Transport for NSW

Technical Note on Calculating Road Vehicle Operating Costs

This document applies to all agencies within the NSW Transport cluster

Evaluation & Assurance
Group Finance & Investment
Corporate Services

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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 to come

TfNSW is working with Infrastructure Australia (IA) and Australian Transport Assessment and Planning (ATAP) to further improve VOC guidance, and this approach may be updated in future guidance materials. 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 1**.

Table 1 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, which do not model changes in road user behaviour, the economic impact is equivalent to the reduction in the resource costs of travel (See **Equation 1**, p13). 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. There are several different equations that are used to do this with different traffic forecasting tools (See **Equation 2**, p15; **Equation 3**, p18 or **Equation 4**, p20).

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. This approach is expected to be developed further, but for now represents the TfNSW recommended parameter values for estimating VOC.

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

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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)

misperceive other costs where the cost is incurred infrequently and 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 parameter values for both in Section 4.

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]

TfNSW recommends two separate types of input data, dependant on the level of accuracy required in the VOC calculation. Where a project does not influence travel behaviour or the VOC benefit does not materially influence the choice of option or funding decision, VKT data aggregated by speed of travel should be used to estimate the VOC benefit. This 'speed bracket' input data is acceptable for most CBAs. An example of this type of data is presented in **Table 3** in Section 3.2.2.

More accurate estimates of VOC require detailed input data which reports the speed, distance, and number of trips for individual 'origin destination' (OD) pairs. OD pairs 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. Example travel zones and OD data are presented in Section 0.

Demand and traffic models can also produce input data at the level of individual road links. **TfNSW does not recommend** the use of this data, as it is overly sensitive to changes on individual links with high congestion and very low speeds.[7] These results can overstate VOC benefits if used in CBA without first being aggregated into speed brackets.

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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.

7 The exception to this is with calibrated and validated traffic models, particularly regional models such as TRARR or urban traffic models that include a small number of individual links. Link data from NSW strategic demand models (such as STM, SMPM, STFM or PTPM) should not be used to estimate VOC benefits.

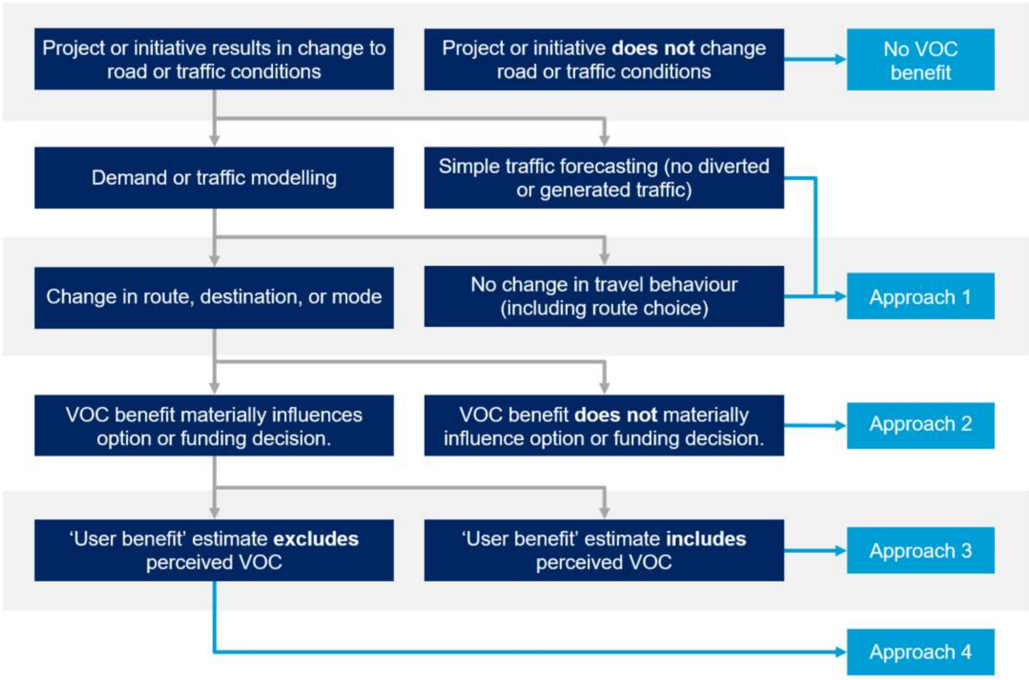
3 Recommended VOC approaches

The VOC approaches detailed in this section are designed to be used in CBA for NSW Transport cluster projects. For simplification, the approaches are presented based on private, conventional fuel vehicles in an urban environment, and example parameters are estimated using the TfNSW depreciation-adjusted VOC model. Rural projects should substitute the TfNSW depreciation-adjusted VOC model with the ATAP uninterrupted flow VOC model where gradient, curvature, or roughness are expected to materially influence the VOC benefit. Additional considerations for commercial vehicles, electric vehicles, and autonomous vehicles are included in Sections 4 through 7.

3.1 Selecting a VOC approach

Depending on project location and traffic forecasting approach, VOC can be calculated using different methodological approaches, input data, and VOC models. TfNSW recommends using one of four VOC approaches, reflecting the level of detail required and covering the preferred benefit equation, input data, and parameters to use. Practitioners should use the following steps when determining the VOC approach to use in a CBA:

Figure 1 VOC approach guide



Source: TfNSW Evaluation & Assurance (2020). **Table 2** provides additional detail on interpreting these criteria and selecting a preferred VOC approach.

All four approaches can be used for either urban (interrupted traffic) or rural (uninterrupted traffic) projects. Urban projects should use the TfNSW depreciation adjusted resource cost parameters reported in Section 4, while rural projects should use the uninterrupted travel VOC model reported in ATAP PV2.

Table 2 Selecting a recommended VOC approach

Decision Point		Question	Clarifications and recommendations
VOC approach (Section 3)			
1.	Project impact	Does the project or initiative results in a change to road or traffic conditions?	Projects which are likely to change any of the VOC factors mentioned in Table 1 should seek to quantify a VOC benefit in the CBA.
2.	Traffic forecasting approach	Does traffic forecasting for the project or initiative use a simple forecasting approach or transport modelling?[8]	Projects assessed using simple traffic forecasting should use Approach 1. In general, simple traffic forecasting is undertaken using spreadsheet analysis, whilst traffic and demand modelling uses computerised models based on software such as CUBE, EMME, or Aimsun.
3.	Travel behaviour impacts	Does traffic forecasting for the project or initiative include any behaviour changes?	Behaviour changes include changes in route, mode, destination, time of travel, or origin, through generally only the first three are commonly assessed. Project teams can test whether network wide VKT has changed between the base case and the project case. Where VKT changes, travel behaviour must also have changed.
4.	Materiality of benefit	Does the VOC benefit materially influence the choice of option or funding decision?	Where excluding the VOC benefit from the CBA would either change the preferred option, or change whether the benefit cost ratio (BCR) of the project is greater or less than 1.0, the VOC benefit is considered to have a material influence.
5.	CBA methodology	Does the user benefit estimate used in the CBA include the impact of perceived VOC?	User benefit approaches in CBA are sometimes estimated by individual components such as travel time, fares, tolls, crowding, etc. In other approaches these are summed into a 'generalised cost' function and reported as a single benefit stream. If the generalised cost function includes perceived VOC (sometimes referred to as fuel costs) then only a resource cost correction is required.
VOC model and parameters (Section 4)			
6.	Traffic environment	Does the project impact interrupted (urban) traffic or uninterrupted (rural) traffic?	Projects which impact interrupted traffic or occur in urban locations should use the TfNSW depreciation-adjusted VOC model to estimate resource costs. Projects that impact uninterrupted traffic, occur in rural areas, or change the gradient, curvature, or roughness of a road should use the ATAP PV2 uninterrupted flow VOC model to estimate resource costs.
Consideration of commercial vehicles (Section 5)			
7.	Commercial vehicles	Does the project impact commercial and freight vehicle traffic?	Projects which impact commercial and freight vehicle traffic should estimate VOC impacts for those vehicle classes. Where input data is available for light commercial vehicle (LCV) and heavy commercial vehicle (HCV) classifications, a weighted average VOC parameter should be developed using the Austroads 20-bin vehicle classification (See Appendix C)
Consideration of electric and autonomous vehicles (Section 6 and 7)			
8.	Electric and autonomous vehicles	Do VOC benefits contribute to greater than 25 per cent of total project benefits?	For urban projects where VOC benefits contribute to greater than 25 per cent of total project benefits, the impacts of electric vehicles should be assessed as a sensitivity.

