TRANSPORT AND INFRASTRUCTURE COUNCIL

Australian Transport Assessment and Planning Guidelines

PV5: Environmental Parameter Values

Environmental parameter values based on Australian data – scoping study

Public consultation draft

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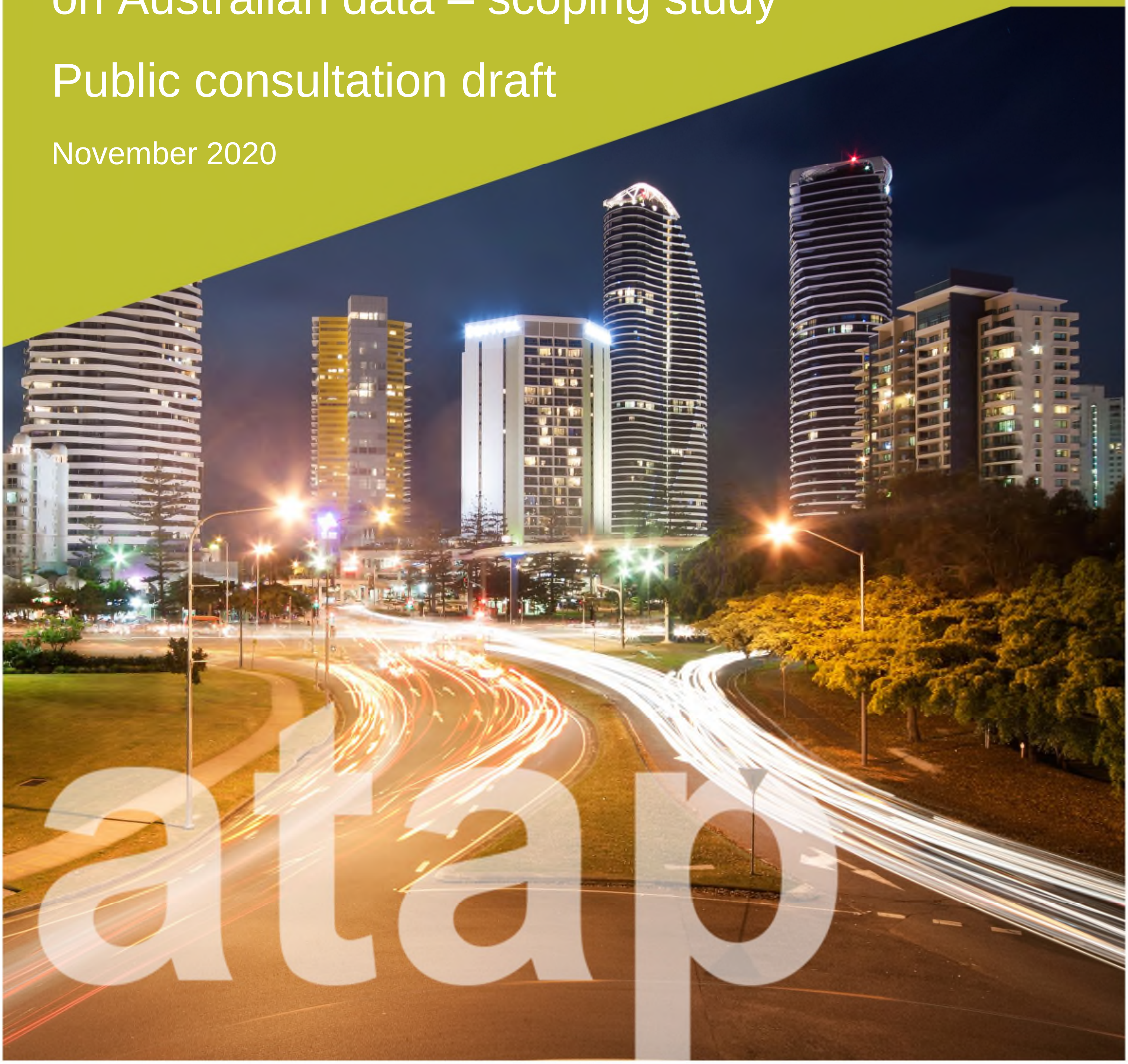

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At a glance

- Environmental parameters values (PV5) published by the Australian Transport Assessment and Planning Guidelines are an important reference for facilitating a consistent approach towards quantifying the environmental cost of transport projects and initiative in Australia
- Current values in PV5 are adapted from European studies and the validity of this approach has been questioned by transport researchers and stakeholders from state and territory transport departments.
- To address this concern, the ATAP steering committee has envisaged a three-phase process for developing Australian-based environmental parameter values.
- As the first phase of this process, this scoping study aims to:
  - identify the preferred methodology for developing Australian-based environmental parameter values,
  - establish the availability of Australian data sources to implement the preferred methodologies, and
  - estimate the data collection costs for bridging the identified gaps in Australian data sources.
- The scope of this study covers eight impact categories: air pollution, greenhouse gas (GHG) emissions, noise pollution, soil and water pollution, biodiversity, nature and landscape, urban barrier effects, upstream and downstream costs.
- The relevant approaches presented in the European Commission’s *Handbook of External Costs of Transport* have been identified as the preferred methodologies for implementation with Australian data.
- Based on the preferred methodologies, the availability of Australian-based data for cost factors and environmental impact of transport are investigated.
- For cost factors, complete data gaps exist in the crop and building damage cost due to air pollution, health cost due to noise pollution, cost of water pollution, and the damage cost of biodiversity loss due to air pollution. Significant data gap is found in the loss and fragmentation of habitat cost due to nature and landscape impacts. Partial data gaps are found in all other cost factors.
- For data that measures the environmental impact of transport, complete gaps are found in Australian data that prevent quantifying the noise impact and the upstream and downstream impacts of all transport modes. Partial data gaps are found in six other impact categories. However, the partial data gaps typically only limit the ability to develop environmental parameter values for specific vehicle classes.
- Estimated costs for data collection tasks depend on whether it is appropriate to utilise existing data from other jurisdictions.
- For bridging major gaps in cost factor data, the cost to commission an Australian study is estimated to range from $100,000 to $200,000. For data gaps that have been deemed acceptable for utilising existing overseas data, data collection based on a value-transfer approach is estimated to cost between $10,000 to $50,000.
- For bridging gaps in environmental impact data, a value-transfer approach is estimated to cost between $0 to $50,000 depending on the cost to purchase overseas data. On the other hand, the cost for collecting local data is estimated to be between $20,000 to $100,000 per data gap depending on the complexity of the data collection task.

1. Introduction

1.1 Role of environmental parameter values

Environmental impacts such as air pollution, greenhouse gas (GHG) emissions and noise pollution and biodiversity loss, are by-products of land transport activities that can harm the wellbeing of the society and the quality of natural environment. Consequently, these impacts (or externalities) should be accounted for when undertaking economic appraisals, such as cost-benefit analysis (CBA), of transport projects or policies.

Transport-related environmental impacts are not direct costs to individuals or businesses but are borne by broader communities, ecosystems and across borders. Costs accrue to either prevent damage by mitigating the impact (avoidance cost approach), or costs caused by the damage such as health costs (damage costs approach) (Austroads 2014).

Due to the lack of explicit market prices, monetising the environmental impacts of transport activities for the purpose of economic appraisals is a challenging task and outcomes vary depending on the assumptions made by individual economic appraisal practitioners.

Environmental parameters values (PV5) published by the Australian Transport Assessment and Planning Guidelines (the Guidelines) are monetised values for a suite of environmental impacts that should be assigned to a unit of transport activities. The PV5 provides a consistent set of inputs for economic appraisals of transport projects and initiatives thereby facilitating a consistent approach for economic appraisals following the ATAP framework.

1.2 Purpose of the scoping study

The purpose of the scoping study is to provide the ATAP Steering Committee (SC) with evidence-based advice on the expected scope of works needed and indicative costs to develop environmental parameter values based on Australian-specific data.

Specifically, a primary task of the future work is the data collection tasks for bridging gaps that currently exist in the Australian data landscape. The primary objectives of the scoping study include the identification of these gaps and cost estimation for undertaking the corresponding data collection tasks.

1.3 Background

Current environmental parameter values used in Australia are established using a *value-transfer* approach that adapts environmental parameter values estimated in European studies with adjustments made to accommodate the Australian context.

Although the value-transfer approach is valid, it is expected that a *direct-valuation* approach that utilises Australian transport and environmental data will generate a more accurate set of PV5 that are closer to their true values in Australia. In turn, Australian-based environmental parameter values are expected to enable more reliable cost-benefit analysis results that will lead to more robust decision-making in the assessment of transport projects.

A key challenge to implementing the direct-valuation approach is the availability, or the lack thereof, of necessary Australian data which are the building blocks for calculating the PV5. To overcome this challenge, the ATAP steering committee has envisaged a three-phase process that will ultimately see such data gaps being bridged with data collection efforts.

To initialise the three-phase process, Australian Road Research Board (ARRB), working in collaboration with Marsden Jacobs Associates (MJA), has been engaged by Austroads, on behalf of the ATAP Steering Committee, to prepare a scoping study that establishes an understanding in terms of required data types and the availability of these data in Australia.

Importantly, findings from this scoping study are expected to inform the set the of environmental parameter values to be developed using existing Australian data in phase 2 and guide the data collection efforts in phase 3.

2. Scope

2.1 Scope of works

Tasks to be undertaken in this scoping study include:

- Establishing a preferred methodology with which environmental parameter values can be developed based on Australian data
- For each environmental parameter, establishing the data requirement based on the preferred methodology, and identify existing Australia data sources that can fully or partially satisfy them
- Identifying any data gaps that prevent immediate adoption of the preferred methodology
- Provide indicative costs of data collection efforts to bridge the data gaps identified
- At an aggregated level, provide an estimation on the scale of difference between current environmental parameter values from and their counterparts developed using Australian data.

2.2 Coverage of environmental parameter values

The environmental parameter values currently presented in ATAP PV5 are disaggregated by impact category, transport mode, vehicle size, location, and fuel type. Disaggregation of parameter values enables practitioners to choose the parameter value that best reflects the specifics of the underlying transport activity. However, disaggregation of parameter values requires corresponding disaggregation in the supporting data needed to calculate them.

To this end, this scoping study provides visibility on data availability for calculating environmental parameter values at both the aggregated and disaggregated levels. Table 2-1 provides the subcategories within each dimension of parameter disaggregation.

Table 2-1 Disaggregation of environmental parameter values

Impact categories	Transport modes (*m*)	Vehicle sizes (*s*)	Locations (*u*)	Fuel types (*f*)
• Air pollution • Greenhouse gas emissions • Noise pollution • Soil and water pollution • Biodiversity • Nature and landscape • Additional costs in urban areas (barrier effect) • Upstream and downstream costs	• Cars • Buses and coaches • Motorcycles, scooters and e-bikes • Passenger rail • Freight rail • Freight road	• Small • Medium • Large • Other applicable classifications	• Urban • Rural	• Petrol • Diesel • Gas • Electric • Renewable • Other energy type

2.3 Exclusions

As the first phase of the proposed three-phase approach to develop Australian-based environmental parameter values, the scoping study does not undertake tasks reserved for the later phases, which include:

- estimating the scale of difference between European-based and Australian-based environmental parameter values at the disaggregated level (Phase 2),
- developing any environmental parameter values (Phases 2 and 3),
- developing detailed data collection methodologies (Phase 3), and
- undertaking data collection task for the data gaps identified (Phase 3).

As shown in Table 2-1, this scoping study focuses on land-based transport modes. Consequently, environmental parameter values for aerial and water-based transport modes are beyond the scope of this study.

In addition, other dimensions for disaggregating environmental parameter values beyond those listed in Table 2-1 are also out-of-scope for this scoping study. An important exclusion here is the traffic condition which is necessary for calculating marginal environmental costs of transport. This point is discussed in more detail in Section 3.5.

2.4 Approach

Table 2-2 provides a brief description on our approach for each task included in the scope of works for this scoping study.

Table 2-2 Approach for tasks in the scope of works

Tasks	Approach
Identify preferred methodology	• Review current methodology and establish the need for an alternative methodology for Australian-based environmental parameter values • Undertake an updated literature review to identify new methodologies that became available after the publication of Studies (2014) • Establish assessment criteria for the preferred methodology based on impact coverage, methodological transparency, reputation of publisher and the time of publication • Apply the four assessment criteria to identify the preferred methodology for calculating environmental parameter values as average environmental cost
Establish data requirement	• Identify the input data required to implement the preferred methodology • For each required input data, use a ‘traffic-light’ system to indicate the appropriateness of fulfilling them with data from another jurisdiction (e.g. Europe) • Provide a short discussion around the difference between parameter values based on average environmental cost and marginal environmental cost of transport activities. This will include an explanation on how practitioners might use them, and the circumstances under which they may differ

Identify gaps in Australian data	• Use data references in the preferred methodology to identify counterpart data sources in Australia • Undertake a data availability investigation based on both public and proprietary sources • Present the outcome of the data investigation in a data availability matrix which identifies the sources and the quality of available Australian data • Report and provide details on any data gaps identified
Provide indicative cost for data collection	• Provide a recommended approach for bridging the data gaps identified • Provide an indicative cost for bridging the data gaps based on the recommended approach • Indicative cost to be based on ARRB-MJA's estimates if the data collection task can be undertaken by ARRB-MJA • For data collection tasks that are beyond the capability of ARRB-MJA, the data collection cost will be based on quotes from a suitably qualified organisation contacted by ARRB-MJA
Estimate scale of difference between European-based and Australian-based parameter values	• Describe the known differences in the main environmental cost drivers between Europe and Australia • Describe the direction and a minimum scale of difference for each impact category.

3. Identification of preferred methodologies

3.1 Overview of current methodology

The extent to which environmental parameter values can be based on Australian data depends largely on the method adopted for deriving them. The concern that current values, as they are published in Austroads (2003), Austroads (2012) and Austroads (2014), do not closely reflect Australian conditions can be attributed to the fact that they are generated using a value-transfer approach: adapting the final headline parameter values from overseas studies for use in Australia.

Specifically, the environmental parameter values presented in Austroads (2003) and Austroads (2012) were based on European parameter values reported in INFRAS & IWW (2000) and European Commission (1999) and indexed to the year of publication, and Austroads (2014) was based on CE Delft et al. (2011). In 2020, ATAP published an interim update of environmental parameter values which indexed values from both Austroads (2012) and Austroads (2014) relying on the same underlying European data.

The Australian context is unique and differs in many ways from the European context. Specifically, these differences include, and not limited to, lower population density, lower vehicle emission standards and higher conservational value in Australia than European Union countries. These differences mean that European environmental parameter values are likely to be either too high or too low to be used directly for the purpose of evaluating the impact of transport activities in Australia. For example, lower population density implies that the parameter value of air pollution may be lower in Australia while the higher conservational value implies the opposite for biodiversity parameter value. An in-depth examination of these differences and how they contribute towards the differences in environmental parameter values between Europe and Australia is provided in section 9.

The validity of the value-transfer method therefore rests on the assumption that the adjustments applied to European parameter values are appropriate and adequate to account for these difference between the two continents. Furthermore, because the parameter values in the European source reports are based on European vehicle emissions and environmental cost valuations, adopting the value-transfer approach means that critical local data on the level and cost of environmental impacts from transport activities play little to no role in determining the environmental parameter values for Australia.

It has been suggested that some practitioners have questioned the validity of this assumption and the continuing reliance on European-based data sets for Australian environmental parameter values. This concern can be addressed by applying a methodology for determining parameter values that utilises Australian vehicle emission data and environmental cost factor data as direct inputs. Specifically, for each environmental impact category listed in Table 2-1, the methodology should describe the responsible pollutants emitted from transport activities, the salient economic valuation of these pollutants and how they are logically related to the environmental parameter values.

