehicle type, are presented in **Table 9**.

Table 9 Fuel and electricity average cost per kilometre (cents/km)

Vehicle Class	Vehicle	Resource cost (c/km)			Perceived cost (c/km)		
		Fuel	Electricity	Total	Fuel	Electricity	Total
Class-E medium (*e.g. Ford Falcon*)	CV	20.0275	-	20.0275	25.0682	-	25.0682
	PHEV	2.2431	4.0437	6.2868	2.8076	4.7278	7.5354
	BEV	-	4.2816	4.2816	-	5.0059	5.0059
Class-B small (*e.g. Ford Fiesta*)	CV	7.2099	-	7.2099	9.0246	-	9.0246
	BEV	-	2.8544	2.8544	-	3.3373	3.3373

Source: TfNSW Economic Advisory (2022) based on Sharma et al (2012) *Conventional, hybrid and electric vehicles for Australian driving conditions – Part 1: Technical and financial analysis*, Australian Competition and Consumer Commission (2018) *Restoring electricity affordability and Australia's competitive advantage: Retail Electricity Pricing Inquiry* indexed to December 2021 per ABS A2328101R, and Australian Institute of Petroleum (2022) *Terminal Gate Prices*

The Class-E and Class-B vehicles used to estimate energy consumption per kilometre do not perfectly align with the small, medium and large car vehicle classes used in ATAP 2016. Class-E vehicles have been treated as medium cars, and Class-B as small cars, for the purposes of estimating operating costs for CBAs.

Insufficient data is currently available to estimate the change in non-fuel costs per kilometre for electric vehicles (e.g. from engine maintenance), as well as the change in electricity costs per kilometre at different speeds. Including EVs in a CBA requires forecasting uptake of EVs in NSW. Currently, there is no consensus view on the likely timeline for uptake of electric and autonomous vehicles in NSW. When forecasting uptake of EVs in the CBA, realistic and plausible assumptions should be used based on available evidence.

For example, forecasts from the Imperial College of London's *Carbon Activity Tracker* suggests EVs will comprise 35% of the vehicle fleet by 2035, and greater than two-thirds of the vehicle fleet by 2050.[15] However, given uptake of EVs in

[15] Imperial College of London (2017) Carbon Tracker Initiative – Expect the Unexpected

Australia has historically been slower than in Europe, America, and Asia, this estimate may represent an upper bound for forecast EV uptake in NSW.

TfNSW does not recommend EV VOC impacts are included in the core CBA results, except where relevant and material to the decision being assessed, or there is additional evidence to support inclusion in the central case.

7 Consideration of connected and autonomous vehicles

The Connected and Automated Vehicles Plan (CAV Plan) outlines NSW's strategic directions and actions to progress connected and automated vehicles (CAVs) over the next five years. While autonomous vehicles and electric vehicles are part of the same wave of new technologies shaping the future of transport, CAVs do not necessarily use EV technologies, or require any other adjustment to VOC calculations.

The introduction of CAV technologies into the NSW vehicle fleet is already beginning to occur. **TfNSW recommends** that VOC for CAVs are separately assessed in CBAs where the additional CAV travel is expected to occur as a direct result of the project, e.g. in the Coffs Harbour, Sydney Olympic Park, or Armidale CAV trials. This should be assessed on a project-by-project basis.

CAV technology is not necessarily linked to the factors and components that influence VOC benefits in CBA. However, the adoption of CAVs may impact demand for travel, patterns of travel behaviour, or other benefit streams in the CBA, such as safety. Where relevant, **TfNSW recommends** these be assessed in the CBA.

8 References

Archondo-Callao, R., 2008. *Applying the HDM-4 model to strategic planning of road works.*

Australian Competition and Consumer Commission, 2018. *Restoring electricity affordability and Australia's competitive advantage: Retail Electricity Pricing Inquiry*

Australian Institute of Petroleum, 2019. *Terminal Gate Prices*

Australian Transport Assessment and Planning, 2016. *Australian Transport Assessment and Planning Guidelines PV2 Road Parameter Values*

Australian Transport Council, 2006. *National Guidelines for Transport System Management in Australia* (Volume 3), 2nd edition.

Australian Transport Council, 2006. *National Guidelines for Transport System Management in Australia* (Volume 4), 2nd edition.