Source: TfNSW Evaluation & Assurance (2020)

[8] Simple traffic forecasts typically rely on spreadsheet analysis or simple traffic models, are often developed based on data from traffic counts, and tend not to estimate changes in route, mode, or destination. Transport modelling typically relies on computerised models (such as 'four-step' models that forecasts changes in travel using four steps: trip generation, trip distribution, mode choice, and route assignment). There are many different types of transport models in use in NSW – for specific guidance on the application of this guidance to different traffic forecasting approaches please contact economicadvisory@transport.nsw.gov.au

3.2 Approach 1: Change in resource costs

3.2.1 When to use Approach 1

Projects that create minor improvements in journey speeds or impact isolated parts of the urban road network should be assessed using Approach 1. This may include changes to the alignment or capacity of arterial and sub-arterial roads, or changes to intersection or interchange layouts.

These road projects use approach 1 because they do not have a large enough impact on road conditions to influence travel behaviour. Where travel behaviour (in terms of destination and route choice) are the same in the base case and project case, the economic impact of the project or initiative is equivalent to the change in resource costs between the base case and the project case.

These projects generally use microsimulation or mesoscopic traffic models to estimate changes in traffic impacts, rather than strategic travel models. Importantly, this approach should not be used with projects that result in generated or induced traffic (e.g. additional trips being made, or changes in destination or mode choice) as it will not capture benefits for new users. Total vehicle kilometres travelled across the modelled area (VKT) should be the same in the base case and project case.

A note on fixed matrix models

Fixed matrix models allow for travellers to change their choice or route (often referred to as re-assigned or diverted traffic) as a result of a project, but do not model other behaviour changes such as switching destination, mode, or time of travel.

ATAP T2 Cost Benefit Analysis guidance recommends treating diverted traffic as induced traffic when calculating user benefits. In effect, this requires using Approach 2 rather than Approach 1 for the calculation of VOC benefits when using fixed matrix traffic models, as well as applying rule of half to other transport benefits (such as travel time savings) estimated for the CBA.

Currently, most CBA that are undertaken based on fixed matrix traffic modelling do not estimate user benefits based on the rule of half, and instead estimate benefits based on the difference in total resource costs between the base case and project case. This approach is not supported by current State and National guidance.

Given the additional time and cost required to estimate consumer surplus benefits for all projects using fixed matrix models, TfNSW is currently investigating the materiality of this change on CBA results. For now, project teams should ensure that whether diverted traffic is treated as existing or induced, it is done so consistently across the CBA.

3.2.2 User guide for Approach 1

This approach relies on the use of a change in resource cost equation (discussed in Appendix A), depreciation-adjusted resource costs (discussed in Section 4), and aggregated input data (discussed in Appendix B).

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 3.2.3, below.

The simplified VOC approach uses Equation 1:

Equation 1 Change in resource costs

$$VOC\ benefit = (Q_1 - Q_2)_s \times AC_s$$

Source: Australia Transport Council (2006)

Where:

- **AC** is the resource VOC, in dollars per kilometre
- **Q** is the quantity of travel, in *vehicle kilometres travelled* (VKT)
- subscript s refers to the relevant 'speed bracket' for aggregate VKT
- Subscript **1** and **2** represent the base case and project case, respectively.

This approach uses resource cost values reported in this document. As there is no change in travel behaviour, perceived costs are not used in Approach 1.

- **Resource costs (*AC*):** Resource costs in **Table 3** are calculated using TfNSW depreciation-adjusted parameter values, which remove capital and interest components from the ATAP urban stop-start VOC model, and add back use-based depreciation. This approach corrects for an issue with the ATAP VOC model identified in the Infrastructure Australia Assessment Framework.

This approach relies on VKT data by 'speed bracket', which is able to be produced by most NSW transport models.[9] An example of this type of data is shown in **Table 3**, along with the resource cost of travel for each different speed bracket.

Table 3 Example of aggregate 'speed bracket' input data for cars

Speed Bracket (***s***) km / hour	Base Case VKT (***Q₁***) Vehicle kilometres travelled	Project Case VKT (***Q₂***) Vehicle kilometres travelled	Resource Cost (**AC**) Cents per kilometre travelled (1)
< 10	143,829	143,182	114.58 (41.50)
10-20	1,118,457	1,119,020	49.62 (41.50)
20-30	2,952,160	2,948,214	36.62
30-40	3,724,987	3,721,073	31.06
40-50	3,068,046	3,073,125	27.96
50-60	2,164,978	2,170,559	25.99
60-70	1,634,770	1,632,808	24.63
70-80	346,299	345,473	23.63
80-90	625,449	625,450	22.87
90-100	427,882	427,952	22.26
Total	**16,206,856**	**16,206,856**	**-**

Source: TfNSW Evaluation & Assurance (2020) Prices are in June 2019 dollars. (1) Values in brackets should be used to sensitivity test VOC costs with a cap at the 20km per hour value

This input data provides a high level 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. **TfNSW does not recommend** using average network travel

[9] Discussions with TfNSW modelling teams are underway to ensure this data is included in standard economic output templates for NSW transport models.

speeds, or average road-type travel speeds in the VOC calculation as a substitute for speed bracket input data, as the resulting VOC benefit will not be sufficiently accurate for use in CBA.

TfNSW recommends that speeds below 5km/hr should be capped at the 5km/hr cost when calculating VOC benefits, as in **Table 3**. A sensitivity test should be undertaken using a 20km/hr cap to test align with guidance in ATAP M2.

3.2.3 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* with Approach 1, rather than the depreciation-adjusted parameter values.

Certain traffic forecasting models used in rural projects, such as TRARR,[10] 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.

3.3 Approach 2: Simplified resource cost correction

3.3.1 When to use Approach 2

Approach 2 is suitable for use with road and public transport projects that influence travel behaviour. This includes any project which is likely to result in travellers switching from public transport to private vehicle travel, or vice versa. It also includes some arterial and most motorway upgrades, which are likely to result in diverted or generated traffic.

Those travellers that change behaviour are often referred to by engineers and economists as ‘induced traffic’ or ‘new users’. In transport economics, benefits from induced traffic are apportioned by half.[11] This is referred to as the ‘rule-of-half’ and is explained in greater detail in the ATAP T2 *Cost-Benefit Analysis*. The rule-of-half is only applied to benefits measured based on *perceived* changes in a user’s costs. The rule-of-half does not apply to benefits that are assessed based on resource costs. This is because resource costs reflect actual costs.