Such a methodology can be developed either through first principles or as adaptations from established methodologies found in other jurisdictions. Using the European methodologies on which current Australian parameter values are based on coupled with Australian-specific input data is both logical and efficient. This approach also provides a consistent methodology between current and future Australian parameter values. Having a consistent methodological basis means that fundamental drivers of any changes in environmental parameter value outputs will be more easily explained and understood by users.

3.2 Literature review for candidate methodologies

Austroads (2014) concluded that parameter values published in the Handbook of External Cost Transport (CE Delft et al. 2011) should be the basis for updating ATAP PV5 values. This conclusion was the result of an extensive literature review and a comprehensive assessment based on six criteria. As noted by Austroads (2014), the methodology in CE Delft et al. (2011) was a leader among other methodologies reviewed in terms of transparency, in addition to the range of environmental impacts assessed. Transparency refers to the level of detail in the description of methodology in terms of input data required to implement the methodology and the logical dependencies between input data and the environmental parameter value of interest. The transparent methodologies in CE Delft et al. (2011) ensure that they can be replicated with Australian data for developing Australian-based environmental parameter values.

The methodologies for CE Delft et al. (2011) therefore represents a possible preferred methodology in the context of this scoping study. To ensure that any methodology adopted for Australia is also consistent with the latest research, the Consultants also reviewed relevant research papers and government guidelines that have become available since June 2013, i.e. since the Austroads (2014) assessment was conducted.

Two criteria are applied to the literature search:

1. the publication must quantify the environmental cost of transport that corresponds to at least one of the impact categories listed in the first column of Table 2-1, and
2. it must be published after June 2013 to account for the fact that CE Delft et al. (2011) has been established by Austroads (2014) as the preferred methodology among methodologies published prior.

Five publications have been identified that satisfy these two criteria and they are:

- Ricardo-AEA (2014)
- Litman and Doherty (2016)
- Gössling S. et al. (2019)
- CE Delft et al. (2019) and
- NZTA (2020).

Ricardo-AEA (2014) and CE Delft et al. (2019) were sponsored by the European Commission and represent updates to CE Delft et al. (2011). The updates are in terms of input data and methodologies for monetising the cost of specific environmental pollutions. Litman and Doherty (2016) is a guidebook for the valuation of various environmental impacts of transport published by the Victoria Transport Policy Institute – an independent Canadian think tank. Gössling S. et al. (2019) is a published research paper that provided various environmental parameter values for cycling and walking in addition to passenger cars. Finally, NZTA (2020) is published by the New Zealand government and provides guidance on monetising various environmental impacts of transport projects.

3.3 Assessment criteria for the preferred methodology

To assess the relative suitability for developing Australian environmental parameter values of the six candidate methodologies including CE Delft et al. (2011), we re-apply two of the criteria in Austroads (2014) and one additional criterion[1]. The two criteria from Austroads (2014) are:

1. Impact coverage
2. Methodological transparency

One additional criterion:

1. Time of publication

3.3.1 Impact coverage

Impact coverage refers the types of environmental impacts of transport whose methodologies for their quantification are discussed in the reviewed publications. As the first of the three assessment criteria, this criterion is designed to identify if new methodologies may have become available for any of the eight impact categories listed in Table 2-1.

Of the six documents reviewed, CE Delft et al. (2011) has the most complete coverage – covering all eight impact categories. Other documents have coverage gaps in at least one of the impact categories. An overview of coverage by the six studies are presented in Table 3-1.

Table 3-1 Impact coverage of reviewed documents

	CE Delft et al. (2011)	Ricardo-AEA (2014)	Litman and Doherty (2016)	Gössling S. et al. (2019)	CE Delft et al. (2019)	NZTA (2020)
Air pollution	✓	✓	✓	✓	✓	✓
GHG emissions	✓	✓	×	✓	✓	✓
Noise pollution	✓	✓	✓	✓	✓	✓
Soil and water pollution	✓	×	×	✓	×	×
Biodiversity	✓	×	×	×	✓	×
Nature and landscape	✓	✓	×	×	✓	×
Urban barrier effect	✓	×	✓	✓	×	×
Upstream and downstream costs	✓	✓	×	×	✓	×

[1] The other four criteria in Austroads (2014) are designed for the evaluation of the value-transfer approach and hence unsuitable for assessing methodologies in the context of this scoping study.

3.3.2 Transparency

Transparency refers to the level of detail in the description of methodologies. Methodologies can only be applied if the relationship between its input data and outputs is clearly understood.

Of the six publications reviewed, only CE Delft et al. (2011), Ricardo-AEA (2014) and CE Delft et al. (2019) provided sufficiently clear description in their methodologies for the impacts they covered. These details include the type of input data required and how to use them to calculate the specific environmental costs of transport.

The other three documents do not provide comparable level of details in their methodologies. Specifically, cost values in Litman and Doherty (2016) are collated from various other studies that have been previously assessed in Austroads (2014). Gössling S. et al. (2019) provided original cost estimates for walking and cycling but also does not detail the methodology for deriving them. Finally, NZTA (2020) focuses on the methodology for monetising the cost of environmental pollution – an important input for calculating the environmental parameter values – but does not explain how they are assigned to transport activity.

Consequently, we will focus on methodologies found in CE Delft et al. (2011), Ricardo-AEA (2014) and CE Delft et al. (2019).

3.3.3 Time of publication

Time of publication refers to the year in which the document was published. It matters because Ricardo-AEA (2014) and CE Delft et al. (2019) are sequential updates to the cost values published in CE Delft et al. (2011). This means that methodologies in Ricardo-AEA (2014) and CE Delft et al. (2019) have updated their methodologies by incorporating newer scientific evidence. For impact categories covered in all three documents, preference is therefore given to methodologies published in more recent years.

3.4 Assessment outcome for the preferred methodologies

Based on these three criteria, CE Delft et al. (2019) represent the preferred methodology for six of the eight environmental impact categories, while CE Delft et al. (2011) presents the preferred methodology for two remaining impact categories (noting that these were not updated in 2019). Table 3-2 presents the results of our assessment for the preferred methodology for each of the impact categories.

Table 3-2 Preferred methodologies by impact category

Impact category	Source of preferred methodology
Air pollution	CE Delft et al. (2019)
GHG emissions	CE Delft et al. (2019)
Noise pollution	CE Delft et al. (2019)
Soil and water pollution	CE Delft et al. (2011)
Biodiversity	CE Delft et al. (2019)
Nature and landscape	CE Delft et al. (2019)
Urban barrier effect	CE Delft et al. (2011)
Upstream and downstream costs	CE Delft et al. (2019)

3.5 Total, average and marginal external cost of transport

For some environmental impacts, CE Delft et al. (2011) and CE Delft et al. (2019) provided separate values for their average external cost and marginal external cost. This section provides a short discussion that distinguishes the various external cost measures of transport.

- Total external costs refer to total value arising from a specific type of transport externality (e.g. air pollution) within a geographical boundary (e.g. Australia). The total external costs are measured in dollars.
- Average external costs are closely related to total cost, as they are the average value of transport external costs per unit of transport activity. Measures of transport activities include vehicle-kilometres-travelled (vkt) for all transport modes, passenger-kilometres (pkm) for passenger transport modes, or tonne-kilometres (tkm) for freight transport modes. Units of average external cost of transport are therefore in dollars or cents per vkt for all transport modes, pkm for passenger transport modes and tkm for freight transport modes. Average external cost is also the basis for environmental parameter values developed in Austroads (2003), Austroads (2012) and Austroads (2014).
- Marginal external costs of transport are the changes in total external costs due to an additional transport activity being added to the traffic. They are measured in the same unit as average external costs. The size of marginal costs therefore, however, may depend on the traffic condition. Marginal external costs also be further classified as short run and long run marginal costs. Their definitions are reproduced from Austroads (2003):
  - Short run marginal external costs measure the increase in total external costs from an additional vehicle entering the system without considering the fixed costs for running the system or additional costs for network extension. Their estimation covers only variable costs of operation.
  - Long run marginal costs also cover costs of system variations (e.g. enlargement of the network), since in the long run infrastructure costs are also to be considered as variable. An example for long run marginal external costs are external costs related to nature and landscape, which are considered as fixed in the short run.

According to CE Delft et al. (2019), except for noise pollution, average and marginal external costs are approximately equal for all other externalities considered in this scoping study. This is because the intensity of their impact does not depend on the density of the traffic flow. For example, a car entering a dense traffic flow emits the same amount of air pollution as a car entering a thin traffic flow, assuming all other factors are equal (location, speed, etc.).

However, for noise pollution, traffic density matters. The additional noise emitted from a car entering into a quiet street with little traffic is much more discernible, and subsequently considered more costly, to the surrounding residents than a car entering busy street already filled with traffic noise. The marginal noise cost under light traffic conditions is expected to be higher than its average cost and vis a vis for heavy traffic conditions, the marginal noise cost will be lower.

Whether average or marginal noise cost is preferred for assessing the external cost transport projects depends on actual scope of the project. For new greenfield projects such as a new road, average cost is best suited since there is no existing traffic. On the other hand, cost-benefit analysis for road upgrades or expansions it is recommended to use the marginal cost as it accounts for the existing traffic condition.

Because marginal environmental costs are essentially average environmental costs that are further differentiated by traffic condition, they can therefore be developed following the same methodology but based on disaggregated data by traffic condition. Using the noise pollution as an example, heath cost of noise in quiet and loud environments are needed to calculate the marginal costs of transport noise in low- and high-traffic conditions, respectively. Data investigation undertaken in this scoping study focuses the availability of Australian data according to the dimensions listed in Table 2-1 and therefore does not consider traffic condition.

4. Review of methods for valuing environmental cost factors

4.1 Overview of methods

The environmental cost factors (referred to as cost factors hereafter) considered in this scoping study all seek to establish the monetary economic value the positive and / or negative impacts of transport projects have on the provision of non-market goods and services over the lifetime of the project.

4.1.1 The concept of economic value

In simple terms, the economic value of a good or service is measured by what people are willing to pay to have the good or service provided, or equivalently, how much people would need to be compensated in money to forego a good or service being provided (Baker 2014).

When undertaking non-market valuation, it is important to understand that economic values and financial values are not the same thing. Economic studies often use financial values where economic values should be used. Using a cup of coffee analogy is useful here:

- The economic value of the cup of coffee is the maximum amount that I would be willing to pay to get the cup of coffee.
- The financial value is the price I pay for the cup of coffee.

For non-market valuation, economic values are the preferred values, not financial values.

Another important point when comparing market and non-market values, we need to make sure we are assessing the values on a like with like valuation basis. This means understanding whether non-market economic values are at-source or at-site, long-term or short term, total, marginal, or average values, and capitalised or per period values.

4.1.2 Valuation methods

In the last 30 years a significant body of research has been undertaken into the question of how to value non-market goods and services. Numerous different methods have emerged to establish the monetary value of these cost factors. The CE Delft studies (2008, 2011, 2019), upon which the Austroads environmental parameter values have been based until now, refer to three overarching approaches to valuing non-market goods and services discussed further in Box 1:

1. damage cost;
2. avoidance (or abatement) cost; and
3. replacement (or repair) cost.

There are a number of specific and widely used methods for valuing non-market goods and services beyond the damage, abatement and replacement cost approaches. These methods are robust provided they are correctly designed and appropriately applied (Baker 2014). These specific and widely used methods fall into two broad categories:

- Revealed preference methods – in this approach observed behaviour is used to impute the dollar value that people place on environmental goods and services. Methods include:

  - Hedonic pricing
  - Travel cost
  - Production functions
  - Averting behaviour
- State preference methods – in this approach surveys are used to estimate how much money people would be willing to pay (WTP) to obtain or prevent loss of an environmental good or service. Methods include:
  - Choice modelling
  - Contingent valuation
  - Contingent behaviour

For purpose of consistency with previous studies and valuations as applied by Austroads (e.g. Austroads 2014), this review focusses on the overarching approaches discussed in those studies and contrasts them with value transfer approaches (drawing on European values) that are currently applied to assessing values for the environmental parameters.

Box 1. Overarching approaches to valuing non-market goods and services

Damage cost

This approach values damages to environmental and social goods and services resulting from an externality (e.g. the health impacts of air pollution). Where the damage experienced cannot be estimated directly through market prices, survey based 'stated preference' methods such as contingent valuation or choice modelling can be used to assess the willingness to pay (WTP) of individuals to avoid the damage. Loss of life associated with air pollution, for example, is typically valued using the concept of a 'value of a statistical life' (VSL). This value is, in turn, measured by estimating how much society is willing to pay to reduce the loss of life (OBPR 2019). 'Revealed preference' methods, such as hedonic pricing, can also be used as a proxy for damage costs (e.g. noise).

Avoidance/ abatement cost

The avoidance cost approach values an adverse environmental impact by estimating the financial cost of avoiding or abating an activity that leads to the adverse impact. In the case of emissions (e.g. greenhouse gas emissions), this is typically done by estimating an avoidance cost function, which provides a proxy for the supply of a preferred emissions outcome (such as an emissions target). Based on this cost function (usually shown as an abatement cost curve), the cost of meeting a preferred outcome can then be estimated. The assumption is that the target reduction level reflects collective preferences with respect to the activity. It is important to note that avoidance cost will generally be a lower bound cost because it reflects the financial cost of avoidance, not the economic value of the benefit of avoidance. The US EPA (2014), for example, provides clear guidance on why the approach is therefore flawed.

Replacement cost

The replacement cost approach estimates the value of an externality based on the financial costs of replacing or repairing the adverse impacts caused by the externality. This approach is often used to value external costs for which estimating damage or avoidance costs are not feasible. This approach may result in an overestimate of costs when it is not economically efficient to repair all damage. On the other hand, the approach will underestimate the economic cost of an impact if it is not possible to replace or repair all damage. As with avoidance cost, the US EPA (2014), for example, makes clear that this approach is flawed because it provides a measure of financial cost, not the economic value of the benefit of avoidance.

A note on value transfer

In an ideal world, environmental values would be estimated for each proposed project, taking into account all of the particular details of the specific policy. However, the use of primary research to estimate environmental values can be costly and time consuming, and in real world policy processes the time and money required often is not available. The value transfer method is used to estimate values for environmental or social outcomes by transferring available information from studies already completed in another location and/or context. For example, the value for an environmental outcome in Australia is estimated by applying an estimate of the value for the same or similar outcome in another country. There are different approaches involving different levels of complexity to undertaking a value transfer procedure. The simplest, but generally least robust approach involves transferring the primary unit value data from the original location directly to the new location, perhaps with some minor adjustments for income differences or exchange rates. More sophisticated approaches involve estimating a function that establishes the relationship between the unit value and the characteristics at the original location to predict the values at another location. Even when more sophisticated adjustments are made, there will often some uncertainty around the value derived through value transfer, especially when the procedure involves transferring a value from another country or region to Australia.

4.2 Assessment of approaches

Suitability of the approaches described above have been assessed against each of the environmental parameter cost factors. Not all approaches were assessed for all parameters and cost factors - a review of literature was used to select the approaches that are most frequently applied to assessing each of the cost factors. The selected approaches were then assessed against four criteria for each cost factor:

Robust. Will the approach provide a reliable estimate of the economic value of the non-market good or service? In the case of the value transfer approach currently applied, is the European source study or studies based on similar characteristics in terms of impacted sites or exposed populations?

- **Feasible**. Is the approach feasible to apply in the Australian context given data requirements?
- **Transparent**. Will application of the approach provide a clear understanding of how the value was derived?
- **Proportionate**. Are the time and resources required to apply this approach proportionate to the likely scale of impact it is valuing?