Australian Transport Council, 2006. *National Guidelines for Transport System Management in Australia* (Volume 5), 2nd edition.

Austroads, 2004. *Guide to Project Evaluation Part 4: Project Evaluation Data.*

Austroads, 2005. *Economic Evaluation of Road Proposals: Harmonisation of Non-Urban Road User Cost Models*

Austroads, 2008. *Guide to Project Evaluation Part 4: Project Evaluation Data.*

Austroads, 2012. *Guide to Project Evaluation Part 4: Project Evaluation Data.*

Bennett, C., & Dunn, R., 1990 *Depreciation of Motor Vehicles in New Zealand*. Transportation Research Record 1262

Hang, D., McFadden, D., Train, K., Wise, K., 2015. *Is Vehicle Depreciation a Component of Marginal Travel Cost?* Journal of Transport Economics and Policy, Volume 50, Part 2.

Infrastructure Australia (2022) *Guide to Economic Appraisal*

Kerali, H.G., Odoki, J.B. and Stannard, E.E., 2000. *Overview of HDM-4. The Highway Development and Management Series, 4.*

New Zealand Transport Agency, 2018. *Economic Evaluation Manual*, January 2016, First edition, Amendment 2.

Sinha, K. C., & Labi, S., 2011. *Transportation decision making: Principles of project evaluation and programming*

Sharma et al, 2012. *Conventional, hybrid and electric vehicles for Australian driving conditions – Part 1: Technical and financial analysis*

Shiftan, Y. and Bekhor, S., 2002. *Investigating individual's perception of auto travel cost. International Journal of Transport Economics/Rivista internazionale di economia dei trasporti, pp.151-166.*

Appendix A VOC input data

It is not always appropriate to use the most granular input data in CBA. This is because all types of input data produced by NSW transport models have limitations that must be considered when calculating VOC benefits. In addition, more granular input data may not necessarily increase the accuracy of the VOC benefit, and may require additional time or effort to calculate.

The following sections provide an overview of the different types of input data that may be used to calculate VOC, as well as limitations when used to calculate VOC.

A.1 Aggregated data

Demand and traffic models (including PTPM's economic output module) can produce 'aggregated' vehicle kilometre-travelled (VKT) data. This output aggregates the total VKT across all links in the demand model road network and then split the data by speed of travel.

A VOC benefit estimated from aggregate data is likely to be less accurate, but can be undertaken with considerably lower time and resourcing requirements.

When using aggregate data to calculate VOC, it is important that:

- Aggregate data is split by speed brackets of at most 10 kilometres per hour. Higher levels of aggregation will reduce the accuracy of the VOC estimate.
- Practitioners should use the stop-start model, rather than the free flow model when estimating VOC impacts. This approach should be used because aggregate data combines travel across all road types. ATAP PV2 recommends switching from the stop-start model to the free-flow model at 60km per hour. However, this approach is **not recommended by TfNSW**, as discontinuities between the VOC parameters estimated by the two models model will result in errors if applied to aggregate data.

Both the ATAP and Austroads VOC models were designed to be applied to outputs from individual road segments, rather than network averages, or averages by road type. For small road projects with a limited model coverage this makes sense. For a large project covering an extensive modelled network, the complexity of link based assessments are problematic.

Using aggregated data from across the full road network will inaccurately estimate VOC impacts for two reasons. First, average travel speeds tend to be relatively stable between the base case and project case when assessed at a network-wide level, for all but the largest interventions. Second, a small change in speed on a link with a low average speed will in reality yield a materially different benefit than the same change in speed on a high speed link. This impact would not be captured if the aggregated data is not split by speed.

A.2 Origin-destination data

Origin-destination (OD) data contains information on the total volume, and average speed and distance for travel between two travel zones (i.e. an 'origin' and 'destination' zone) in a transport model. OD data is the most complex input data used to calculate VOC.

OD data represents a weighted average for all possible routes between an origin and destination travel zone. These routes may have different lengths, speeds, or road types, which is not fully reflected if VOC is calculated using OD data. Because of this, OD data does not contain speed or distance data that is as accurate as data assessed at a link level.

However, for NSW demand models, new and continuing users can only be identified when assessing travel at an OD level. This is because travel assigned to individual links within the model is aggregated across all user types.