Approach 2 is considered a ‘simplified’ resource cost correction because it includes a simplifying assumption that travellers perceive VOC as a fixed cost per kilometre. This assumption is used in many strategic demand models to forecast behavioural changes.[12]

Under this assumption, only a resource cost correction is required to be estimated, and user benefits for new and existing users can be ignored (when VOC is a fixed cost per kilometre, these ‘consumer surplus’ benefits are always equal to zero). The benefit of this approach for CBA practitioners is that it can be estimated using aggregate VKT data, as used with Approach 1. This data is significantly easier to

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10 TRAffic on Rural Roads

11 TfNSW uses the definition of induced traffic outlined in the ATAP Guidelines - the sum of diverted and generated traffic. Diverted traffic refers to freight, passengers or vehicles that switch from one mode, route, time of day, origin or destination to another as the result of an initiative. Generated traffic refers to altogether new demand resulting from an initiative. Induced traffic is based on kilometres-travelled rather than trips. Under this approach, traffic is considered to be ‘induced’ even if it results from additional travel from an existing user (e.g. changing route but not destination).

12 Including STM and PTPM. Other approaches assume that travellers perceive that VOC increases in low speed and very high speed environments.

analyse in comparison to the origin-destination (OD) matrices required for more detailed VOC approaches.

As this approach uses aggregate VKT data rather than OD matrices, it is less accurate than the detailed approaches documented in Approach 3 and 4. **TfNSW recommends** that where a VOC benefit estimated using this approach materially influences the choice of option or funding decision for a Business Case, a sensitivity test is undertaken using either Approach 3 or 4.

3.3.2 User guide for Approach 2

This approach relies on the use of a simplified resource cost correction equation (discussed in Appendix A), parameter values based on constant perceived costs and depreciation-adjusted resource costs (discussed in Section 4), and aggregated input data (discussed in Section Appendix B).

The simplified VOC approach uses **Equation 2**:

Equation 2 Simplified resource cost correction

$$VOC\ benefit = Q_{2s}(PC - AC)_s - Q_{1s}(PC - AC)_s$$

Source: TfNSW Evaluation & Assurance (2020) based on Australia Transport Council (2006)

Where:

- **PC** is a fixed perceived VOC, in dollars per kilometre
- **AC** is the resource VOC, in dollars per kilometre
- **Q** is the quantity of travel, in *vehicle kilometres travelled* (VKT)
- subscript s refers to the relevant 'speed bracket' for aggregate VKT
- subscript **1** and **2** represent the base case and project case, respectively.

This approach uses the following resource cost and perceived cost values:

- **Resource costs (*AC*):** Resource costs are calculated using TfNSW depreciation-adjusted parameter values, which remove capital and interest components from the ATAP urban stop-start VOC model, and add back use-based depreciation. This approach corrects for an issue with the ATAP VOC model identified in the Infrastructure Australia Assessment Framework.
- **Perceived costs (*PC*):** constant perceived costs based on the PTPM behavioural VOC value of $0.339 (in 2016 dollars). This equates to $0.3654 in June 2019 dollars.

The parameter values in **Table 4** should be used for **PC** and **AC**.

Table 4 Parameter values for simplified VOC benefit approach

Speed Bracket (***s***) km / hour	Perceived cost (***PC***) cents per VKT	Resource cost (***AC***) cents per VKT (1)	VOC Benefit (**PC – AC**) cents per VKT (1)
< 10	36.54	114.58 (41.50)	-78.04 (-4.96)
10-20	36.54	49.62 (41.50)	-13.07 (-4.96)
20-30	36.54	36.62	-0.08
30-40	36.54	31.06	5.49
40-50	36.54	27.96	8.58
50-60	36.54	25.99	10.55
60-70	36.54	24.63	11.91
70-80	36.54	23.63	12.91
80-90	36.54	22.87	13.68
90-100	36.54	22.26	14.28

Source: TfNSW Evaluation & Assurance (2020). Prices are in June 2019 dollars. (1) Values in brackets should be used to sensitivity test VOC costs with a cap at the 20km per hour value

Projects that increase the average speed of travel tend to result in a net benefit under Approach 2. This is because travellers that do not perceive the impact that speed has on operating costs (particularly from fuel efficiency) underestimate the cost of travel at low speeds, but overestimate the cost of travel at high speeds.

A worked example for Approach 2 is shown below.

Worked example using aggregate data

The table below shows a worked example based on speed bracket data taken from the standard PTPM economic output spreadsheet. In this example, the transport initiative has resulted in an increase in car use (in aggregate, Q_2 is greater than Q_1).

Table 5 Worked VOC benefit example using aggregate data

PTPM Outputs			Benefit Calculation (Jun-2019 dollars)		
Speed bracket (km/h)	Q_1 (km)	Q_2 (km)	PC - AC (cents)	VOC benefit ($, 2hr AM)	VOC benefit[(a)] ($m, annual)
< 10	143,829	143,182	-78.04	505.21	1.07
10-20	1,118,457	1,119,020	-13.07	-73.85	-0.16
20-30	2,952,160	2,948,214	-0.08	4.90	0.01
30-40	3,724,987	3,721,073	5.49	-213.10	-0.45
40-50	3,068,046	3,073,125	8.58	433.66	0.92
50-60	2,164,978	2,171,715	10.55	707.85	1.50
60-70	1,634,770	1,632,808	11.91	-232.89	-0.49
70-80	346,299	345,473	12.91	-106.30	-0.23
80-90	625,449	625,450	13.68	0.14	0.00
90-100	427,882	427,952	14.28	9.97	0.02
Total	**16,206,856**	**16,208,012**	-	**1,035.58**	**2.19**

Source: TfNSW Evaluation & Assurance (2020). Note (a) calculated using an expansion factor of 6.29 and an annualisation factor of 336 from TfNSW (2020) *Economic Parameter Values*

Despite an increase in total kilometres travelled, the VOC benefit is positive, as the average network speed has increased due to the initiative. Infrastructure Australia notes in the Assessment Framework that base ATAP VOC model estimates can be significantly higher than other VOC models such as Austroads 2012. The VOC benefit estimated here is approximately 40 per cent lower than the base ATAP model which includes time-based depreciation. The result is sensitive to capping VOC at the 20km/h value.

As with Approach 1, **TfNSW does not recommend** using average network travel speeds, or average road-type travel speeds in the VOC calculation as a substitute for speed bracket input data, as the resulting VOC benefit will not be sufficiently accurate for use in CBA.

TfNSW recommends that speeds below 5km/hr should be capped at the 5km/hr cost when calculating VOC benefits, as in **Table 3**. A sensitivity test should be undertaken using a 20km/hr cap to test align with guidance in ATAP M2.

3.3.3 Adjustment for rural projects

As with Approach 1, 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.

Note that when using the PV2 VOC model, PC – AC may change between the base case and the project case for rural projects as a result of changes to pavement roughness, gradient, or curvature.

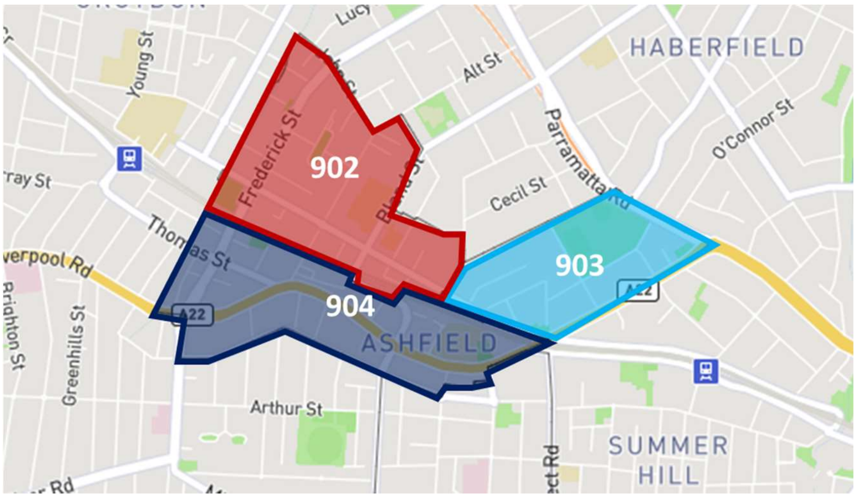
3.4 Approach 3: Detailed resource cost correction

3.4.1 When to use Approach 3

TfNSW recommends using Approach 3 or 4 where VOC benefits materially influence the choice of option or funding decision for a Business Case. Both approaches use OD matrices rather than aggregate network data to estimate the VOC benefit.