Results of the assessment are presented in Table 4-1. It is worth noting the following key points from the assessment:

- **Value transfer, based on European values, is the approach applied to assessing all cost factors in the most recent valuation study** (Austroads 2014). This is not the preferred approach for any of the cost factors. This is primarily because the value transfer method based on European values is not robust or, at best, has questionable robustness. Use of the value transfer method also lacks transparency. Although the methods used to derive the respective estimates are provided at a general level, specific information on how the European estimates have been derived is lacking, even in the source studies, with the key uncertainty typically being how gaps in exposure data were addressed[2].

  We note that value transfer based on Australian studies may be appropriate for future valuations. This is discussed further in subsequent sections.

- **For two of the cost factors – impacts of air pollution on buildings and crops and impacts of air pollution on biodiversity – no preferred approach has been identified**. The damage cost approach (impact pathways) is the underlying approach that has been applied in European studies to assessing the costs of air pollution on crops, buildings and biodiversity. There is significant doubt about the feasibility and proportionately of applying the impact pathways approach to estimating these cost factors however, because the impacts they are valuing are likely to be very location specific and because in many circumstances they are likely to be immaterial given low concentrations in rural areas. On the other hand, there is significant doubt as to whether the European values upon which the current values are based, will provide a reasonable reflection of the impacts of air pollution on crops, buildings and biodiversity in Australia.
- **On balance, it may be appropriate to continue to apply value transfer drawing on values** provided in Delft 2019, ensuring appropriate adjustments are made to reflect the Australian context.

[2] For example, the impact pathway method used to derive health cost estimates is well established. Application of this method to derive health cost estimates for countries and cities across European countries and cities is less clear, however. Lack of exposure data for many countries meant that data from a small number of country studies was used to extrapolate to the other European countries (see Preiss & Klotz 2008). This process is not fully explained. Use of information on exposure of buildings, crops and biodiversity to derive air pollution damage cost estimates for these variables is even less clear. Extrapolation to address data gaps is also applied to derive values for other environmental parameters.

Table 4-1: Alternative approaches to estimating cost factors for environmental parameters - 'traffic light' assessment

Parameter and cost factor/ approach	Assessment criteria				Preferred	Comment
	Robust	Feasible	Transparent	Proportionate		
Air pollution						
Health impacts						Austroads currently uses value transfer drawing on EU valuations. Damage cost approach (impact-pathway) is the most robust approach and should be applied in the Australian context, although unlikely to be proportionate for non-urban areas.
Value transfer (EU)	🟡	🟢	🟡	🟢		
Damage cost (VSL [WTP] & direct costs of morbidity)	🟢	🟢	🟢	🟡	√	
Abatement cost (cost of emission reductions)	🟡	🟢	🟡	🟢		
Impacts on buildings and crops					No preferred approach	Austroads currently uses value transfer. Underlying method applied in EU valuations uses impact-pathway approach to assess damage costs. This is the most robust approach, but it is doubtful that it is feasible or proportionate to apply in the Australian context.
Value transfer (EU)	🔴	🟢	🔴	🟢		
Damage cost (direct costs)	🟢	🔴	🟢	🟡		
Abatement cost (cost of emission reductions)	🟡	🟡	🟡	🟡		
Greenhouse gas emissions						Austroads currently uses value transfer based on EU valuations that apply avoidance cost. Damage cost could be a more robust approach, but it is unlikely to be feasible to apply.
Value transfer (EU)	🟡	🟢	🟡	🟢		
Damage cost (social cost)	🟢	🟡	🟡	🟡		
Abatement cost (cost of emission reductions)	🟡	🟢	🟢	🟢	√	
Noise pollution						Austroads currently uses value transfer based on a combination of WTP to avoid annoyance and direct cost of health effects from EU valuations. A more feasible approach, focussing on urban areas, is hedonic pricing as a proxy for the amenity costs of noise.
Value transfer (EU)	🟡	🟢	🟡	🟢		
Damage cost (WTP & direct cost of health effects)	🟢	🟡	🟡	🟡		
Damage cost (hedonic pricing)	🟢	🟢	🟡	🟡	√	
Soil and Water pollution						Austroads currently uses value transfer based on avoidance/repair cost applications in EU valuations. WTP using a stated preference technique is likely to provide a more reliable estimate of the economic value of avoided water pollution. Repair cost is appropriate for soil pollution.
Value transfer (EU)	🔴	🟢	🟡	🟢		
WTP (stated reference)	🟢	🟢	🟢	🟡	√	
Repair cost	🟡	🟢	🟢	🟡	√	
Biodiversity *(air pollution)*						

Value transfer (EU)	🔴	🟢	🔴	🟢	No preferred approach	Austroads currently uses value transfer. As with health impacts, damage cost is the most robust approach and is used in EU valuations. There is doubt as to whether the approach is feasible in the Australian context, however.
Damage cost (direct costs)	🟢	🔴	🟢	🟡		
Abatement cost (cost of emission reductions)	🔴	🟢	🟡	🟢		
Nature and landscape *(habitat loss, open space loss)*						Austroads currently uses value transfer, based on repair/replacement cost approach used in EU valuations. Both the method and source data mean that derived estimates are likely to significantly understate the economic value of these areas in some circumstances. WTP for these areas using a stated preference method is likely to provide a more robust value for habitat loss and fragmentation. Hedonic pricing will provide a robust method for loss of open space in urban areas.
Value transfer (EU)	🔴	🟢	🔴	🟢		
WTP (stated preference)	🟢	🟢	🟢	🟡	√	
WTP (hedonic pricing)	🟢	🟢	🟢	🟡	√	
Repair/replacement cost	🟡	🟡	🟢	🟢		
Barrier effects						Austroads currently uses value transfer, based on cost of travel time as an avoidance cost used in EU valuations. This is an appropriate approach in the Australian context
Value transfer (EU)	🟡	🟢	🟡	🟢		
Avoidance cost (cost of time)	🟢	🟢	🟢	🟡	√	
Upstream costs						Austroads currently uses value transfer, based on EU valuations using damage cost. As per main air pollution section, damage cost approach is preferred.
Air pollution						
Value transfer	🟡	🟢	🟡	🟢		
Damage cost (VSL [WTP] & direct costs of morbidity)	🟢	🟢	🟢	🟡	√	
Abatement cost (cost of emission reductions)	🟡	🟢	🟡	🟢		
Greenhouse gas emissions						Austroads currently uses value transfer, based on EU valuations using avoidance cost. As per main air pollution section, avoidance cost approach is preferred.
Value transfer	🟡	🟢	🟡	🟢		
Damage cost (social cost)	🟢	🟡	🟡	🟡		
Abatement cost (cost of emission reductions)	🟡	🟢	🟢	🟢	√	

Key: 🟢 yes 🟡 Maybe 🔴 no

5. Data requirements based on preferred methodologies

5.1 Air pollution

Air pollution has a wide range of harmful effects on the health of humans, flora and fauna, the natural environment and infrastructure. For air pollution produced by transport movements, CE Delft et al. (2019) has identified its effect on human health as the primary impact that need to be quantified for its environmental cost. Transport related air pollutants that damage human health are particulate matters (PM_{10}, $PM_{2.5}$) and nitrogen oxides (NO_X). Inhalation of these substances can lead to a higher risk of respiratory and cardiovascular disease.

CE Delft et al. (2019) also includes crop losses, material and building damage, and biodiversity loss as secondary impacts due to air pollution from transport activities. However, biodiversity loss due to transport activities is considered as a stand-alone impact category in this scoping study, as stipulated by the project brief.

For crop losses – damage to agricultural crops in terms of yield loss from air pollution, emissions of NO_X, volatile organic matters (VOC) and sulphur dioxide (SO_2) from transport activities are potentially responsible. For material and building damages – building surface damage from particles and building surfaced damage from corrosion from NO_X and SO_2.

To implement the CE Delft et al. (2019) methodology for air pollution parameter values using Australian data, two types of input data are required: emissions factors and cost factors.

- **Emissions factors** – the quantity of air pollutants emitted from one unit of vehicle-kilometre-travelled (in g/vkt), including:
  - $PM_{2.5}$ and PM_{10}
  - NO_X
  - VOC
  - SO_2
- **Cost factors** – the economic cost attributed to impacts from one unit of culpable pollution (in $/tonne or c/tonne), including:
  - Health costs from a unit emission of $PM_{2.5}$ and PM_{10} and NO_X
  - Crop losses costs from a unit emission of NO_X, VOC and SO_2
  - Building and surface costs from a unit emission of $PM_{2.5}$, PM_{10}, and NO_X and SO_2.

Disaggregated parameter values are calculated by the dimensions listed in Table 2-1. Emission factors for each air pollutant will vary by transport mode, vehicle size, fuel type and location[3] as the intensity of polluting emissions are dependent on these factors. Cost factors are expected to vary by location as they are potentially dependent on the density of population, building value and land use of the area, but independent of the emission source.

Air pollution parameter values for a specific transport mode, vehicle size, fuel type and location can be calculated by multiplying the corresponding emission factor with the corresponding cost factors under each of the three impacts and then summing up their products.

The formula to calculate Australian-based air pollution parameter value (V_{msfu}^{Air}) for transport mode m, size s, fuel type f in location u can be represented as

$$V_{msfu}^{Air} = \underbrace{\left(HC_u^{PM_{2.5}} \times E_{msfu}^{PM_{2.5}} + HC_u^{PM_{10}} \times E_{msfu}^{PM_{10}} + HC_u^{NO_X} \times E_{msfu}^{NO_X}\right)}_{Health\ cost} + \underbrace{\left(CLC_u^{NO_X} \times E_{msfu}^{NO_X} + CLC_u^{VOC} \times E_{msfu}^{VOC} + CLC_u^{SO_2} \times E_{msfu}^{SO_2}\right)}_{Crop\ losses\ cost} + \underbrace{\left(BMC_u^{PM_{2.5}} \times E_{msfu}^{PM_{2.5}} + BMC_u^{PM_{10}} \times E_{msfu}^{PM_{10}} + BMC_u^{NO_X} \times E_{msfu}^{NO_X} + BMC_u^{SO_2} \times E_{msfu}^{SO_2}\right)}_{Building\ and\ material\ damage\ cost}$$

, where required Australian input data are:

- $HC_u^{PM_{2.5}}, HC_u^{PM_{10}}$ and $HC_u^{NO_X}$ are respectively the health cost factors attributed to PM and NO_X in location u,
- $CLC_u^{NO_X}, CLC_u^{VOC}$ and $CLC_u^{SO_2}$ are respectively the crop losses cost factors attributed to NO_X, VOC and SO_2 in location u,
- $BMC_u^{PM_{2.5}}$, $BMC_u^{PM_{10}}$, $BMC_u^{NO_X}$ and $BMC_u^{SO_2}$ are respectively the material and building damage cost factors attributed to PM, NO_X and SO_2 in location u, and
- $E_{msfu}^{PM_{2.5}}$, $E_{msfu}^{PM_{10}}, E_{msfu}^{NO_X}, E_{msfu}^{VOC}$ and $E_{msfu}^{SO_2}$ are respectively the emission factors of PM, NO_X, VOC and SO_2 for transport mode m, size s, fuel type f and in location u

[3] For road transport modes, traffic congestion in the urban area may cause higher emission of pollution due to higher fuel consumption in stop-start the traffic

CE Deft et al. (2019) also detailed the methodology to the quantify the cost factors for their study. Specifically, their cost factors are based on an impact-pathway approach, which requires the following methodological steps: emissions – transmission – concentration (dose) – impact/damage (humans, ecosystems, buildings) – monetisation – costs. Understanding the exact modelling approach for each of the cost factors is beyond the scope of this scoping study as these pertain to the specific methodology for the valuation of environmental prices rather than environmental parameter values for transport activities which are the focus of this scoping study. A high-level understanding of this methodology, however, is helpful in two ways: first, it will help us understand how comparable Australian-based cost factors are to CE Delft et al.(2019) if they exist; second, it provides methodological guidance in the future phase of the project if data collection is deemed necessary to compute the parameter value for Australia . More information on the on the detailed cost valuation method can be found in CE Delft et al. (2019) and CE Delft (2018).

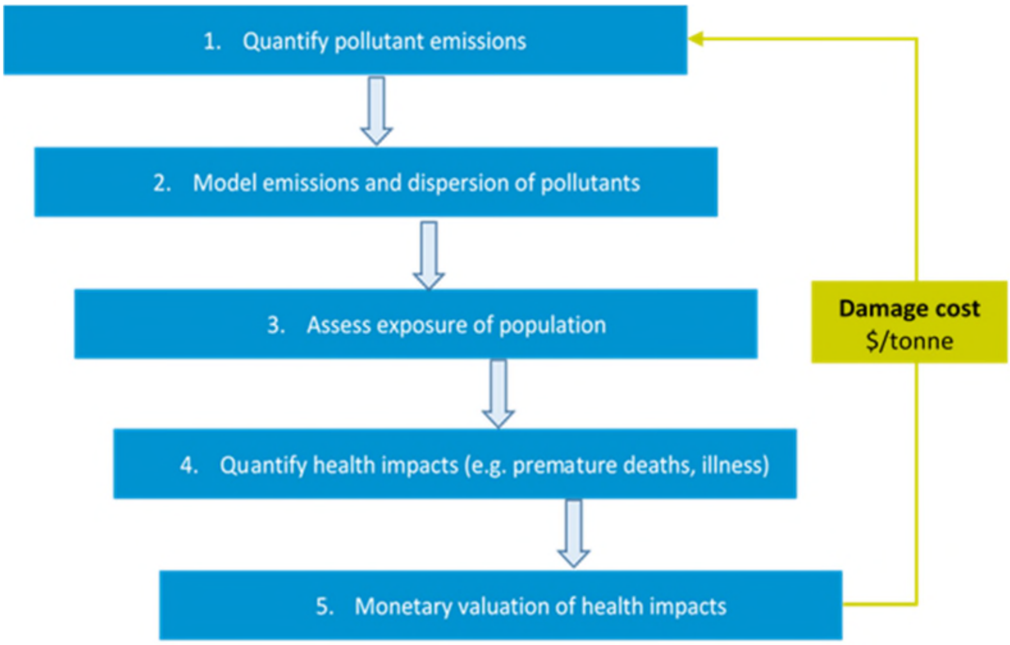
Further discussion of cost factor data requirements

Health cost factor

As outlined in Table 4-1, the damage cost approach is the preferred method for assessing air pollution health cost factors. Damage cost estimates are derived by applying the impact-pathway approach. As shown in (Figure 1), the impact-pathway approach involves the following steps for each pollutant:

1. Emissions modelling
2. Modelling dispersion of emissions and concentrations of pollutant in key airsheds
3. Modelling to assess exposure of populations to the pollutants at different concentrations
4. Assessment of health impacts (mortality and morbidity) of exposed populations, considering both acute and long-term exposure, based on concentration response functions (CRF) of exposed populations.
5. Valuing costs of health impacts (mortality and morbidity), with Value of Statistical Life (VSL) and Value of Statistical Life Year(VLY) used to value mortality impacts and hospitalisation costs and lost productivity and reduced quality of life used to value morbidity impacts.

Figure 1: Impact pathway approach to valuing health damage costs of air pollution



A critical sixth step requires dividing the total monetary value of health impacts by the quantity of emissions to obtain an estimate of the damage costs – typically expressed as $/tonne of pollutant emitted.

Noting the sixth step, data requirements for generating air pollution health cost factors are outlined in Table 5-1.