OD data raises challenges for the application of VOC methodologies because it aggregates the speed and distance for several possible alternative routes.

For example, drivers travelling from Lane Cove to Alexandria (a single OD pair) could take either Victoria Road or the M1. Those that take the M1 can then choose between travelling over the Sydney Harbour Bridge and via the CBD, or continuing through the Harbour Tunnel. These routes have different road types and speeds, which would be captured if the VOC analysis was based on link data. OD data would instead apply an average speed and distance to all travellers making this journey.

A.3 Link data

Link data is the most granular data available to calculate VOC benefits. It allows for accurate estimation of VOC with a few notable limitations:

- it is not possible to identify and disaggregate induced traffic
- it relies heavily on the accuracy and robustness of the transport model in use.

This approach is best applied to calibrated and validated traffic models, rather than with strategic demand models such as STM and PTPM. When applying the VOC model to individual links, links with speeds below 5 kilometres per hour should be treated as 5 kilometres per hour.[16]

Link data raises challenges for the application of VOC methodologies, because it is not possible to disaggregate induced traffic. It also relies on the use of highly granular demand model outputs, which may not be suitable for use in CBA.

Average speeds and volume to capacity ratios for individual links in STM and PTPM may not be estimated with sufficient accuracy for use in CBAs. STM and PTPM are strategic models and therefore not designed to accurately assign road travel along specific routes. Also, as they estimate demand for travel rather than traffic, the forecast levels of congestion on road links may be overstated.

A.4 Discontinuities in stop-start and free-flow models

The ATAP VOC models for stop-start and free-flow traffic will report different costs per kilometre for the same speed of travel. This can impact the accuracy of benefit calculations where an individual link or OD pair is assessed as stop-start in one scenario but free-flow in another.

When using the ATAP VOC models, it is best to hold the VOC model constant for individual links or OD pairs between the Base Case and Project Case, when undertaking analysis on OD data or link data (for aggregate data, use the approach listed in Section A.1). This is because the economic impact of the project should be

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16 TfNSW recommends that VOC per kilometre should be capped at 5km per hour, though this recommendation is under development and may be refined at a future date. Alternative approaches cap maximum cost per kilometre at the 10km per hour rate or the 20km per hour rate.

based on the change in actual travel conditions resulting from the project, rather than any change in the VOC model used.

Appendix B Vehicle classification

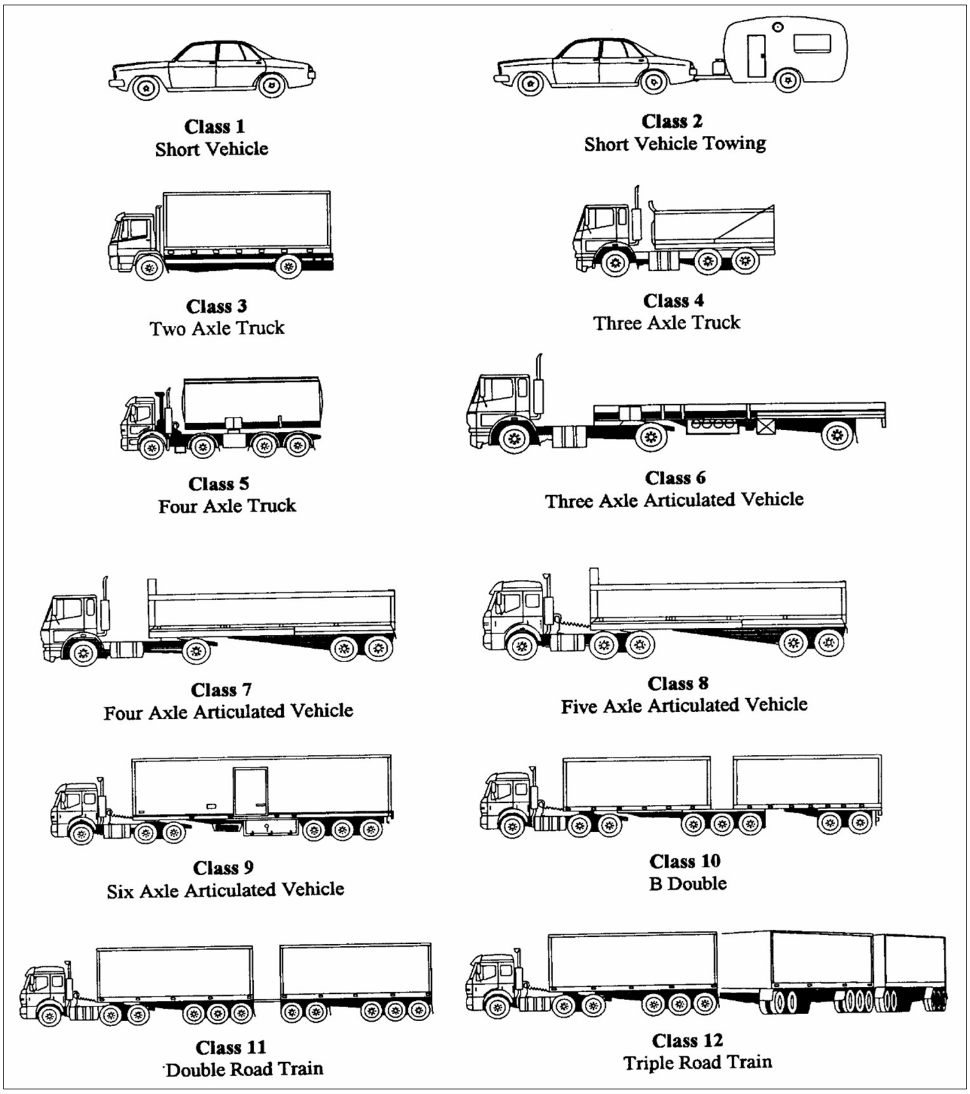
A number of vehicle classification systems are used in this document and by other state and federal guidance documents. This section provides an overview of the different vehicle types and a concordance between classifications. More detail can be found on the Austroads website.