OD matrices are very large files that contain an estimate of all trips between 'travel zones' within a larger area. The Sydney Travel Model (STM) and Public Transport Project Model (PTPM) contain almost 3,000 separate travel zones. **Figure 2** shows three travel zones that cover the Ashfield area in Sydney's Inner West:

Figure 2 Travel zones in Ashfield



Source: Transport for NSW Travel Zone Explorer (2020)

Table 6, below, shows an example data set with the data required to calculate VOC for travel between three travel zones, summarised into 9 rows of data. For the full set of STM travel zones, almost 9 million rows of data are required.

Approach 3 measures the resource cost correction, as in Approach 2. This approach is suitable when either:

- Perceived costs are assumed to be a fixed cost per kilometre, so consumer surplus benefits are equal to zero
- Perceived costs vary with the speed of travel, but the increase in consumer surplus from changes in perceived VOC are captured elsewhere in the CBA, such as in a 'user benefit' line item.

  When perceived costs vary with the speed of travel, the consumer surplus benefit will be non-zero and should be estimated as in Approach 4. However, if the VOC consumer surplus benefit is also estimated in another benefit stream, then Approach 4 will result in doubling counting and as such Approach 3 should be used instead.

3.4.2 User guide for Approach 3

This approach relies on the use of a resource cost correction equation (discussed in Appendix A), parameter values based on *either* constant or variable perceived costs, and depreciation-adjusted resource costs (discussed in Section 4), and input data from OD matrices (discussed in Appendix B).

Approach 3 uses a detailed resource cost correction equation:

Equation 3 Resource cost correction for OD data

$$VOC\ benefit = Q_{2ij}(P_2 - AC_2)_{ij} - Q_{1ij}(P_1 - AC_1)_{ij}$$

Source: ATAP (2016)

Where:

- **P** is the perceived VOC, in dollars per kilometre
- **AC** is the resource VOC, in dollars per kilometre
- **Q** is the quantity of travel in vehicle kilometres travelled, derived from the number of trips multiplied by average trip length
- subscript ***i*** and ***j*** refer to the origin travel zone and destination travel zone, respectively
- subscript **1** and **2** represent the base case and project case, respectively.

When applying formulas to origin-destination data, variable perceived costs and resource costs per kilometre 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.

Table 6 Example origin-destination input data

Input data					
Origin travel zone (*i*)	Destination travel zone (*j*)	Quantity (**Q_1**) VKT	Quantity (**Q_2**) VKT	Average speed $_1$ km / hour	Average speed $_2$ km / hour
902	902	25,753	23,178	23.3	21.9
903	902	44,738	49,212	25.2	23.7
904	902	18,086	21,703	27.4	28.9
902	903	28,999	23,199	24.7	22.8
903	903	22,722	23,858	28.5	27.8
904	903	16,599	18,259	32.2	31.0
902	904	65,391	62,121	34.4	32.5
903	904	13,852	12,467	36.0	35.7
904	904	25,018	26,269	34.7	35.6

Source: TfNSW Evaluation & Assurance (2020). Prices are in June 2019 dollars.

Table 7 Parameter values for example origin-destination input data

Parameter values					
Origin travel zone (*i*)	Destination travel zone (*j*)	Perceived cost (P_1) cents/km	Resource cost (AC_1) cents/km	Perceived cost (P_2) cents/km	Resource cost (AC_2) cents/km
902	902	36.54	38.07	36.54	39.43
903	902	36.54	36.50	36.54	37.72
904	902	36.54	34.91	36.54	34.01
902	903	36.54	36.85	36.54	38.49
903	903	36.54	34.22	36.54	34.68
904	903	36.54	32.25	36.54	32.84
902	904	36.54	31.30	36.54	32.13
903	904	36.54	30.66	36.54	30.79
904	904	36.54	31.19	36.54	30.83

Source: TfNSW Evaluation & Assurance (2020). Prices are in June 2019 dollars.

Table 7 uses resource cost and perceived cost values reported in this document:

- **Resource costs (*AC*):** Resource costs are calculated using the TfNSW depreciation-adjusted VOC model.
- **Perceived costs (*P*):** constant perceived costs based on the PTPM behavioural VOC value of $0.339 (in 2016 dollars). With approach 3, variable perceived costs (found in **Table 10**) could also be used.

3.5 Approach 4: Detailed VOC benefit

3.5.1 When to use Approach 4

TfNSW recommends using Approach 4 where VOC benefits materially influence the choice of option or funding decision for a Business Case. Approach 4 uses OD matrices rather than aggregate network data to estimate the VOC benefit, and is used to estimate both the consumer surplus benefit and resource cost correction for VOC.

For CBAs that separately estimates the individual components of road user benefits (e.g. travel time savings, reliability, toll costs), Approach 4 is required in order to capture both the private benefits to road users from VOC changes, and the changes in social costs for all NSW residents.

3.5.2 User guide for Approach 4

This approach uses the equation for calculating the full increase in social welfare[13] for existing and induced traffic from ATAP T2 *Cost Benefit Analysis* (discussed in Appendix A), parameter values based on either variable or constant perceived costs, and depreciation-adjusted resource costs (discussed in Section 4), and origin-destination input data (discussed in Section Appendix B).

The benefit equation is shown in **Equation 4**:

[13] 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

Equation 4 Increase in social welfare using OD data

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

Source: ATAP (2016)

Where:

- **P** is the perceived VOC, in dollars per kilometre
- **AC** is the resource VOC, in dollars per kilometre
- **Q** is the quantity of travel in vehicle kilometres travelled, derived from the number of trips multiplied by average trip length
- subscript ***i*** and ***j*** refer to the origin travel zone and destination travel zone, respectively
- 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.

Approach 4 uses the same input data and parameter values as Approach 3, examples of which are presented in **Table 6** and **Table 7**, above. As with the other approaches discussed above, rural projects should instead use the ATAP PV2 VOC model to estimate resource costs (AC).

3.6 Reporting results

TfNSW recommends that the CBA should clearly label whether the VOC impact reported in the results table represents the consumer surplus, resource cost, or resource cost correction components. The CBA should also sensitivity test the impact of capping VOC parameters at the 20km/h values.

Table 8 shows the results of VOC analysis undertaken using the different benefit equations, using the example data for the 2 hour AM peak period shown in **Table 5**. Constant perceived VOC have been applied for all approaches.

Table 8 VOC Benefit (ATAP model, 2hr AM peak, 2019 prices)

VOC benefit category		Increase in Social Welfare approach	Consumer Surplus and Resource Cost Correction approach	Consumer Surplus and Resource Cost Correction approach *(20km/hr sensitivity)*
		Equation 4	*Equation 3*	*Equation 3*
		A + B	C + D	C + D
A	Change in willingness-to-pay	614		
B	Change in social costs	422		
C	Change in consumer surplus		0	0
D	Resource cost correction		1,036	608
	Total	**1,036**	**1,036**	**608**

Source: Estimated by Evaluation & Assurance (2020)

While results are consistent across all VOC equations, they will differ if alternative assumptions, input data, or another VOC model is used.