Table 5-1: Air pollution health damage costs data – levels of disaggregation required

Variable	Pollutant	Health impact	Mode	Fuel type	Major urban	Regional/ rural
Emissions (t)	Y	NA	Y	Y	Y	N
Health cost ($)	Y	Y	N	N	Y	N

Key: Y – yes, required; N – no, not required, NA – not applicable

The following points should be noted about these requirements:

- To ensure all relevant health costs are captured, costs will need to be disaggregated by health impact. These will typically include:
  - Increases in daily mortality (short-term exposure)
  - Increases in annual mortality (long-term exposure)
  - Hospital admissions for respiratory disease, cardiovascular disease, cardiac disease, pneumonia and bronchitis
  - Emergency room attendances for asthma.
- Emissions will need to be disaggregated by vehicle mode and fuel type. This information can, in turn, be used to disaggregate health costs on a proportional basis.

- Emissions and health cost data should be generated for major urban centres – Sydney and Melbourne as a minimum but ideally for other major urban centres including Brisbane, Perth and Adelaide and regional industrial centres such as the Hunter Valley, Latrobe Valley and Wollongong.
- Data for other urban centres and for regional and rural areas can be extrapolated from urban centre estimates on a proportional basis considering differences in population and population density.

Buildings and crops cost factors

Similar to assessing health damage costs, assessing the non-health (buildings and crops) damage costs of air pollution typically involves applying an impact-pathway approach. This in turn requires developing concentration-response functions to assess the damages of air pollutants on buildings and on crops. Direct pricing methods are then applied to valuing the cost of cleaning or replacing building materials or reduced crop yields.

5.2 GHG emissions

Greenhouse gas (GHG) emissions refer to the suite of gaseous chemical compounds found in the earth atmosphere that are known to be responsible for climate change. For emissions from land-based transport modes, CE Delft et al. (2019) has included carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) as greenhouse gases contributing to climate change.

GHG-induced climate change – rising of global temperature – can have flow-on environmental consequences such as drought, floods and heatwaves that causes significant economic and social damage outside the transport system. There are two major ways to monetise climate change costs: damage cost approach and the avoidance cost approach. CE Delft et al. (2019) establishes climate change cost using the avoidance cost approach. The avoidance cost approach is based on the cost of the most cost-effective option to achieve a predetermined level of GHG emission reduction. The damage cost approach is based on the evaluation of the total costs of climate change under the assumption that climate change is progressing at an unmitigated pace. CE Delft et al. (2019) chose not to adopt the damage cost approach by citing its limitations in adequately incorporating the economic damage from the either melting of polar ice caps or the El Niño effect.

To implement the CE Delft et al. (2019) methodology for GHG parameter values, two types of input data are required: emissions factors and cost factors.

- **Emissions factors** – The quantity of GHG emitted from one unit of transport performance measure (in g/vkt), including:
  - CO_2
  - N_2O
  - CH_4
- **Cost factors** – the economic cost attributed to impacts from one unit of culpable pollution (in $/tonne or c/tonne), including:
  - Climate change costs from a unit emission of CO_2-equivalent of GHG.

Although CO_2, N_2O, CH_4 are all considered as greenhouse gases, climate change cost is commonly quantified in units of CO_2-equivalents. This means that, depending on unit of Australian emissions factor data, a conversion assumption may need to be made to convert emission factors for N_2O and CH_4 into emission factors measured in units of CO_2-equivalent. Such conversion factors are known as Global Warming Potential (GWP) index. For CO_2, GWP is standardised to 1. We recommend ATAP to adopt the GWP values of 298 for N_2O and 25 for CH_4 as these are published by the Australian government in Clean Energy Regulator (2016).

Disaggregated parameter values are calculated by the dimensions listed in Table 2-1. Emission factors for each GHG will vary by transport mode, vehicle size, fuel type and location[4] as the intensity of GHG emission are dependent on these factors. The cost factor for GHG emissions, however, does not vary by location as it is based on the cost avoidance approach and thus is assumed equal in urban and rural areas.

[4] For road transport modes, traffic congestion in the urban area may cause higher emission of GHG due to higher fuel consumption in stop-start the traffic

The formula to calculate an Australian-based GHG parameter value $\left(V_{msfu}^{GHG}\right)$ for transport mode m, size s, fuel type f in location u therefore can be expressed as follows:

$$V_{msfu}^{GHG} = CCC^{CO_2} \times \left(E_{msfu}^{CO_2} + E_{msfu}^{N_2O} \times GWP^{N_2O} + E_{msfu}^{CH_4} \times GWP^{CH_4}\right)$$

, where required Australian input data are:

- CCC^{CO_2} which is the climate change cost factor due to the emission of CO_2
- $E_{msfu}^{CO_2}$, $E_{msfu}^{N_2O}$ and $E_{msfu}^{CH_4}$ which are respectively the emission factors of CO_2, N_2O, and CH_4 , for transport mode *m*, size *s*, fuel type *f* in location *u*, and
- GWP^{N_2O} and GWP^{CH_4} which are Global Warming Potentials for N_2O and CH_4 respectively

Further discussion of cost factor data requirements

While valuing the cost of greenhouse gas emissions would ideally involve assessing damage costs to generate a social cost of carbon, in practical terms this approach has been proven to be very difficult, with recent studies generating widely differing values. The fallback option involves valuing greenhouse gas emissions based on avoided (or abatement) cost of emissions, CO_2 equivalent ($CO_{2\text{-}e}$).

Valuing emissions using the abatement cost approach should not simply focus on short-term, marginal abatement costs but consider the average cost of abatement with a given policy objective in mind. For example, as discussed in CE Delft et al. (2019), a widely agreed policy objective is to reduce greenhouse gas emissions to a level necessary to prevent temperature rises above 1.5-2.0 degrees Celsius (thus avoiding potentially catastrophic climate changes). There is general agreement that this requires keeping the atmospheric concentration of CO_2 to below 450 ppm (parts per million), which in turn requires countries to substantially reduce emissions by about 2050. With an objective such as this, short-to-medium term (e.g. up 2030) and longer term (2030-2050) abatement cost estimates for Australia will be required.

5.3 Noise pollution

Transport activity generates noise emissions, or noise pollution, that impacts the people who live and work close to transport corridors. CE Delft et al. (2019) has included annoyance cost and health cost in the noise cost of transport activities. Annoyance is the disturbance individuals experience when they are exposed to traffic noise (CE Delft et al.2019). Health impacts from traffic noise include ischaemic heart disease and hypertension. The annoyance impact is separated by CE Delft et al. (2019) from other health impacts due to the unique method applied for its valuation.

Calculating the average cost of transport noise pollution means that the total cost of noise pollution for each transport mode must first be determined. To do this, the total cost of noise pollution per transport mode is calculated as the product of the total number of people exposed to transport noise and the annoyance and health impact cost factors of noise pollution for an average person. Cost factors are first obtained by broad transport categories: road and rail, and by different noise levels.

A weighting factor is used to account for the fact that noise from some vehicle classes are more of a nuisance than others. This weighting factor is then used to allocate the total noise costs to specific vehicle classes. For example, on urban roads, CE Delft et al. (2019) applied a weighting factor of 1 to the noise cost of passenger car; 1.5 to light commercial vehicles; and 9.8 to buses, coaches and heavy commercial vehicles (3.5-7.5t). For railway noise, the cost of noise from passenger trains is normalised as 1 and freight train noise is scaled up by a factor of 4.

To implement the CE Delft et al. (2019) methodology for noise pollution parameter values, four types of input data are required: population exposure, cost factors, transport performance and weighting factors.

- **Total number of people exposed to transport noise** – The number of people exposed to transport noise in bins of adjusted decibel base (dB(A)[5]:
  - Number of people exposed to road noise
  - Number of people exposed to rail noise
- **Cost factors** – the economic cost attributed to impacts from being exposed to traffic noise in bins of dB(A) over the period of a year (in $/dB/person/year), including:
  - Annoyance cost from by noise levels per person per year
  - Health cost by noise levels per person per year
- **Transport performance data** – measures of transport activities of each vehicle class under road and rail modes (in vkt, pkm or tkm)
  - measures of transport activities for all road vehicle classes
  - measures of transport activities for all rail train classes
- **Weighting factor** – a suite of factors that adjusts the average noise costs by vehicle class
  - Weighting factors for each road vehicle class
  - Weighting factors for each rail vehicle class

[5] The noise bin is in intervals of 5 dB(A) in CE Delft et al. (2019)

The formula to calculate an Australian-based noise pollution parameter value $\left(V_{msfu}^{Noise}\right)$ for transport mode m, size s, fuel type f in location u therefore can be expressed as follows:

$$V_{msfu}^{Noise} = \frac{\underbrace{\sum_{c=1}^{C}\left(AC_{cd}^{Noise} \times P_{cd} + HC_{cd}^{Noise} \times P_{cd}\right)}_{Total\ noise\ cost} \times \underbrace{W_{msfu}}_{Weighting\ factor}}{VKT_{dm}}$$

, where required Australian input data are:

- AC_{cd}^{Noise} which is the annoyance cost factor in noise band indexed by *c and C* is the number of noise bands (categories); and transport category *d* and *d* can represent either road or rail transport.
- HC_{cd}^{Noise} which is the health cost factor in noise band indexed by *c* with a maximum of *C*; and transport category *d* and *d* can represent either road or rail transport.
- P_{cd} is the number of people exposed to noise band *c* from transport category *d*
- VKT_{dm} is the vehicle-kilometre-travelled by mode *m* within transport category *d and M* is the number of modes within transport category *d* for mode *m*
- W_{msfu} is the weighting factor for mode *m*, size *s*, fuel type *f*, and in location *u*

Further discussion of cost factor data requirements

The preferred approach to assessing a noise cost factor is a hedonic pricing approach, which would use a reduction in property values resulting from noise exposure as a proxy for the amenity and disturbance costs of noise. While the value currently used by Austroads (2014) is based on value transfer from EU WTP and direct health cost studies, the approach used in those studies is complex and appears to be better suited to the European context where the focus is on the average cost of noise pollution on exposed populations in densely settled areas. Also, a recent Defra analysis (2014), indicates that the amenity costs of noise are likely to substantially outweigh the direct health costs of noise.

The hedonic pricing approach, as applied in a number of overseas studies including by the New Zealand Transport Agency (2010) and in an older Canadian study (Bein et al. 1996), use hedonic price valuations to determine the costs of noise generated by transport projects on affected property values. This is usually expressed as $ per year per dB (decibels) of noise change. In a project assessment, this cost factor would then be applied to numbers of affected households to determine a total noise cost.

5.4 Soil and water pollution

Two types of environmental discharges were considered when CE Delft et al. (2011) assessed the soil and water pollution of road and rail transport activities: heavy metal and organic toxic substances. Heavy metals are ejected into the surrounding soil and water from fuel combustion and following abrasions (wearing) of brakes, tyres, rail tracks and overhead power lines (for electrified rail). Organic toxic substances such as persistent organic pollutants (POP) may also be released into the surrounding soil and water environment from fuel combustion.

The approach of CE Delft et al. (2011) to establish the average cost of soil and water pollution from transport has three steps:

1. Quantify the total land volume affected by soil and water pollution: 5 metres on either side of the road or rail corridor and a 20 cm in depth.
2. Obtain total soil and water pollution cost by multiplying the affected land volume by a cost factor for soil and water pollution
3. Allocate the total cost to specific modes and vehicle classes by transport performance data.

CE Delft et al. (2011) opted for a repair cost approach to measure the cost factor for soil and water pollution in preference to the damage cost approach due to the complex relationship between infrastructure use and this type of pollution. The repair cost refers to the total cost required to decontaminate a m^3 of soil and water from all identified pollutants.

To implement the CE Delft et al. (2011) methodology for soil and water pollution parameter values, two types of input data are required: total affected land and water volume and cost factors.

- **Total land mass affected** – The total volume of land masses subject to pollution on either side of the transport corridor:
  - Land mass affected by the road network (in m^3)
  - Land mass affected by the rail network (in m^3)
- **Cost factors** – the cost to decontaminate one unit (m^3) of affected land volume from the following pollutants (in $/$m^3$)
  - Heavy metal and organic substances (e.g. POP)
- **Transport performance data** – measures of transport activities of each vehicle class under road and rail modes (in vkt, pkm or tkm)
  - measures of transport activities for all road vehicle classes
  - measures of transport activities for all rail train classes

The formula to calculate an Australian-based soil and water pollution parameter value $(V_{msfu}^{SoilWater})$ for transport mode m, size s, fuel type f in location u therefore can be expressed as follows:

$$V_{msfu}^{SoilWater} = \frac{\underbrace{\left(DC_d^{SoilWater} \times L_d\right)}_{Total\ soil\ and\ water\ pollution\ cost} \times \overbrace{\frac{VKT_{dsfmu}}{\sum_m^M VKT_{dsfmu}}}^{Allocation\ by\ VKT}}{VKT_{dsfmu}}$$

where required Australian input data are:

- $DC_d^{SoilWater}$ which is the decontamination cost for one unit of land or water volume in transport category *d* where *d* can represent either road or rail transport
- L_d is the total land (or water) volume subject to soil and water pollution from transport category *d*
- VKT_{dmsfu} is the vehicle-kilometre-travelled by mode *m* within transport category *d and M* is the number of modes within transport category *d* for mode *m*, size *s,* fuel type *f*, and in location *u.*

Moreover, a more complete assessment of the impacts of transport infrastructure on water pollution would involve assessing the impact of run-off from roads on the quality of water in receiving environments. This in turn would require additional information on:

- **Total waterways affected**
  - The length of waterways subject to pollution due to stormwater runoff from the transport corridor:
  - waterways affected by the road network (in km or km^3)
  - waterways affected by the rail network (in km or km^3)

Specifically, to determine the waterways affected require the following information:

  - Rainfall-runoff coefficient to determine the volume of run-off and volume entering waterways
  - Pollutant loads in the stormwater runoff including heavy metals, organic toxins and sediment
  - The marginal impact of these pollutants on water quality relative to other sources.

- **Cost factor -** the cost of pollutants on waterways (in $/km or $/$km^3$).

Further discussion of cost factor data requirements

While valuing the cost of water pollution would ideally involve assessing willingness to pay to avoid damage to receiving water bodies, in practical terms this approach would be difficult to apply in the context of different transport types and location.

Impacts on receiving water bodies will vary widely depending on the type of receiving water body, its condition, and ability to accommodate heavy metal and inorganic substances. Impacts will also depend on jurisdictional differences in legally permissible levels of heavy metal and organic substances. Willingness to pay will also benefit on the location of the receiving water body and how it is used. For example, the economic impacts of heavy metals and organic substances on a high use urban lake used for primary contact activities will be different to a less used lake, all other factors constant.

Willingness to pay could be estimated by developing a national stated preference survey covering these issues. In the absence of this evidence base our initial work suggests there are few if any directly relevant Australian willingness to pay studies.

In the absence of willingness to pay evidence a repair cost approach to measure the cost factor using Australian estimates of the cost to decontaminate one unit of affected land volume from the following pollutants (in $/m^3$) could be developed. Where the repair cost approach is used, the limitations of the approach will need to be recognised (Box 1).

5.5 Biodiversity

Biodiversity loss is caused by and exacerbated by air pollution. Air pollutants can cause acute, severe and long-term impacts on ecosystems. Damages to ecosystems are of importance as these impacts lead to a decrease in biodiversity, for both flora and fauna. CE Delft et al. (2019) identified the most important damages for consideration are:

- The acidification of soil, precipitation and water (e.g. by NO_x and SO_2); and
- The eutrophication of ecosystems (e.g. by NO_x or NH_3)

CE Delft et al. (2019) consider biodiversity as an aspect of air pollution. Therefore, the input data required for calculating this parameter value is similar to that used for the air pollution parameter. In addition, these two aspects follow a similar methodology. However, biodiversity requires the assessment of specific pollutants, which differ from the overall list for air pollution.