Table 10 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 / HCV)	Rigid (HCV)	3	Light Rigid
		4	Medium Rigid
		5	Heavy Rigid
	Articulated (HCV)	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 2 Austroads typical configurations ('12 bin' vehicle class)



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

Appendix C Key indices

Table 11 Key indices for back-casting and forecasting

Indices	Actuals							Forecast		
	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
CPI Sydney	107.25	108.88	111.08	113.35	114.75	117.05	118.80	120.88	123.00	125.76
CPI Private Motoring	98.65	97.23	97.23	100.00	101.83	103.86	105.42	107.26	109.14	111.60
CPI Maintenance & Repair	101.43	104.55	105.43	106.55	108.00	110.16	111.81	113.77	115.76	118.36
CPI Motor vehicles	95.68	97.20	95.15	93.48	92.73	94.58	96.00	97.68	99.39	101.62
AWE NSW ($)	1502.20	1534.15	1540.80	1585.90	1614.10	1654.45	1679.27	1712.85	1751.39	1790.80
PPI road freight	107.20	105.45	106.53	108.60	111.00	113.22	114.92	116.93	118.98	121.65
Fuel cost exc GST (cent/L) - petrol	75.71	61.76	60.25	68.74	69.94	71.34	72.41	73.68	74.97	76.66
Fuel cost exc GST (cent/L) - diesel	76.23	57.26	58.68	69.02	70.23	71.64	72.71	73.98	75.28	76.97

Sources: Estimated by Economic Advisory, TfNSW. Notes on data sources and forecasting methodology provided below: (1) ABS 6401.0 All Groups CPI Sydney. CPI forecast from 2021/22 NSW Treasury Budget Paper 1. (2) ABS 6401.0 CPI private motoring Australia. Assume growth by Sydney CPI. (3) ABS 6401.0 CPI maintenance & repair of motor vehicles Australia. Assume growth by Sydney CPI. (4) ABS 6401.0 CPI motor vehicles Australia. Assume growth by Sydney CPI. (5) ABS 6302.0 Average Weekly Earnings, Full Time Adult Ordinary Time Earnings NSW Seasonally Adjusted. Assume growth by wage price index from NSW Treasury Budget Paper 1. (6) ABS 6427.0 Producer Price Index Australia road freight transport. Assume growth by Sydney CPI. (7) Average of actual Sydney monthly fuel prices from Exxon Mobil TGP. Assume growth by Sydney CPI.
Note: * 2020/21 data escalated to December 2021.