3.7 Documenting assumptions

TfNSW recommends the following assumptions are documented clearly in the CBA methodology paper or Economic Appraisal appendix when submitting a business case. If no methodology paper or appendix is provided, these assumptions must be reported in the *Cost Benefit Analysis* section of the *Program Justification* or *Value for Money* chapter of the Business Case. Assumptions to be documented include:

- The VOC approach used in the CBA, as above
- The VOC model used in the CBA, discussed in Section 4
    - Document whether cost per kilometre has been capped at a maximum value, and the maximum value applied. Document the vehicle mix used for LCV and HCV vehicle categories if applicable.
- The benefit equation used in the CBA, discussed in Appendix A
    - Document whether part of the VOC benefit is included in a separate benefit item in the CBA. For example, where user benefits are estimated using changes in generalised cost, the Willingness-to-Pay (WTP) or consumer surplus benefit may already be included in that benefit stream.
- The input data used in the CBA, discussed in Appendix B
- Whether uptake of electric vehicles have been considered in the CBA.

4 Recommended VOC Models

4.1 Recommended interrupted flow VOC model

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.

TfNSW recommends using a depreciation-adjusted version of the ATAP interrupted flow VOC models for urban road and public transport projects. The base ATAP PV2 model is detailed in Transport and Infrastructure Council (2016) *Australian Transport Assessment and Planning (ATAP) Road Parameter Values PV2.*

4.1.1 TfNSW depreciation adjusted VOC model

The depreciation-adjusted VOC model for private vehicles uses the base formula from ATAP (2016), with an additional depreciation adjustment. 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.[14]

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

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

Source: TfNSW Evaluation & Assurance (2020)

Equation 6 VOC model for private vehicles, free flow model

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

Source: TfNSW Evaluation & Assurance (2020)

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 9 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.

[14] 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

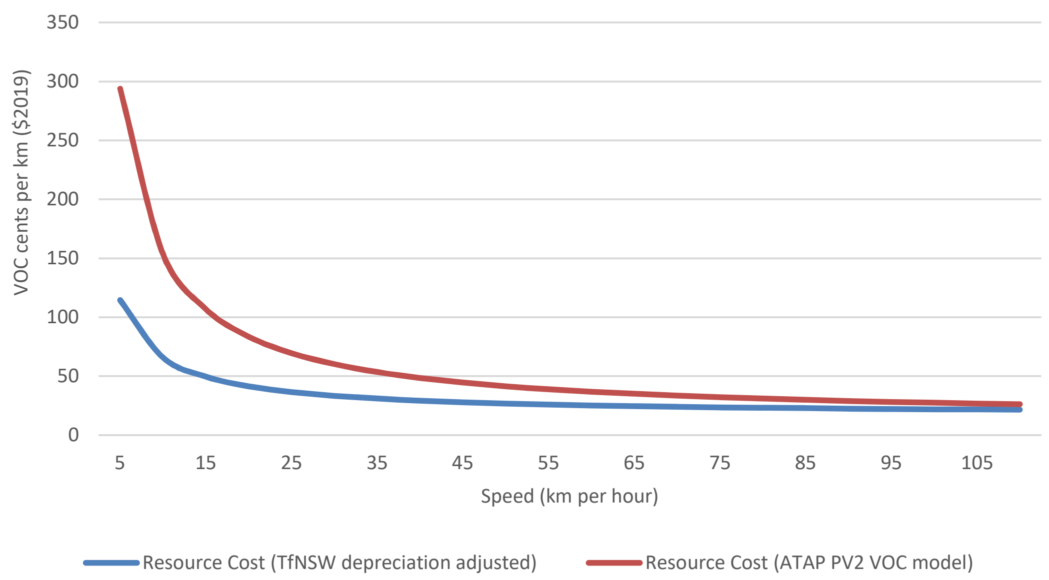
Table 9 Depreciation-adjusted model coefficients (cents/km, 2019 prices)

Vehicle Type	Stop-start model		Free flow model			Depreciation	
	A	B	C_0	C_1	C_2	D	E
Cars							
Small Car	13.3475	893.4041	27.4909	-0.1335	0.0011	-7.2945	1.6848
Medium Car	13.4831	1401.9961	37.3509	-0.1866	0.0013	-15.2457	3.6508
Large Car	15.3783	1959.3314	49.2120	-0.2367	0.0015	-21.8147	5.2239
Utility vehicles							
Courier Van-Utility	17.0281	1450.1832	41.1315	-0.1966	0.0015	-9.8032	1.2244
4WD Mid-Size Petrol	22.4914	1419.9117	43.3391	-0.1646	0.0014	-16.1181	1.8397
Rigid trucks							
Light Rigid	36.2991	1649.3983	55.0413	-0.2651	0.0027	-12.2342	1.4239
Medium Rigid	38.2589	2414.8697	66.9773	-0.3208	0.0028	-25.5155	3.1336
Heavy Rigid	61.0795	2731.3507	87.9327	-0.5904	0.0057	-30.2617	3.5267
Articulated trucks							
Articulated 4 Axle	90.3703	3550.8738	119.3189	-0.7736	0.0077	-37.0309	4.2054
Articulated 5 Axle	97.3792	3941.5427	128.1211	-0.7266	0.0071	-40.8365	4.6375
Articulated 6 Axle	105.4576	4264.9639	137.5122	-0.7350	0.0071	-44.2721	5.0277
Combination vehicles							
Rigid + 5 Axle Dog	130.9546	3985.6067	145.4988	-0.6842	0.0069	-38.6538	4.3897
B-Double	131.4257	4907.0762	161.8582	-0.7724	0.0073	-50.5418	5.7397
Twin steer + 5 Axle	135.9194	4680.3125	160.2120	-0.7385	0.0072	-47.1008	5.3489
A-Double	153.8668	6082.3124	196.1207	-0.8901	0.0079	-63.8098	7.2465
B-Triple	159.6593	7623.6772	228.8270	-1.0555	0.0087	-83.0071	9.4266
A B combination	182.0005	6686.9568	223.0189	-0.9635	0.0085	-69.5421	7.8974
A-Triple	203.7212	7624.1800	253.3243	-1.0826	0.0092	-79.9724	9.0820
Double B-Double	213.2552	7454.6907	255.0945	-1.0560	0.0092	-50.5418	5.7397
Buses							
Heavy Bus	68.9837	4949.7869	133.2524	-0.6910	0.0050	-44.4406	5.1376

Source: TfNSW Evaluation & Assurance (2020) based on ATAP (2016). Coefficients produce VOC estimates in June 2019 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 3**.

Figure 3 VOC with and without depreciation (medium car, stop start model)



Source: TfNSW Evaluation & Assurance (2020)

4.2 Recommended uninterrupted flow VOC model

TfNSW recommends using the ATAP uninterrupted flow VOC model to assess the VOC benefit for rural road projects. The uninterrupted flow model can also be used to assess the change in VOC where there is a change in average freight payload.[15] Note that the uninterrupted flow model produces resource costs, not perceived costs.

Based on publicly available documentation, it is not clear what proportion of the uninterrupted flow VOC model represents capital and interest costs. For now, **TfNSW recommends** using the uninterrupted flow model as presented in Transport and Infrastructure Council (2016) *Australian Transport Assessment and Planning (ATAP) Road Parameter Values PV2*.

4.3 Recommended 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 take into account 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.

TfNSW recommends using the same behavioural VOC values that are used in the transport forecasting approach, if using a constant perceived VOC per kilometre. For variable perceived costs, **TfNSW recommends** the parameters in **Table 10**.