To implement the CE Delft et al. (2019) methodology for biodiversity (included as an aspect of air pollution) parameter values, two types of input data are required: emission factors and cost factors.

- **Emission factors** – The quantity of air pollutants emitted from one unit of transport performance measure (in g/vkt), including:
  - NO_x
  - SO_2
  - NH_3
- **Cost factors** – the economic cost attributed to impacts from one unit of culpable pollution (in $/tonne or c/tonne), including:
  - the cost of the acidification of soil, precipitation, and water bodies from a unit emission of NO_x and SO_2
  - the cost of the eutrophication of an ecosystem from a unit emission of NOx and NH_3

Disaggregated parameter values can be calculated by the dimensions listed in Table 2-1. Emission factors for each air pollutant will vary by transport mode, vehicle size, fuel type and location[6] as the intensity of polluting emission are dependent on these factors. Cost factors vary by location as they are dependent on the density of flora and fauna (particularly native species), the presence of key water bodies (i.e. drinking water dams), the value of any ecosystem present and land uses within the affected area, but independent of the emission source.

[6] For road transport modes, traffic congestion in the urban area may cause higher biodiversity impacts due to higher fuel consumption in stop-start the traffic

The value of biodiversity parameter values for a specific transport mode, vehicle size, fuel type and location can be calculated by first multiplying the corresponding emission factor with the corresponding cost factors under each of the three impacts and then summing up their products.

The formula to calculate Australian-based air biodiversity parameter value (V_{msfu}^{Bio}) for transport mode m, size s, fuel type f in location u can be represented as:

$$V_{msfu}^{Bio} = Acidification$$

, where required Australian input data are:

- $A_u^{NO_x}$ and $A_u^{SO_2}$ are respectively the soil acidification factors attributed to NO_x and SO_2 in location u
- $EE_u^{NO_x}$ and $EE_u^{NH_3}$ are respectively the ecosystem eutrophication factors attributed to NO_x and NH_3 in location u
- E_{msfu}^{NOx}, $E_{msfu}^{SO_2}$ and $E_{msfu}^{NH_3}$ are respectively the emission factors of NO_X, SO_2 and NH_3 for transport mode m, size s, fuel type f in location u

As noted in air pollution, CE Deft et al. (2019) also detailed the methodology that led to the quantification of the cost factors for their study. Specifically, their cost factors are based on an impact-pathway approach, which requires the following methodological steps: emissions – transmission – concentration (dose) – impact/damage – monetisation – costs.

5.6 Nature and landscape

Habitat loss and habitat fragmentation are two major environmental consequences that correspond to the concept of nature and landscape impacts. Habitat loss refers to the loss of land available for the ecosystem due to use of land for transport infrastructure in the forms of road pavements and railway tracks. Habitat fragmentation impact refers to the process where formerly large and continuous natural land area being divided by transport infrastructure into smaller fragments of its former self. Animals that were once able to roam between the fragmented landscape, freely and safely, are most affected by this impact of transport activities.

Loss or fragmentation of open space and parklands can be a further consequence of transport infrastructure. This open space provides amenity and recreational values to people residing in urban areas.

The approach of CE Delft et al. (2019) to establish the average cost of nature and landscape impact from transport has three steps:

1. Quantify the total affected area by network length
2. Obtain total nature and landscape cost by multiplying network distance by a cost factor for habitat loss and habitat fragmentation
3. Allocate the total cost to specific modes and vehicle classes by transport performance data

To implement the CE Delft et al (2019) methodology nature and landscape parameter values, three types of input data are required: total network length, cost factors, and transport performance data.

- **Total affected area by network length** – The total affected area by network length of the transport infrastructure (in km or km^2)
  - total length of the road network
  - total length of the rail network
- **Cost factors** – the economic value (in \$/km or \$/km^2) associated with
  - cost of habitat loss from a unit of the transport network
  - cost of habitat fragmentation a unit of the transport network
- **Transport performance data** – measures of transport activities of each vehicle class under road and rail modes (in vkt, pkm or tkm)
  - measures of transport activities for all road vehicle classes
  - measures of transport activities for all rail train classes

CE Delft et al. (2019) presented two ways to estimate the cost factors due to habitat loss and habitat fragmentation: bottom-up approach and restoration cost approach. CE Delft et al. (2019) calculated the cost factors from their counterparts in a Swiss study based on a bottom-up approach. While in the previous edition, CE Delft et al. (2011) based the cost factor on the restoration approach.

The formula to calculate an Australian-based nature and landscape parameter values (V_{msfu}^{Nature}) for transport mode m, size s, fuel type f in location u can be expressed as follows:

$$V_{msfu}^{Nature} = \frac{\underbrace{\left(HLC_d^{Nature} \times NL_d + HFC_d^{Nature} \times NL_d\right)}_{Total\ nature\ and\ landscape\ cost} \times \overbrace{\frac{VKT_{dmsfu}}{\sum_m^M VKT_{dmsfu}}}^{Allocation\ by\ VKT}}{VKT_{dmsfu}}$$

, where required Australian input data are:

- HLC_d^{Nature} is the habitat loss cost for one unit of network length in transport category *d* where *d* can represent either road or rail
- HFC_d^{Nature} is the habitat fragmentation cost for one unit of network length in transport category *d* where *d* can represent either road or rail
- NL_d is the total network length of transport category *d*
- VKT_{dmsfu} is the vehicle-kilometre-travelled by mode *m* within transport category *d and M* is the number of modes within transport category *d* for mode *m*, size *s,* fuel type *f*, and in location *u*

Further discussion of cost factor data requirements

As outlined in Table 4-1, the preferred approaches to assessing suitable WTP values for the loss or fragmentation of habitat or urban open spaces are likely to be respectively:

- A stated preference technique, such as choice modelling, to assess WTP for the non-market values of ecosystems and habitat potentially impacted by transport infrastructure
- Hedonic pricing, a revealed preference technique, to assess the amenity and recreational use values of open space.

It is possible that suitable WTP values could be derived through value transfer from relevant Australian studies. It is important, however, that a range of values are derived to reflect:

- Different ecosystem and habitat types, having different levels of ecological value (e.g. high, medium, low conservation status)
- In the case of urban open space, different types of open space that reflect different types and levels of use.
- Scale and scope and timing of fragmentation and loss, given the relationship between habitat loss, fragmentation, the speed at which loss and / or fragmentation occur, and economic value is likely to be highly non-linear.

5.7 Barrier effects in urban areas

Like the habitat fragmentation effect in rural areas, road and rail corridors can become barriers in urban areas for pedestrians, cyclists, and other non-motorised travellers. As such, the primary negative outcome of the barrier effect is known as the separation effect and it causes a loss of time for non-motorised travellers who must wait when stopped by red traffic lights or lowered boom gates before resuming their journey across the road or rail. The barrier effect can also manifest in two other less prominent ways: the additional space required to accommodate cyclists on roads which leads to a scarcity problem and the visual intrusion effect due to aesthetic property or the lack thereof for transport infrastructure.

The approach taken by CE Delft et al. (2011) only accounts for separation cost. Scarcity and aesthetic costs are not included due to the lack of a reliable method to measure them.

The method for calculating the average separation cost requires the estimation of total separation cost. This estimation requires three input data: the average time loss due to the separation effect for each person living in the urban area, the average value of time for each person living in the urban area and the total number of people in the urban area. Multiplying the first two input data produces the separation cost per person and multiplying all three input data produces the total separation cost in the urban area. The total separation cost is then allocated to specific vehicle classes by their share in overall transport performance. This approach is originally implemented in a Swiss study by Ecoplan/INFRAS (2008) whose values are transferred to other European cities in CE Delft et al. (2011).

To implement the methodology for barrier effects parameter values adopted by Ecoplan/INFRAS (2008) , four types of Australian input data are required: average waiting time per pedestrian, the value of travel time for pedestrians, total number of pedestrians and transport performance measures.

- **Average waiting time per pedestrian** – the average waiting time spent by a pedestrian on waiting to cross the road or road at a traffic light or boom gate (in annual hours per person)
  - Average waiting time per pedestrian at road crossings
  - Average waiting time per pedestrian at railway crossings
- **Cost factors** – the value of travel time for pedestrians (in $/hour)
  - Average value of travel time of a pedestrian
- **Total number of residents** – the size of population who are subject to the separation effect
  - Number of people living in the urban area
- **Transport performance data** – measures of transport activities of each vehicle class under road and rail modes (in vkt, pkm or tkm)
  - measures of transport activities for all road vehicle classes
  - measures of transport activities for all rail train classes
- The formula to calculate an Australian-based urban barrier effect parameter value $\left(V_{msfu}^{Barrier}\right)$ for transport mode m, size s, fuel type f in location u therefore can be expressed as follows:

$$V_{msfu}^{Barrier} = \frac{\overbrace{\underbrace{\left(TLPP_d^{Barrier} \times VTPP_u\right)}_{Separation\ cost\ per\ person} \times Pop_u}^{} \times \overbrace{\frac{VKT_{dmsfu}}{\sum_m^M VKT_{dmsfu}}}^{Allocation\ by\ VKT}}{VKT_{dmsfu}}$$

where the term $\left(TLPP_d^{Barrier} \times VTPP_u\right) \times Pop_u$ is the *Total separation cost*.

, where required Australian input data are:

- $TLPP_d^{Barrier}$ is the average waiting time per person due to separation effect due to transport category *d* where *d* can represent either road or rail
- $VTPP_u$ is the average value of travel time for a pedestrian living in location *u*
- Pop_u is the number of residents or the size of population living in location *u*
- VKT_{dmsfu} is the vehicle-kilometre-travelled by mode *m* within transport category *d and M* is the number of modes within transport category *d* for mode *m*, size *s,* fuel type *f*, and in location *u*

5.8 Upstream and downstream costs

Upstream and downstream costs refer to the value of negative environmental externalities that arise from processes which are inputs and derivatives of transport operations. Taking a life-cycle viewpoint, these processes may include the production of transport fuel and energy (well-to-tank), the manufacture of vehicles and infrastructure, and maintenance and disposal of vehicles. Upstream and downstream costs are therefore important factors to consider when measuring the lifecycle environmental impact of a transport project.

The approach taken by CE Delft et al. (2019) for quantifying the average cost of upstream and downstream impacts of transport operations focuses on the well-to-tank emissions. For electric vehicles, costing the environmental impact of well-to-tank process is especially important because their environmental footprint may be diverted upstream if the well-to-tank process that generated the electricity that powers them is not emissions free. Well-to-tank emission includes air pollutants and GHG emitted in the process of:

- Extracting energy sources
- Processing (e.g. refining or electricity production)
- Transport and transmission
- Building of energy plants and other infrastructures

To calculate the cost of well-to-tank emission in transport performance requires data on the emissions factor that describes the amount of air pollutants and GHG generated by fuel/power production facilities for each unit of energy. Linking this emission factor to transport activity is the fuel consumption factor that describes the rate at which vehicles consume fuel or power measured in vkt. Multiplying these two factors together will provide the emission factors measured in vkt.

To implement the CE Delft et al. (2019) methodology upstream parameter values, four types of input data are required: emissions factors, cost factors, energy consumption data, and transport performance data.

- **Air pollutant and GHG emission factors** during the well-to-tank processes
  - The culpable gaseous emissions for these factors are as they are described under the previous sections for air pollution and GHG with the distinction that these factors are for emissions during the well-to-tank (WTT) process of producing energy
- **Cost factors** – economic value of each unit of air pollutant and GHG emitted during the well-to-tank processes. These cost factors are essentially the same as described under the previous sections for air pollution and GHG except that the air pollution cost factors will need to reflect damage cost estimates for the locations where well-to-tank processes (e.g. refineries and power stations) are typically located.
- **Energy consumption rate** – the amount of power and fuel consumed by a vehicle per unit of vkt
  - Average litres of petrol, diesel or gas consumed for a road vehicle powered by a fossil-fuel engine for travelling over one kilometre
  - Average litres of diesel consumed for a diesel train for travelling over one kilometre
  - Average kilowatts of electricity consumed by an electric vehicle for travelling one kilometre
  - Average kilowatts of electricity consumed by an electric train for travelling one kilometre

- **Transport performance data** – measures of transport activities of each vehicle class under road and rail modes (in vkt, pkm or tkm)
  - measures of transport activities for all road vehicle classes
  - measures of transport activities for all rail train classes

The formula to calculate Australian-based upstream and downstream parameter value $\left(V_{msfu}^{UpDown}\right)$ for transport mode m, size s, fuel type f in location u can be represented as follows:

$$V_{msfu}^{UpDown} = \left\{ \left[AC^{NOx} \times WTTE_f^{NOx} + AC^{PM_{10}} \times WTTE_f^{PM_{10}} + AC^{PM_{2.5}} \times WTTE_f^{PM_{2.5}} + CLC_u^{VOC} \times WTTE_f^{VOC} + \left(CLC_u^{SO_2} + BMC_u^{SO_2}\right) \times WTTE_f^{SO_2}\right] + \left(CCC^{CO_2} \times WTTE_{fu}^{CO_2e}\right)\right\} \times EC_{msfu}$$

, where required Australian input data are:

- $AC^{NO_x} = HC_u^{NOx} + CLC_u^{NOx} + BMC_u^{NOx}$ is the total air pollution cost factor due to the emission of NO_x
- $AC^{PM_{10}} = HC_u^{PM_{10}} + BMC_u^{PM_{10}}$ is the total air pollution cost factor due to the emission of PM_{10}
- $AC^{PM_{2.5}} = HC_u^{PM_{2.5}} + BMC_u^{PM_{2.5}}$ is the total air pollution cost factor due to the emission of $PM_{2.5}$
- $AC^{SO_2} = CLC_u^{SO_2} + BMC_u^{SO_2}$ and it is the total air pollution cost factor due to the emission of SO_2
- $CLC_u^{VOC}, HC_u^{NOx}, CLC_u^{NOx}, BMC_u^{NOx}, HC_u^{PM_{10}},\ BMC_u^{PM_{10}} HC_u^{PM_{2.5}},\ BMC_u^{PM_{2.5}} CLC_u^{SO_2}$and $BMC_u^{SO_2}$ are cost factors defined in the air pollution section
- CCC^{CO_2} is the cost of climate change defined in the GHG section
- $WTTE_f^{PM_{10}}, WTTE_f^{PM_{2.5}}, WTTE_f^{NOx}, WTTE_f^{VOC}$, $WTTE_f^{SO_2}$ and $WTTE_f^{CO_2e}$ are respectively the emission factors of PM_{10}, $PM_{2.5}$, NO_X , VOC, SO_2 and CO_2-equivalent for each unit of energy produced in the well-to-tank process
- EC_{msfu} is the unit of energy consumption for one unit of vkt by vehicle under mode *m*, size *s*, fuel type *f*, and travelling in location *u*

5.9 Units of measurement

The methodologies for calculating the parameter values presented so far are in units of dollar per vehicle-kilometres-travelled ($/vkt). For passenger and freight transport modes, the economic values associated with their impacts may also need to be measured in units for passenger and freight movements (i.e. pkm and tkm). Hence, a converting process is required to convert parameter values calculated in $/vkt to $/pkm for passenger transport modes and $/vkt to $/pkm for freight transport modes.

The process of converting parameter values measured in $/vkt to $/pkm or $/tkm is straightforward as it can be achieved by multiplying a conversion ratio that tracks the relative transport performance measured in vkt to pkm or tkm for a vehicle class. The intuition of this process is that, to obtain the average cost per pkm or tkm, the total environmental cost value for is first calculated by multiplying the parameter value in $/vkt to the total transport activity measured in vkt, and this total cost figure can then be reallocated by the total pkm or tkm of a transport mode or vehicle type.

To illustrate with an example, the parameter value of air pollution (V_{msfu}^{AIR}) can be converted to a corresponding value measured in pkm (V_{msfu}^{AIRpkm}) for a passenger transport mode as:

$$V_{msfu}^{AIRpkm} = V_{msfu}^{AIR} \times \frac{VKT_{msfu}}{PKM_{msfu}}$$

where PKM_{msfu} measures the passenger-kilometre for mode *m*, size *s,* fuel type *f*, and travelling in location *u*

Similarly, for freight modes, a corresponding parameter values in tkm can be obtained from V_{msfu}^{AIR} as:

$$V_{msfu}^{AIRtkm} = V_{msfu}^{AIR} \times \frac{VKT_{msfu}}{TKM_{msfu}},$$

where TKM_{msfu} measures the tonne-kilometre for mode *m*, size *s,* fuel type *f*, and travelling in location *u.*

Data required for this conversion process are transport performance data measured in pkm for passenger vehicle/train classes and in tkm freight vehicle/train classes.

6. Summary and analysis of requirement for Australian-based data

This section provides a consolidated view of the necessary input data required based on the preferred methodologies. The summary of the required data is presented in two separate sections that correspond to two broad categories of data: cost factor data and environmental impact data.

- Cost factor data (section 6.1) corresponds to the average economic costs attributed to environmental pollution regardless of the source of pollution (e.g. transport, manufacturing, power generation).
- Environmental impact data (section 0) corresponds to the data needed to determine the environmental pollution attributed to specific transport activities (e.g. GHG emitted by freight vehicles in the urban area).

For each data requirement, the available approaches for the collection of each data requirement is also considered. While establishing the specific methodologies for Australian data is beyond the scope of this study, this assessment aims to identify data requirements that can be fulfilled with a value transfer approach. Data obtained using the value transfer approach come from existing sources outside Australia. This approach therefore should only be considered if corresponding Australian data is absent and the foreign data is expected to be similar to that from Australia. The benefit of this approach is the savings on time and financial cost for collecting Australian data.

6.1 Cost factor data

Table 6-1 provides the full list of cost factor data required for implementing the preferred methodologies described in section 4. For each data, we use a traffic light system to indicate whether Australian-specific source is necessary for fulfilling the data needs, where green means Australian data is required, yellow means Australian data may be required and red means that Australian data is not required.

Table 6-1 Summary of cost factor data required from Australian sources

Impact category	Data required	Australian data preferred?	Comment
Air pollution	Cost factors for health impacts of various pollutants	🟢	• The preferred methodology, applying impact-pathway analysis, requires Australian-specific cost factors to be developed
	Cost factors for impacts of various pollutants on buildings and crops	🟡	• The most robust approach, applying the impact-pathway approach, may not be feasible in the Australian context
GHG emission	GHG abatement cost factor	🟢	• The preferred methodology, requires cost factors to be developed over different timeframes using Australian abatement cost estimates
Noise pollution	Noise damage cost factor	🟢	• An Australian-specific damage cost factor should be used. Preferably, this would be developed through a hedonic pricing study
Soil and Water pollution	Soil damage cost factor	🟢	• Clean-up cost is suitable for soil pollution
	Waterways damage cost factor	🟢	• WTP for clean waterways is the preferred approach
Biodiversity (Air pollution)	Cost factor for impacts of various pollutants on ecosystems	🟡	• As per impacts of air pollution on buildings and crops, the most robust approach, applying the impact-pathway approach, may not be feasible in the Australian context
Nature and landscape	Cost factors for impacts of transport infrastructure on habitats and open space	🟢	• Cost factors should be developed to reflect loss or fragmentation of different habitats with different levels of conservation status. Also, for different types of open space.
Urban barrier effect	Value of travel time	🟢	• An Australian-specific value or range of values should be used
Upstream and downstream costs	Air pollution and GHG emission cost factors	🟢	• As per air pollution health impacts and GHG abatement cost factors

Key: 🟢 yes 🟡 maybe 🔴 no

6.2 Environmental impact data

Table 6-2 provides the full list of environmental impact data required for implementing the preferred methodologies described in section 4. For each data, we use a traffic light system to indicate whether Australian-specific source is necessary for fulfilling the data needs, where green means Australian data is required, yellow means Australian data may be required and red means that Australian data is not required.

Table 6-2 Summary of environmental impact data required from

Impact category	Data required	Australian data preferred	Comment
Air pollution	Vehicle emission factors for air pollutants	🟡	• Average emission factors of air pollutants depend on a number of country-specific factors including vehicle emission standards, fuel quality, and fleet composition. • Since these factors may vary from country to country, we therefore recommend using Australian-based emission factors whenever possible.
GHG emission	Vehicle emission factors for GHG	🟡	• Based on the same reasoning for air pollutant emission factors, we therefore recommend using Australian-based emission factors for GHG whenever possible.
	Global warming potential	🔴	• Since global warming is a global phenomenon, this data can be transferred from another country if an Australian estimate is not available
Noise pollution	Total number of people exposed to transport noise	🟢	• Total number of people exposed to transport noise is determined by the geographic layout of the transport network and the distribution of residents along these networks. • Because these are unique conditions for each country, we therefore recommend this data to be based on Australian transport networks and land use information.
	Weighting factors	🔴	• Weighting factors describes the relative disturbance people assigned to noise generated by different transport modes and vehicle classes. • We expect these factors to be similar across countries as the noise characteristics of various transport modes and the human perception towards them are not expected to be significantly different between countries.
Soil and water pollution	Total land mass affected	🟢	• These data are determined by country-specific transport networks and geography, hence should not be based on sources from another country
	Total water mass affected		
Biodiversity	Vehicle emission factors	🟢	• Based on the same reasoning for air pollutant emission factors, we therefore recommend using Australian-based emission factors for air pollutants that causes biodiversity damage.

Impact category	Data required	Australian data preferred	Comment
Nature and landscape	Total network length	yes	• This data is determined by country-specific transport networks and hence should not be based on sources from another country
Urban barrier effect	Average waiting time per pedestrian	yes	• This data depends on the layout of transport network, traffic signalling standards and the travel behaviour of pedestrians in each country • We therefore recommend using Australian-based pedestrian waiting time.
	Total number of people	yes	• Population size is country specific hence we recommend using Australian-based data
Upstream and downstream costs	WTT emission factors for air pollutants	maybe	• WTT emission factors for fossil fuel are expected to be different between countries due to their geographic locations. This means upstream emissions associated with the transport of fuel from the site of production to the end user are likely to be different between countries. • WTT emission factors for electricity generations are also likely to differ between countries depending on the fuel used for generation. Europe, for example, is likely to have a significantly smaller WTT emission factor due to their extensive use of nuclear power plants. • We recommend using Australian-based WTT emission factors for air pollutants and GHG whenever possible.
	WTT emission factors for GHG	maybe	
	Energy consumption rate	maybe	• For fossil fuel powered transport, average fuel consumption rate will depend on a number of country-specific factors including vehicle emission standards, fuel quality, and fleet composition. • For electric transport modes, the energy consumption rates are expected to be similar between countries as these vehicles have similar technologies
Noise pollution Soil and water pollution Nature and landscape Urban barrier effect	Transport performance	yes	• The level of transport activities depends on a number of country specific factor including the size of the economy, the availability of alternative transport mode, freight and passenger tasks. • We therefore recommend using data that reflects Australian transport activities.

Key: ● yes ● maybe ● no

7. Availability of Australian data

7.1 Availability of Australian cost factor data

This section presents summary findings of our investigation into Australian sources of cost factor data – primarily government reports and research papers, based on data requirements for cost factors discussed in Table 6-2. These are presented in series of tables below.

In each table, for each identified source, quality of the data is also assessed. Quality of data based on its relevance, coverage, and comprehensiveness. Relevance is measured by the year in which the most recent data became available in the identified source. Relevance of the data source is high if it was released within the last five years. The 5-year criterion is chosen somewhat arbitrarily but it is chosen to account for valuations that have taken place since the last major update of ATAP PV5 (Austroads 2014). Coverage refers to geographic coverage of the data. Given that ATAP PV5 is a national guideline, broad geographic coverage is important. Comprehensiveness refers to a range of other considerations, which vary depending on the cost factor under consideration. For air pollution health costs for example, comprehensiveness is high if it covers a range of pollutants, the major health impacts and values the health impacts. Together, data quality is high if it is relevant, has national coverage and is comprehensive.

Air pollution

Four recent Australian studies have been identified that either apply the full impact pathway approach to assessing health damage costs of air pollution or apply a number of impact pathway steps. These are outlined in Table 7-1. Notable features of the studies include:

- While none of the studies individually meet all the criteria necessary for them to qualify as having high quality data, taken together the studies cover-off on the criteria.
- This suggests that drawing on the four studies.
- It should be feasible to generate a reliable range of values for the air pollution health cost factor.

No recent Australian studies have been identified that apply the impact pathway approach (or other approaches) to assessing non-health (buildings and crops) damage costs of air pollution.

Table 7-1 Potential Australian sources for air pollution health cost factor

Author and date	Title	Format	Geographic coverage	Pollutants covered	Health impacts	Health impact values	Data quality
Golder Associates (2013)	Exposure Assessment & Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards	Report	Sydney, Melbourne, Brisbane, Perth, Adelaide	$PM_{2.5}$, SO_2, NO_2, O_3	Mortality, Morbidity	No	Medium-High
PAE Holmes & Marsden Jacob (2013)	Economic Analysis to Inform the National Plan for Clean Air (Particles)	Report	Sydney, Melbourne, Brisbane, Perth, Adelaide	$PM_{2.5}$	Mortality, Morbidity	Yes	Medium-High

Author and date	Title	Format	Geographic coverage	Pollutants covered	Health impacts	Health impact values	Data quality
Marsden Jacob & Pacific Environment (2018)	Revised Fuel Quality Standards: Economic Analysis	Report	Sydney, Melbourne, Other state capital cities (combined)	$PM_{2.5}$, SO_2, NO_2, O_3	Mortality, Morbidity	Yes	Medium-High
Aurecon (2018)	Review of Ambient Air Quality NEPM for SO_2, NO_2 and O_3	Report	Sydney, Melbourne, Newcastle, Wollongong, Latrobe Valley	SO_2, NO_2, O_3	Mortality, Morbidity	Yes	Medium-High

Greenhouse gas emissions

Numerous economic studies have been undertaken over the past 10 years that involve a direct or implied cost of carbon abatement. Some of these studies have a specific focus on the costs of Australian policy objectives. Other studies have an international focus, examining the cost to countries (including Australia) of meeting international objectives (e.g. objectives under the Paris Climate Agreement). Table 7-2 summarises a selection of the most relevant studies. Some of the studies focus on medium term policy objectives (e.g. to 2030) others have a longer-term focus (e.g. to 2050). Between them, the studies provide a range of potential values of carbon abatement cost factors. Table 7-2 also refers to quarterly price data published by the Renewable Energy Regulator for Australian Carbon Credit Units. These provide an indication of marginal abatement costs in the very short term.

Table 7-2 Potential Australian sources for greenhouse gas emissions abatement cost factor

Author and date	Title	Format	Geographic coverage	Timeframe	Policy objective	Data quality
Department of Treasury (2011)	Strong growth, low pollution, modelling a carbon price	Report/ model	National	Medium term	Yes	Medium-High
SKM (2012)	Modelling the Renewable Energy Target, Report for the Climate Change Authority	Report/ model	National	Medium term	Yes	Medium-High
Treasury and DIICCSRTE (2013)	Climate Change Mitigation Scenarios: Report to the Climate Change Authority	Report/ model	National, international	Medium to long term	Yes	Medium-High
Climate Works (2014)	Pathways to Deep Carbonisation in 2050	Report/ model	National	Medium to long term	Yes	Medium-High
CSIRO (2015)	Australian National Outlook 2015	Report/ model	National	Medium to long term	Yes	High
McKibben Software Group (2015)	Economic Modelling of Australian Action Under A New Global Climate Change Agreement	Report/ model	National, international	Medium to long term	Yes	High
Finkel et al. (2017)	Independent Review into the Future Security of the National Electricity Market	Report	National	Short to medium term	Yes	Medium-High

Author and date	Title	Format	Geographic coverage	Timeframe	Policy objective	Data quality
Liu et al. (2019)	Global Economic and Environmental Outcomes of the Paris Agreement	Report	National, international	Short to medium term	Yes	Medium-High
Clean Energy Regulator (2020)	Quarterly Carbon Market Report	Report, database	National	Short term	No	Medium

Noise pollution

No recent Australian studies have been identified that apply hedonic pricing to valuing the amenity costs of traffic noise.

Soil and water pollution

Numerous economic studies have been undertaken over the past 10 years that involve assessing the economic value of water quality. It is doubtful, however, that these studies, either individually or in combination, will provide the data necessary to enable their use in value transfer to value the impacts of transport infrastructure on water quality.

Table 7-3 Potential Australian sources for water pollution cost factor

Author and date	Title	Format	Study type	Geographic coverage	Data quality
Cooper (2017)	The Value of Melbourne's Waterways: A Report on Preliminary Estimates Using Choice Modelling prepared for Melbourne Water and the Department of Environment Land, Water and Planning	Report	Stated preference	Melbourne	Medium-High
Deloitte Access Economics (2016)	Economic and social value of improved water quality at Sydney's coastal beaches	Report	Stated preference	Sydney	Low-medium
Gillespie Economics (2018)	Willingness to Pay for the Outcomes of Improved Stormwater Management	Report	Stated preference	Sydney	Medium-High
Morrison (2016)	The Value of Improvements in Urban Stream Health in Southern Sydney Cooks River and Georges River Catchments	Report	Stated preference	Sydney	High
Bennett (2008)	The economic value of improved environmental health in Victorian rivers	Report	Stated preference	Victoria	Medium
Bennett (2016)	Estimating the non-market benefits of environmental flows in the Hawkesbury-Nepean River	Report	Stated preference	Sydney	Medium-high
Rolfe (2013)	Calibration of values in benefit transfer to account for variations in geographic scale and scope: Comparing two choice modelling experiments	Report	Stated preference	National	Medium

Biodiversity (air pollution)

No recent Australian studies have been identified that apply impact pathway approach to valuing the costs of air pollution on biodiversity.

Nature and landscape

Australian studies having potential relevance to valuation of habitat loss or open space are listed in Table 7-4. None of the studies individually are suitable for providing a full range of values for loss of habitat of different types and conservation status, or urban open space. Taken together, however, they could possibly be used as a basis for value transfer.

Table 7-4 Potential Australian sources for habitat and open space loss cost factors

Author and date	Title	Format	Ecosystem/ habitat type(s)	Geographic coverage	Data quality
Whitten et al. (2001)	Non-market values of wetlands	Report	Wetlands	South Australia, NSW	Medium
Ho et al. (2013)	The Value of WA Native Forests and Bushland	Article	Woodlands	Western Australia	Medium
Rolfe et al. (2015)	Meta-analysis: Rationale, Issues and Applications	Book chapter	Wetlands	National	Medium-high
Varcoe et al. (2015)	Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	Report	Various	Victoria	Medium-high
Marsden Jacob (2017)	A park, a wetland, a lake or a freeway? Hedonic pricing of green, blue and grey infrastructure in Melbourne greenfield developments.	Report	Wetlands	Urban Melbourne	Medium-high
Evangelio et al. (2018)	What makes a locality attractive? Estimates of the amenity value of parks for Victoria	Report	Parks	Victoria	Medium-high

Urban barrier effects

A number of Australian studies have placed a value on travel time and/or leisure time. These are outlined in Table 7-5. Combined, these studies should provide a reasonable range of travel time estimates that could potentially be used for valuing the cost of time associated with the urban barrier effect.