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15 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.

Table 10 Perceived VOC – private vehicles (2019 prices)

Speed (km/h)	Small Car	Medium Car (*recommended variable cost*)	Large Car	All Car (*recommended constant cost*)
5	95.0	134.9	180.8	36.54
10	60.2	80.5	104.5	36.54
15	48.6	62.4	79.1	36.54
20	42.8	53.4	66.4	36.54
25	39.3	47.9	58.7	36.54
30	37.0	44.3	53.7	36.54
35	35.3	41.7	50.0	36.54
40	34.1	39.8	47.3	36.54
45	33.1	38.3	45.2	36.54
50	32.3	37.1	43.5	36.54
55	31.7	36.1	42.1	36.54
60	31.2	35.2	40.9	36.54
65	30.7	34.6	40.0	36.54
70	30.3	34.0	39.1	36.54
75	30.0	33.4	38.4	36.54
80	29.7	33.0	37.8	36.54
85	29.5	32.6	37.2	36.54
90	29.2	32.2	36.7	36.54
95	29.0	31.9	36.3	36.54
100	28.9	31.6	35.8	36.54
105	28.7	31.4	35.5	36.54
110	28.5	31.1	35.2	36.54

Source: Estimated by Evaluation & Assurance (2020), June 2019 prices

The perceived cost parameters in **Table 10** are based on the following assumptions about the proportion of all travellers that perceive different cost components:

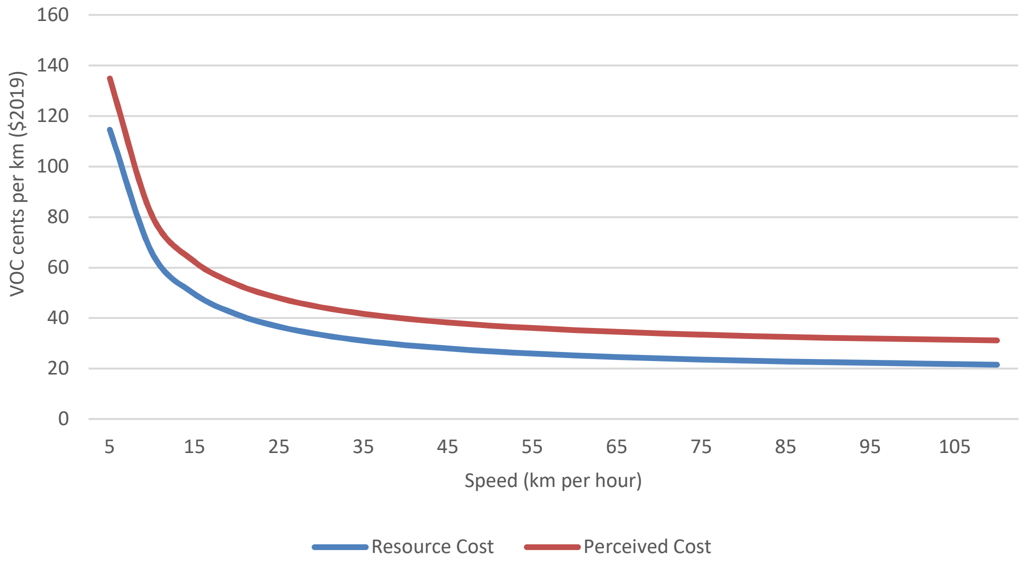
Table 11 Perceived VOC components for private vehicles

Perceived cost components	Proportion perceiving cost component	Comments
No costs	3%	A proportion of travellers do not perceive VOC. This may be due to misperception of costs or because costs are paid for by another party
Fuel	96%	TfNSW has included GST, fuel excise, and rebates in the fuel cost component of perceived costs, and calculated fuel consumption based on the ATAP PV2 interrupted travel stop-start fuel consumption model.
Depreciation	20%	For the purpose of estimating perceived VOC, TfNSW has included both time-based and use-based depreciation, as private individuals are less likely to accurately estimate use-based depreciation.
Other costs	22%	Other costs may comprise insurance, maintenance, or servicing costs. TfNSW has included the costs of maintenance and engine oil, but not insurance, when estimating perceived VOC.
All cost elements	5%	TfNSW has included resource costs (including depreciation) as well as taxes and subsidies (GST, fuel excise, and fuel rebates) to estimate VOC for those that perceive 'all' costs of travel

Source: Estimated by TfNSW Evaluation & Assurance (2020) from ATAP T2 (2018) *Cost Benefit Analysis*, Shiftan & Bekhor (2002) *Investigating individual's perceptions of auto travel cost*

Under these assumptions, perceived VOC for private vehicles are slightly higher than the depreciation adjusted resource costs, as shown in **Figure 4** below.

Figure 4 Resource and perceived VOC (medium car, stop start model)



Source: TfNSW Evaluation & Assurance (2020)

For commercial vehicles, the perceived cost of travel has been estimated using the full financial cost of travel, equivalent to resource costs plus taxes and subsidies. The perceived cost of travel for selected LCV and HCV vehicle types is presented in **Table 12** below.

Table 12 Perceived VOC – commercial vehicles (2019 prices)

Speed (km/h)	LCV		Rigid Truck			Articulated (selected)			
	Courier Van-Utility	4WD Petrol	Light	Medium	Heavy	4 Axle	5 Axle	6 Axle	B-Double
5	219.7	148.1	231.0	231.7	281.9	395.3	438.5	473.7	563.0
10	121.2	89.3	136.2	139.7	178.4	252.1	278.0	300.6	360.9
15	88.3	69.8	104.6	109.1	143.9	204.4	224.5	242.9	293.5
20	71.9	60.0	88.7	93.8	126.6	180.5	197.7	214.0	259.8
25	62.1	54.1	79.3	84.6	116.2	166.2	181.7	196.7	239.6
30	55.5	50.2	72.9	78.4	109.3	156.7	170.9	185.1	226.2
35	50.8	47.4	68.4	74.1	104.4	149.9	163.3	176.9	216.5
40	47.3	45.3	65.0	70.8	100.7	144.7	157.6	170.7	209.3
45	44.6	43.7	62.4	68.2	97.8	140.8	153.1	165.9	203.7
50	42.4	42.4	60.3	66.2	95.5	137.6	149.5	162.0	199.2
55	40.6	41.3	58.6	64.5	93.6	135.0	146.6	158.9	195.5
60	39.1	40.4	57.1	63.1	92.1	132.8	144.2	156.3	192.5
65	37.8	39.7	55.9	61.9	90.7	131.0	142.1	154.1	189.9
70	36.7	39.0	54.9	60.9	89.6	129.4	140.4	152.2	187.7
75	35.8	38.5	54.0	60.1	88.6	128.0	138.8	150.5	185.7
80	35.0	38.0	53.2	59.3	87.8	126.8	137.5	149.1	184.1
85	34.3	37.5	52.5	58.6	87.0	125.8	136.3	147.8	182.6
90	33.6	37.2	51.9	58.0	86.3	124.8	135.3	146.7	181.3
95	33.0	36.8	51.3	57.5	85.7	124.0	134.3	145.6	180.1
100	32.5	36.5	50.8	57.0	85.2	123.3	133.5	144.7	179.0
105	32.0	36.2	50.4	56.5	84.7	122.6	132.7	143.9	178.0
110	31.6	36.0	49.9	56.2	84.2	122.0	132.0	143.2	177.2

Source: Estimated by Evaluation & Assurance (2020), June 2019 prices

5 Consideration of commercial vehicles

VOC parameters are available for 20 separate vehicle classes, as classified by Austroads (see **Table 19**, p38). 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, **TfNSW recommends** parameters to 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 13 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 Evaluation & Assurance, or TfNSW Network & Asset Intelligence.

Table 13 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 Evaluation & Assurance, TfNSW from ABS Survey of Motor Vehicle Use 2018. See Appendix C 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 14 provides energy consumption per kilometre in Australian conditions, for different vehicle classes.[16] 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 14 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 15** have been used to convert the energy consumption values into perceived and resource costs per kilometre.

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

Table 15 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	69.9	70.1
Fuel excise	41.6	41.6
GST	11.15	11.17
Total	**122.6**	**122.9**
Resource Cost (AC)	**69.9**	**70.1**
Perceived Cost (P)	**122.6**	**122.9**
Electricity cost components (2)	Electricity (cents/kWh)	
Electricity resource costs	26.6	
Environmental tariffs and schemes	1.7	
GST	2.8	
Total	**31.1**	
Resource Costs (AC)	**26.6**	
Perceived Costs (P)	**31.1**	

Source:
(1) Australian Institute of Petroleum (2019) *Terminal Gate Prices*, prices as at June 2018
(2) Australian Competition and Consumer Commission (2018) *Restoring electricity affordability and Australia's competitive advantage: Retail Electricity Pricing Inquiry*, prices as at June 2018

Average costs per kilometre for fuel and electricity, by vehicle type, are presented in **Table 16**.

Table 16 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	8.7500	-	8.7500	15.3438	-	15.3438
	PHEV	0.9800	4.5220	5.5020	1.7185	5.2870	7.0055
	BEV	-	4.7880	4.7880	-	5.5980	5.5980
Class-B small (*e.g. Ford Fiesta*)	CV	3.1500	-	3.1500	5.5238	-	5.5238
	BEV	-	3.1920	3.1920	-	3.7320	3.7320

Source: TfNSW Evaluation & Assurance (2020) 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,* and Australian Institute of Petroleum (2019) *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. The vehicle operating costs presented in **Table 17** and **Table 18** assume no change in non-fuel costs per kilometre for electric vehicles, and no change in electricity costs per kilometre at different speeds of travel.

Figures in **Table 17** and **Table 18** have been adjusted to remove depreciation using the approach outlined in Section 4.

Table 17 VOC for medium-size CV, PHEV and BEV (cents/km, 2019 prices)

Medium Car	Speed of travel									
	20	30	40	50	60	70	80	90	100	110
Conventional Vehicle (CV)										
Non-fuel resource cost	34.82	27.76	24.23	22.11	20.70	19.69	18.94	18.35	17.88	17.49
Resource cost	**43.77**	**35.21**	**30.92**	**28.35**	**26.64**	**25.42**	**24.50**	**23.78**	**23.21**	**22.75**
Perceived cost	**41.99**	**33.38**	**29.08**	**26.50**	**24.78**	**23.55**	**22.62**	**21.91**	**21.33**	**20.86**
Plug-in Hybrid Electric Vehicle (PHEV)										
Non-fuel resource cost	34.82	27.76	24.23	22.11	20.70	19.69	18.94	18.35	17.88	17.49
Resource cost	**40.32**	**33.26**	**29.73**	**27.61**	**26.20**	**25.19**	**24.44**	**23.85**	**23.38**	**22.99**
Non-fuel perceived cost	31.93	24.83	21.27	19.14	17.72	16.71	15.95	15.35	14.88	14.49
Energy perceived cost	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01
Perceived cost	**38.94**	**31.83**	**28.28**	**26.15**	**24.73**	**23.71**	**22.95**	**22.36**	**21.89**	**21.50**
Battery Electric Vehicle (BEV)										
Non-fuel resource cost	34.82	27.76	24.23	22.11	20.70	19.69	18.94	18.35	17.88	17.49
Resource cost	**39.61**	**32.55**	**29.02**	**26.90**	**25.49**	**24.48**	**23.72**	**23.14**	**22.67**	**22.28**
Non-fuel perceived cost	31.93	24.83	21.27	19.14	17.72	16.71	15.95	15.35	14.88	14.49
Energy perceived cost	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
Perceived cost	**37.53**	**30.42**	**26.87**	**24.74**	**23.32**	**22.31**	**21.54**	**20.95**	**20.48**	**20.09**

Source: TfNSW Evaluation & Assurance (2020)

Table 18 VOC for small-size CV and BEV (cents/km, 2019 prices)

Small Car	Speed of travel									
	20	30	40	50	60	70	80	90	100	110
Conventional Vehicle (CV)										
Non-fuel resource cost	32.95	25.92	22.41	20.30	18.89	17.89	17.14	16.55	16.08	15.70
Resource cost	**39.89**	**31.88**	**27.87**	**25.47**	**23.87**	**22.72**	**21.87**	**21.20**	**20.66**	**20.23**
Perceived cost	**30.73**	**25.74**	**23.24**	**21.74**	**20.74**	**20.03**	**19.50**	**19.08**	**18.75**	**18.47**
Battery Electric Vehicle (BEV)										
Non-fuel resource cost	32.95	25.92	22.41	20.30	18.89	17.89	17.14	16.55	16.08	15.70
Resource cost	**36.14**	**29.11**	**25.60**	**23.49**	**22.09**	**21.08**	**20.33**	**19.74**	**19.27**	**18.89**
Non-fuel perceived cost	22.71	18.77	16.80	15.62	14.83	14.27	13.85	13.52	13.26	13.04
Energy perceived cost	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73
Perceived cost	**26.44**	**22.50**	**20.53**	**19.35**	**18.56**	**18.00**	**17.58**	**17.25**	**16.99**	**16.78**

Source: TfNSW Evaluation & Assurance (2020)

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.[17] However, given uptake of EVs in Australia has historically been slower than in Europe, America, and Asia, this estimate may represent an upper bound for forecast EV uptake in NSW.

The impact of electric vehicles on transport CBAs is still in development, and significant additional research is required. As such, **TfNSW recommends** that where VOC benefits contribute to greater than 25 per cent of total project benefits, the impacts of electric vehicles are assessed as a sensitivity.

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.

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

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.

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Appendix A VOC benefit equations

The benefit equation is used to calculate the benefit to the NSW community from changes in VOC. The traffic forecasting approach used in the CBA will influence the choice of benefit equation that can be used.

A.1 Benefit equations

Benefit equations are presented separately for use with simple traffic forecasts (Section A.1.1) and complex transport models (Section A.1.2 – Section A.1.3)

A.1.1 Benefit equation for simple traffic forecasts

This equation estimates VOC benefits for demand forecasts that are undertaken using a simple traffic forecasting approach with no generated or diverted traffic.

Equation 7 Change in social cost for existing traffic

$$VOC\ benefit = (AC_1 - AC_2)Q_1$$

Source: Australia Transport Council (2006)

Where:

- **AC** is the resource cost of travel in dollars
- **Q** is the quantity of travel in kilometres
- Subscript **1** and **2** represent the base case and project case, respectively.

A.1.2 Benefit equations for use with transport model outputs

This equation estimates VOC benefits as the sum of changes in consumer surplus for travellers, offset by correction for the difference between the private (perceived) cost of travel and the social (resource) cost of travel.

Additional benefit equations are reported in ATAP (2018) and ATC (2006) that calculate VOC based on willingness-to-pay and social costs. These equations produce the same net benefit as **Equation 8** when applied correctly.

Equation 8 Consumer surplus and resource cost correction approach

$$VOC\ benefit = 0.5 \times (P_1 - P_2)(Q_2 + Q_1) \\ +[Q_2(P_2 - AC_2) - Q_1(P_1 - AC_1)]$$

Source: ATAP (2016)

Where:

- **P** is the perceived cost of travel in dollars
- **AC** is the resource cost of travel in dollars
- **Q** is the quantity of travel
- Subscript **1** and **2** represent the base case and project case, respectively.