Table 7-5 Potential Australian sources for value of travel time cost factor

Author and date	Title	Format	Geographic coverage	Focus	Data quality
Austroads (1997)	Value of travel time savings	Report	National	Value of on-road travel time	Medium

Author and date	Title	Format	Geographic coverage	Focus	Data quality
Lake and Ferreira(2002)	Modelling tolls: values of time and elasticities of demand: a summary of evidence	Report	Queensland, National	Value of on-road travel time	Medium
Larsonand Shaikh (2004)	Recreation Demand Choices and Revealed Values of Leisure Time	Journal article	National	Value of leisure time	Medium
Australian Transport Council (2006)	National Guidelines for Transport System Management in Australia, Volume 4: Urban transport	Report	National	Value of on-road travel time	Medium-High
Ho et al. (2016)	Vehicle value of travel time savings: evidence from a group-based modelling approach	Journal article	National	Value of on-road travel time	Medium-High
Victoria Transport Policy Institute	Transportation Cost and Benefit Analysis II – Travel Time Costs	Report	Victoria	Value of on-road travel time	Medium-High

7.1.1 Gaps in cost factor data

Table 7-6 indicates that gaps exist in Australian cost factor data for most of the environmental parameters. Some of gaps are relatively minor, but other gaps are major indicating a need for significant new studies to rectify the gaps if the preferred methodology is to be adopted.

Table 7-6 Gaps in Australian cost factor data

Impact category	Data required	Gaps in Australian data	Gap type	Data issue
Air pollution	Health cost factors	Values for $PM_{2.5}$, PM_{10}, NO_2, SO_2, VOCs	Partial gap	Impact pathways ‘sixth step’ needs to be completed for each pollutant
	Non-health cost factors	Values for NO_x, VOCs, SO_2	Complete gap	No relevant studies completed in Australia
GHG emissions	GHG abatement cost factor	Range of abatement values, $CO_{2\text{-}e}$, short, medium, and long term.	Partial gap	Existing studies should be reviewed to produce a reliable range of values.
Noise pollution	Noise cost factor	Value (or range of values) expressed as $ per year per dB	Complete gap	No relevant studies completed in Australia
Water pollution	Soil pollution cost factor	Cost to decontaminate affected land in $/m3	Partial gap	No relevant studies completed in Australia but value transfer from overseas studies may be reasonable
	Water pollution cost factor	Value of reduced water quality in $/km or km^2	Complete gap	No relevant studies completed in Australia
Biodiversity (air pollution)	Air pollution biodiversity cost factor	Values for SO_2, VOCs	Complete gap	No relevant studies completed in Australia
Nature and landscape	Habitat loss and fragmentation cost factor	Values for habitats of different types and conservation status	Significant gap	Studies completed in Australia provide only a partial basis for valuation

Impact category	Data required	Gaps in Australian data	Gap type	Data issue
		Value for urban open space		
Urban barrier effect	Value of travel time	Value of travel time for pedestrians and cyclists	Partial gap	Numerous relevant Australian studies but none specifically focussed on pedestrians and cyclists
Upstream and downstream cost	Air pollution and GHG abatement cost factors	As per air pollution and GHG emission impact categories		

7.2 Availability of Australian environmental impact data

This section presents the findings of our investigation for Australian sources of environmental impact data based on the data requirement established in section 5. A variety of data sources have been identified including public databases, research papers, government reports and official guidelines. Table 7-7 is a data availability matrix for the environmental impact data. Data sources are presented as letter codes in this table. Information for the data source can be looked up by the letter code in Table 7-8. For ease of reference, the headline information for each data source is provided in Table 7-8. Further details for each data source can be found in Table A- in Appendix A.

Quality of the environmental impact data is also assessed for each source identified. Specifically, we assess the quality of data based on its relevance and comprehensiveness. Relevance is measured by the year in which the most recent data became available in the identified source. Relevance of the data source is high if its most recent data was released within the last five years. The 5-year criterion is chosen somewhat arbitrarily but it is chosen to account for environmental impacts of transport activities that took place after the last major update of ATAP PV5 in Austroads (2014). Comprehensiveness refers to the geographic coverage of the data. Comprehensiveness of the data is high if it covers the whole country rather than specific regions. This criterion is chosen because ATAP PV5 is a national guideline. Together, data quality is high if both relevance and comprehensiveness of the data source are high; medium if one of them is high; and low if neither are considered high.

Table 7-7 Data availability matrix for environmental impact data

Impact category	Data required	Source 1	Source 2	Source 3	Source 4
Air pollution	Vehicle emissions factors for air pollutants	A^{HQ}	B^{MQ}	D^{MQ}	C^{LQ}
GHG emission	Vehicle emissions factors for GHG	A^{HQ}	L^{HQ}	M^{HQ}	B^{MQ}
	Global warming potential	S^{HQ}			
Noise pollution	Total number of people exposed to transport noise	R^{MQ}	E^{LQ}	F^{LQ}	
	Weighting factors	No Australian data identified			
Soil and water pollution	Total land mass affected	G^{HQ}			
	Total waterways affected	No Australian data identified			
Biodiversity	Vehicle emissions factors	A^{HQ}	B^{MQ}		
Nature and landscape	Total network length	G^{HQ}			
Urban barrier effect	Average waiting time per pedestrian	J^{MQ}	K^{MQ}		
	Total number of urban residents	H^{HQ}			
Upstream and downstream costs	WTT emissions factors for air pollutants	No Australian data identified			
	WTT emissions factors for GHG	L^{HQ}			
	Energy consumption rate	M^{HQ}	N^{HQ}	O^{HQ}	B^{MQ}
Noise pollution	Transport performance	O^{HQ}	P^{HQ}	Q^{HQ}	
Soil and water pollution					
Nature and landscape					
Urban barrier effect					

Note: Superscripts to data sources indicate their data quality: HQ = high quality; MQ = medium quality; LQ = low quality

Table 7-8 Australian sources for environmental impact data - simplified view

Data source code	Author and Date	Geographic Coverage	Data medium	Mode	Name	Data quality
A	Emisia (2018)	National	Software	Road	COPERT[7] Australia	High[1]
B	ACG (2007)	National	Report	Rail	Australian Rail Transport Facts	Medium
C	ENVIRON (2013)	NSW	Report	Rail	Scoping Study of Potential Measures to Reduce Emissions from New and In-Service Locomotives in NSW and Australia	Low
D	LCRA (2016)	VIC	Report	Rail	Air Quality Assessment – Caufield to Dandenong	Medium
E	Brown (1994)	National	Journal article	Road	Exposure of the Australian Population to Road Traffic Noise	Low
F	Australian Government (2018)	NSW	Report	Rail	The health effect of environmental noise	Low
G	Australian Government (2016)	National	Geographic Information System (GIS) data	Road Rail	Dynamic National Map Transport Infrastructure	High
H	ABS (2020)	National	MS Excel file	Road Rail	Population Estimates by Significant Urban Area, 2009 to 2019	High
I	ATAP (2018)	National	Guideline	Road Rail	Worked Examples: W4 Active Travel – 4.1 Pedestrian / cycle signalised crossing or overpass	High
J	TMR (2020)	QLD and NSW	Report	Road	Options for reducing pedestrian delays at traffic signals	Medium

[7] COPERT stands for COmputer Program to calculate Emissions from Road Transport

Data source code	Author and Date	Geographic Coverage	Data medium	Mode	Name	Data quality
K	Jusayan (2015)	VIC	Report	Rail	Delay Due to Level Crossing	Medium
L	Australian Government (2019a)	National	Guidelines	Road Rail	National Greenhouse Accounts (NGA) Factors	High
M	Green Vehicles Guide	National	Database	Road	Green Vehicles Guide	High
N	ATAP (2016)	National	Guideline	Road	PV2 Road Parameter Values	High
O	ABS (2019)	National	MS Excel file	Road	Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2018	High
P	Australian Government (2019b)	National	Report and MS Excel file	Road Rail	Australian Infrastructure Statistics—Yearbook 2019	High
Q	Smit (2020)	National	Software	Road	The Australian Fleet Model (AFM)	High
R	Queensland Government (2020)	QLD	Online tool	Road Rail	Transport noise corridors mapping tool	Medium
S	Clean Energy Regulator (2016)	National	Guideline	Road Rail	Global warming potentials	High

Notes: Fees apply, please see Table 8-2.

7.2.1 Gaps in environmental impact data

Complete gaps

Table 7-7 suggests that gaps exist in Australian environmental impact data for calculating parameter values of noise pollution and upstream and downstream costs. Specifically, no Australia data source has been identified for the weighting factors required to calculate noise pollution parameter values or for the WTT emissions factors for air pollutants for calculating upstream and downstream costs parameter values. Because these gaps encompass entire vehicle classes or fuel types, they are hence classified as complete gaps in Table 7-9.

Partial data gaps

For impact categories other than noise pollution and upstream and downstream costs, at least one Australian source is available to meet their respective data requirements stipulated by the preferred methodologies. However, these data sources vary in their levels of coverage and aggregation which affects their potential to be used for calculating fully disaggregated environmental parameter values along the dimensions listed in Table 2-1. To provide visibility on these partial gaps in Australian data sources, detailed data availability matrices for each required data are provided in Appendix B. Table 7-9 below provides a summary of the partial data gaps identified from the detailed data availability matrices.

Table 7-9 Gaps in Australian environmental data

Impact category	Data required	Gaps in Australian data	Gap type	Data issue
Air pollution	Emissions factors	Hybrid-engine road vehicles	Partial gap	No Australian data identified for a specific vehicle class
		LPG-engine non-SUV passenger vehicles by sizes	Partial gap	Insufficiently disaggregated data by vehicle size
		Diesel engine non-SUV passenger vehicles by medium and small sizes	Partial gap	No Australian data identified for specific vehicle sizes
		Compact LPG-engine SUVs	Partial gap	No Australian data identified for a specific vehicle size
		CNG-engine buses	Partial gap	No Australian data identified for a specific vehicle class
GHG emissions	Emissions factors	CNG-engine buses	Partial gap	No Australian data identified for a specific vehicle class
Noise pollution	Weighting factor	All vehicle classes	Complete gap	No Australian data identified
	Total number of people exposed to transport noise	Noise mapping data in other states outside QLD	Partial gap	Regional data Require additional data processing
Soil and water pollution	Total waterways affected	All transport modes	Complete gap	No Australian data identified
Biodiversity	Emissions factors (NH3)	See air pollution gaps for road vehicles Diesel-engine trains	Partial gap	No Australian data identified for specific vehicle classes/sizes
Urban barrier effect	Average waiting time of pedestrians	National average waiting time	Partial gap	Regional data
Upstream and downstream cost	WTT air pollutant emission factors	All fuel types	Complete gap	No Australian data identified

Impact category	Data required	Gaps in Australian data	Gap type	Data issue
	Energy consumption rate	2-wheeler transport modes Buses Trams	Partial gap	No Australian data identified for specific vehicle classes
		Electric passenger trains by size	Partial gap	Insufficiently disaggregated data by train size

8. Data collection costs

This section provides the estimated costs for bridging data gaps identified in section 7.

The size of estimated costs also depends on the methodology taken for the data collection task. For some data gaps, multiple data collection approaches are identified. In these cases, “Option 1” represents our recommended approach, and “Option 2” represents a low-cost option that typically requires value-transfer or extrapolation based on overseas or regional data sources. It is expected that Option 1 will produce higher quality data than Option 2 but at the expense of higher data collection cost.

These cost estimates are sourced from various suppliers who are deemed to be suitably qualified for undertaking the data collection costs. Data collection costs provided by ARRB and MJA are based on our respective business costs and past project experiences.

In addition, cost breakdowns and supporting assumptions for the proposed data collection methodology are also provided for each data gap

8.1 Cost estimates for bridging gaps in cost factor data

This section provides our estimates of the potential cost associated with bridging the cost factor data gaps identified in Table 7-6. These costs are indicative and based on our recommended approach for data collection, which in some circumstances includes adapting overseas data for Australia.

Table 8-1 Cost estimates for bridging gaps in cost factor data

Impact category	Data required	Gaps in Australian data	Methodology for data collection	Source	Indicative cost[8]	Cost breakdown and assumptions
Air pollution	Health cost factors	$PM_{2.5}$, PM_{10}, NO_2, SO_2, VOCs	Apply impact pathways 'sixth step' for major pollutants drawing on data from recent Australian studies	Marsden Jacob	$100,000	Assumes damage cost estimates for five pollutants (approx. $20,000/ pollutant) covering: • each capital city • major regional centres • weighted averages for other regional centres and towns • weighted averages for rural areas. Steps include: • Review of relevant literature ($2000/pollutant) • Data compilation ($2000/pollutant) • Damage cost estimates for capital cities ($3,000/pollutant) • Damage cost estimates for major regional centres ($3,000/pollutant) • weighted averages for other regional centres and towns ($4,000/pollutant)

[8] Approximations. Estimates are based on the time and cost of work of a similar nature that has previously undertaken, or preliminary assessment of the steps required, and the time required to complete those steps.

Impact category	Data required	Gaps in Australian data	Methodology for data collection	Source	Indicative cost[8]	Cost breakdown and assumptions
						• weighted averages for rural areas ($4,000/pollutant) • reporting ($2,000/pollutant) Note, the 2nd and 3rd last steps are likely to require GIS analysis considering population and population density.
	Non-health cost factors	NOx, VOCs, SO_2	Impact pathway approach likely to be prohibitively expensive, requiring representative CRFs for building damage and crop yields to be developed for a range of locations. Therefore, continue to apply value transfer based on overseas studies. Review to ensure best practice has been adopted and update if necessary.	Marsden Jacob	$5,000 - $10,000	Approximately 2-3 days, for each of buildings and crops, to review European methods and update data, if necessary, with more specific Australian data (if available).
GHG emissions	Abatement cost factor	Range of abatement values, CO_{2-e}, short, medium, and long term.	Review recent Australian studies to generate range of values for short- and long-term emissions abatement.	Marsden Jacob	$15,000 to $20,000 -	Approximately 7-9 days of work covering: • review of Australian studies outlined in Table 7-2 ($5,000) • analysis and generation of short-, medium- and long-term abatement costs ($5,000 - $10,000) • reporting ($5,000)

Impact category	Data required	Gaps in Australian data	Methodology for data collection	Source	Indicative cost[8]	Cost breakdown and assumptions
Noise pollution	Noise damage cost factor	Value (or range of values) expressed as $ per year per dB increase	**Option 1**: Undertake a hedonic pricing study across a number of urban sites to generate Australian specific values.	Marsden Jacob	$65,000 to $100,000 plus -	Cost will depend on number of sites selected. Sites will need to be representative of different cities and different traffic conditions and noise exposure (e.g. freeways, highways, main roads). A hedonic price study covering a small number of sites of similar traffic conditions (e.g. in different cities) could entail approximately 30 days of work, costing in the order of $65,000 and entail: • study design ($5,000) • noise monitoring and analysis ($15,000) • data collection (including property market data) ($15,000) • hedonic modelling (15,000) • reporting ($15,000)
			Option 2: Alternatively, a partial value transfer approach could be applied drawing on estimates from overseas studies of the percentage impact of traffic noise on property values – typically a reduction of 0.5-1.2% per dB increase. This would be applied to Australian property data.	Marsden Jacob	$20,000 to $30,000	Approximately 8-12 days of work covering: • review of overseas studies ($5,000) • property market data collection for a range of sites ($5,000 - $12,000) • analysis ($5,000 - $8,000) • reporting ($5,000)

Impact category	Data required	Gaps in Australian data	Methodology for data collection	Source	Indicative cost[8]	Cost breakdown and assumptions
Soil and water pollution	Soil repair cost	No Australian value	Continue to apply value transfer based on overseas studies. Review to ensure best practice has been adopted and update if necessary.	Marsden Jacob	$6,000 to $10,000	Approximately 3-5 days to review European methods and update data, if necessary, with more specific Australian data (if available).
	Value of reduced water quality	No Australian value	Stated preference study into economic value of waterways impacted by roadworks	Marsden Jacob	$80,000 to $100,000	Likely to involve a choice modelling study. This will typically involve the following steps: • study design ($5,000) • choice modelling survey design and undertake ($30,000 - $40,000) • focus groups ($15,000 - $20,000) • econometric analysis and WTP valuation ($10,000 - $15,000) • reporting ($20,000).
Biodiversity (air pollution)	Air pollution biodiversity cost factor	Values for SO_2, VOCs	Impact pathway approach likely to be prohibitively expensive, requiring representative CRFs to be developed for a range of locations. Therefore, continue to apply value transfer based on overseas studies. Review to ensure best practice has been adopted and update if necessary.	Marsden Jacob	$5,000	Approximately 2-3 days to review European methods and update data, if necessary, with more specific Australian data (if available).
Nature and landscape	Habitat loss and fragmentation cost factor	Values for habitats of different types and conservation status	Stated preference study into WTP for habitats of different types and conservation status	Marsden Jacob	$80,000 to $100,000	As per value of reduced water quality choice modelling study outlined above.