A.1.3 Resource cost correction

In some cases, the equation used to estimate VOC benefits will need to be changed to avoid double counting with other benefits estimated in the CBA. Where a generalised cost or consumer surplus benefit is estimated that includes perceived VOC impacts, a resource cost correction should be separately estimated. The resource cost correction is shown in **Equation 9**.

This equation can also be used when perceived VOC does not vary with speed of travel.

Equation 9 Resource cost correction

$$VOC\ Resource\ Cost\ Correction = Q_2(P_2 - AC_2) - Q_1(P_1 - AC_1)$$

Source: TfNSW Evaluation & Assurance, and Australia Transport Council (2006)

Where:

- **P** is the perceived cost of travel
- **AC** is the resource cost of travel
- **Q** is the quantity of travel
- Subscript **1** and **2** represent the base case and project case, respectively.

This corrects for the difference between resource costs and perceived costs. This correction is not equivalent to the price impacts of taxes and subsidies, or a ‘tax wedge’, because costs other than taxes and subsidies are misperceived by users. This occurs where travellers do not perceive any costs (e.g. the costs of travel are paid for by a separate party), or do not perceive some costs (e.g. if components such as use-based depreciation or tyre wear are not considered when making travel decisions).

Appendix B 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.

B.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, **TfNSW recommends** 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.

Limitations of aggregated 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 that is not split by speed of travel 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 yield a materially different benefit than the same change in speed on a high speed link. This impact would not be captured if aggregated data is not split by speed.

B.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.

Limitations of origin-destination data

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.

B.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.

TfNSW recommends this approach is only 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.[18]

Limitations of link data

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.

[18] 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.

B.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.

TfNSW recommends holding 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 B.1). This is because the economic impact of the project should be based on the change in actual travel conditions resulting from the project, rather than any change in the VOC model used.

Appendix C Vehicle classification

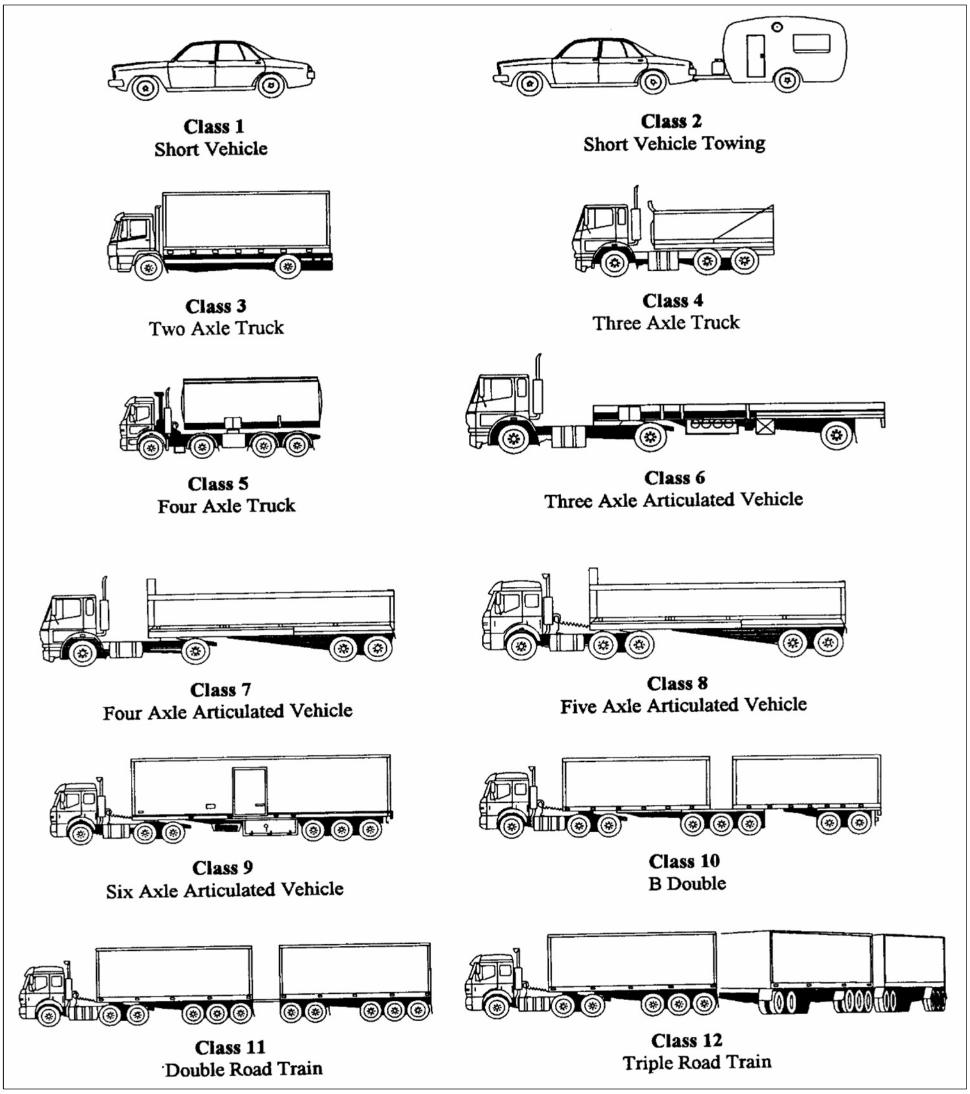
A number of vehicle classification systems are used in this document and by other state and federal guidance documents. This section provides an overview of the different vehicle types and a concordance between classifications. More detail can be found on the Austroads website.

Table 19 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 Evaluation & Assurance, 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 5 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 D Key indices

Table 20 Key indices for back-casting and forecasting

Indices	Uses	Historical							Forecast		
		2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19*	2019-20	2020-21	2021-22
CPI Sydney (Index) (Year average)	Congestion cost; operating & maintenance cost; infrastructure cost; environmental externality costs; active transport costs; road maintenance cost; disability costs	102.58	105.23	107.25	108.88	111.08	113.35	115.23	117.82	120.76	123.78
CPI Private Motoring (Index)	Light VOC	100.60	102.33	98.65	97.23	97.23	100.00	102.33	104.63	107.24	109.92
CPI Maintenance & Repair (Index)	Vehicle costs	104.28	103.00	101.43	104.55	105.43	106.55	108.70	111.15	113.92	116.77
CPI Motor vehicles (Index)	Vehicle price	98.53	95.55	95.68	97.20	95.15	93.48	93.65	95.76	98.15	100.60
AWE NSW ($)	Value of travel time; labour costs; option value	1,403.35	1,440.05	1,502.20	1,534.15	1,540.80	1,585.90	1,614.10	1,658.49	1,708.24	1,763.76
PPI road freight	Value of freight travel time; heavy VOC	104.23	106.28	107.20	105.45	106.53	108.60	111.60	114.11	116.96	119.89
Fuel cost excl. GST (Cent/L) - petrol	Unleaded petrol fuel cost	83.00	90.56	75.71	61.76	60.25	68.74	75.92	77.63	79.57	81.56
Fuel cost excl. GST (Cent/L) - diesel	Diesel fuel cost	85.44	93.99	76.23	57.26	58.68	69.02	82.61	84.47	86.58	88.75

Sources: Estimated by Evaluation & Assurance, TfNSW. Notes on data sources and forecasting methodology provided below: (1) ABS 6401.0 All Groups CPI Sydney. CPI forecast from 2017/18 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: * 2018-19 data escalated to June 2019.