Impact category	Data required	Gaps in Australian data	Methodology for data collection	Source	Indicative cost[8]	Cost breakdown and assumptions
	Urban open space loss cost factor	Value for urban open space	Hedonic price study into WTP for open space in urban areas	Marsden Jacob	$50,000 to $80,000	Cost will depend on number of sites selected. Sites will need to be representative of different cities. A hedonic price study covering a small number of sites could entail approximately 20-25 days of work, costing in the order of $50,000 and entail: • study design ($5,000) • data collection (including property market data) ($15,000) • hedonic modelling (15,000) • reporting ($15,000).
Urban barrier effect	Value of travel time	Value of travel time for pedestrians and cyclists	Value transfer drawing on existing Australian studies	Marsden Jacob	$5,000 to $8,000	Approximately 2-3 days to review Australian studies, derive estimate of value of time for cyclists and pedestrians, and write brief report.
Upstream and downstream costs	Air pollution and GHG abatement cost factors	As per air pollution and GHG emission impact categories	As per air pollution and GHG emission impact categories except that additional work will be required to ensure that air pollution cost factors reflect location of well-to-tank processing facilities.	Marsden Jacob	$6,000 to $10,000	Approximately 3-4 days to identify locations of major facilities and derive estimates of damage costs based on location and work previously undertaken for air pollution health cost factor estimates.

8.2 Cost estimates for bridging gaps in environmental impact data

This section provides our estimates on the potential cost associated with bridging the environmental impact data gaps identified in Table 7-9. These costs are indicative and based on our recommended approach for data collection, which includes adapting European data for Australia. For gaps that can be bridged by ARRB's expertise, the data collection costs are based on ARRB's business costs. For data gaps whose data collection effort requires expertise outside ARRB's capabilities, we have provided these costs based on quotes gathered from suitably qualified organisations. Cost estimates for environmental data gaps are provided in Table 8-2.

Table 8-2 Cost estimates for bridging gaps in environmental impact data

<table>
<tr><th>Impact category</th><th>Data required</th><th>Gaps in Australian data</th><th>Methodology for data collection</th><th>Source</th><th>Indicative cost[9]</th><th>Cost breakdown and assumptions</th></tr>
<tr><td rowspan="5">Air pollution</td><td rowspan="5">Emissions factors</td><td>Hybrid-engine road vehicles</td><td rowspan="6">Expand vehicle class in COPERT Australia</td><td rowspan="6">Emisia SA/ Transport Energy/Emission Research (TER)</td><td rowspan="6">Approximately, $40,000 plus GST.</td><td rowspan="6">Cost includes:
• Updating emissions factors based on 2018 fleet ($12,000) composition in Australia
• Expanding vehicle classes in COPERT Australia ($13,000)
• Training and support ($8,000 for 12 hours)
• Drafting of technical report ($11,000)
• License fee for COPERT Australia ($650)
• All prices quoted are excluding GST.</td></tr>
<tr><td>LPG-engine non-SUV passenger vehicles by sizes</td></tr>
<tr><td>Diesel engine non-SUV passenger vehicles by medium and small sizes</td></tr>
<tr><td>Compact LPG-engine SUVs</td></tr>
<tr><td>CNG-engine buses</td></tr>
<tr><td>GHG emissions</td><td>Emissions factors</td><td>CNG-engine buses</td></tr>
<tr><td>Noise pollution</td><td>Weighting factor</td><td>All vehicle classes</td><td>Adopt weighting factors in CE Delft et al. (2019)</td><td>-</td><td>-</td><td></td></tr>
</table>

[9] Approximations. Estimates are based on the time and cost of work of a similar nature that has previously undertaken, or preliminary assessment of the steps required, and the time required to complete those steps.

Impact category	Data required	Gaps in Australian data	Methodology for data collection	Source	Indicative cost[9]	Cost breakdown and assumptions
	Total number of people exposed to transport noise	Noise mapping data in other states outside QLD	**Option 1**: Develop noise maps for other states in Australia by acoustic specialists	Acoustic Engineering Services (AES) Ltd and ARRB	$160,000 to $230,000	Cost includes: • Road traffic noise mapping and generation of population noise exposure statistics - $100k to $150k per jurisdiction depending on road length and complexity of modelling (a large city can be time consuming to model due to large numbers of bridges and overpasses, tunnels need to be accounted for etc) • Rail traffic noise mapping and generation of population noise exposure statistics - $30k to $50k per jurisdiction depending on rail length and complexity again. This assumes the models have already been built during the road traffic noise modelling stage • $30,000 for ARRB to use the noise mapping data and spatial census data to determine the total number of people exposed to transport noise.
			Option 2: Develop noise pollution parameter values based on QLD noise exposure data	ARRB	Approximately $30,000	• ~$10,000 for undertaking workshop between jurisdictions to discuss the suitability of using Qld noise data in other states and, • ~$20,000 to use Qld noise mapping data as input to generate population exposure data in a GIS software.

Impact category	Data required	Gaps in Australian data	Methodology for data collection	Source	Indicative cost[9]	Cost breakdown and assumptions
Soil and water pollution	Water mass affected	Estimating the level of contamination adjacent to transport networks	Specialised study led by ARRB in partnership with a suitably qualified hydrologist.	ARRB	$100,000	Cost includes: • $70,000 for subcontracting hydrologist • $20,00 for consulting with relevant data holders (e.g. Water authorities and water quality unit within state transport departments) • $10,000 project management fee by ARRB)
Biodiversity	Emissions factors (NH3)	See air pollution gaps for road vehicles	Expand vehicle class in COPERT Australia	Emisia SA/ Transport Energy/Emission Research (TER)	Included in the cost for gaps air pollution emission factors	-
		Diesel-engine trains	Convert from European emission factors	ARRB	$7,000~$15,000	Cost includes • Data purchase cost round $2,000 – $10,000 • Data processing cost: $5,000
Urban barrier effect	Average waiting time of pedestrians	National average waiting time	**Option 1**: Observational study and intercept interviews at major city centres	ARRB	$50,000 to $80,000	Cost includes: • Study design 10,000 • Field data collection ($20,000 – $50,000, depending on number of observation sites) • Data analysis ($10,000) • Report preparation ($10,000)
			Option 2: Develop urban barrier effect parameter values based on Brisbane and Sydney data	ARRB	$5,000	Cost includes: • workshop between jurisdictions to discuss the suitability of using Qld waiting time data in other states

Impact category	Data required	Gaps in Australian data	Methodology for data collection	Source	Indicative cost[9]	Cost breakdown and assumptions
Upstream and downstream cost	WTT air pollutant emission factors	All fuel types	Convert from European data	ARRB	$10,000 – $20,000	Cost includes • Data purchase costs for TREMOD model ($5,000 – $15,000) • ARRB fee for converting the data to suit Australian context ($5,000)
	Energy consumption rate	2-wheeler transport modes Buses Trams	Contact vehicle manufactures to obtain indicative figure	ARRB	$10,000	Cost includes: • undertaking interview with manufacturers ($7,500) and • desktop research ($2,500)
		Electric passenger trains by size	Contact vehicle manufactures to obtain indicative figure	ARRB	$10,000	

8.3 Summary of data collection costs

This section presents a summary of data collection costs presented in Table 8-1 and Table 8-2.

Table 8-3 Summary of data collection costs

Impact category	Cost for collecting cost factor data		Cost for collecting environmental impact data		Total cost	
	Recommended approach	**Low cost approach**	**Recommended approach**	**Low cost approach**	**Recommended approach**	**Low cost approach (if available)**
Air pollution	$105,000 to $110,000	N/A	$20,000	N/A	$125,000 to $130,000	N/A
GHG	$15,000 to $20,000	N/A	$20,000	N/A	$35,000 to $40,000	N/A
Noise pollution	$65,000 to $100,000	$20,000 to $30,000	$160,000[1] to $230,000[1]	$30,000	$225,000[1] to $330,000[1]	$50,000 to $60,000
Soil and water pollution	$86,000 to $101,000	N/A	$100,000	N/A	$186,000 to $201,000	N/A
Biodiversity	$5,000	N/A	$7,000 to $15,000	N/A	$12,000 to $20,000	N/A
Nature and landscape	$130,000 to $180,000	N/A	N/A	N/A	$130,000 to $180,000	N/A
Urban barrier effect	$5,000 to $8,000	N/A	$50,000 to $80,000	$5,000	$55,000 to $88,000	$10,000 to $13,000
Upstream and downstream cost	$6,000 to $10,000	N/A	$30,000 to $40,000	N/A	$36,000 - $50,000	N/A
Total cost					**$804,000 to $1,039,000**	**$584,000 to $694,000**

Table notes:

1. Cost estimate is for each state in Australia

9. Expected scale of difference between Australian-based and European-based parameter values

In this section, we provide a brief discussion on the anticipated scale of difference between Australian-based and European-based parameter values. We base our expectations on the known differences in the main cost drivers between Europe and Australia for each impact category.

Table 9-1 presents the main cost drivers in each impact category and their expected differences between Europe and Australia.

Table 9-1 Expected scale of difference between Australia-based and European-based environmental parameter values

Impact category	Main cost driver	Known differences in cost drivers between Australia and Europe	Expected scale of difference between Australian-based and European-based parameter values
Air pollution	Health cost of air pollution	Uncertain Australian cities and rural areas generally have significantly lower population densities than in Europe. There are also possible differences in concentration response functions between Europe and Australia. Austroads estimates based on value transfer include adjustments to account for these differences. It is possible that adjustments have over compensated. PAE Holmes & Marsden Jacob (2013) applied both impact pathway and benefit transfer approaches to estimating costs of $PM_{2.5}$. The former produced estimates 1.5x benefit transfer values on average. Marsden Jacob (2018) took a similar approach, with impact pathway estimates being approximately 5% > benefit transfer estimates.	Up to plus or minus 50%
	Emission factor	Higher in Australia This is based on the fact that Europe has implemented more stringent air pollution vehicle regulations (Euro 6) than Australia (Euro 5). For example, the NOx emission rate is 55% lower in Euro 6 than Euro 5.	
GHG emission	Cost of climate change	Similar Based on the avoidance cost approach, the cost to implement low emission technologies are expected to be similar between Europe and Australia	At least 5% higher in Australia
	Emission factor	Higher in Australia	

Impact category	Main cost driver	Known differences in cost drivers between Australia and Europe	Expected scale of difference between Australian-based and European-based parameter values
		NTC reports suggests that Australian vehicles emit 41% more GHG than Europeans vehicles.[10]	
Noise pollution	Health cost of noise pollution	Similar We expect similar physiological reaction to transport noise exposure between Europeans and Australians. However, method proposed for assessing costs of impacts is significantly different to that proposed for Australia	At least 5% lower in Australia
	Total number of people exposed to traffic noise	Significantly smaller in Australia This is due to the significantly lower population density in Australia.	
Soil and water pollution	Soil repair cost	Similar The cost to decontaminate lands is expected to be similar between Europe and Australia	Insignificant difference expected
	Value of reduced water quality	Uncertain, but this impact is not effectively captured in European studies	
Biodiversity (air pollution)	Damage cost caused by NH_3	Exposure of biodiversity to air pollutants will generally be higher in Australia	At least 10% higher in Australia
Nature and Landscape	Habitat loss and fragmentation cost	Australia is significantly richer in flora and fauna than Europe. This is evidenced by Australia's National Biodiversity Index (NBI) of 0.853. In contrast, NBI is 0.365 for Germany and 0.423 for France.[11]	Substantially higher in Australia
Urban barrier effect	Value of time for pedestrians	Uncertain	10% higher or lower

[10] https://www.ntc.gov.au/sites/default/files/assets/files/Carbon-dioxide-emissions-intensity-for-new-Australian-light-vehicles-2019.pdf

[11] https://www.cbd.int/gbo1/annex.shtml

Impact category	Main cost driver	Known differences in cost drivers between Australia and Europe	Expected scale of difference between Australian-based and European-based parameter values
Upstream and downstream costs	WTT emission factors	Significantly higher in Australia In the case of electricity, WTT air pollution and GHG emissions are likely to be much higher in Australia than Europe due to the wide use of nuclear power plants in Europe to generate electricity. According to the International Energy Agency, the average carbon intensity of electricity generation was about 307gCO_2/kWh in the European Union and 740 gCO_2/kWh in Australia in the year of 2015.	50-150% higher in Australia.

10. Conclusions

To facilitate the development of Australian-based environmental parameter values, this scoping study has been prepared with the objectives to:

- identify the preferred methodology for developing Australian-based environmental parameter values
- establish the availability of Australian data sources to implement the preferred methodologies
- estimate the data collection costs for bridging the identified gaps in Australian data sources.

Based on the criteria of impact coverage, transparency and time of publication, the methodologies for valuing the environmental impacts of transport in CE Delft et al. (2011) and CE Delft et al. (2019) have been identified as the preferred methodologies for calculating the eight environmental impact of transport activities.

Based on the preferred methodologies, the availability of Australian-based data for cost factors and environmental impact of transport are investigated. For cost factors, complete data gaps exist in the crop and building damage cost due to air pollution, health cost due to noise pollution, cost of water pollution, and the damage cost of biodiversity loss due to air pollution. Significant data gap is found in the loss and fragmentation of habitat cost due to nature and landscape impacts. Partial data gaps are found in all other cost factors.

Estimated cost for data collection tasks depends on whether it is appropriate to utilise existing data from other jurisdictions. For bridging major gaps in cost factor data, the cost to commission an Australian study is estimated to range from $100,000 to $200,000. For data gaps that have been deemed acceptable for utilising existing overseas data, data collection based on a value-transfer approach will cost around $10,000 to $50,000.

For data that measures the environmental impact of transport, complete gaps are found in Australian data that prevent quantifying the noise impact and the upstream and downstream impact of all transport modes. Partial data gaps are found in other six impact categories. However, the partial data gaps typically only prevent the development of environmental parameter values for specific vehicle classes.

For bridging gaps in environmental impact data, a value-transfer approach will cost around $0 to $50,000 depending on the cost to purchase overseas data. On the other hand, the cost for collecting local data is around $20,000 to $80,000 per data gap depending on the complexity of the data collection task.

Table 10-1 summarises the main findings of the scoping study for each impact category in terms of the preferred methodology for calculating them, the gaps in Australian data sources for implementing the preferred methodology, the estimated cost for the data collection option, and the anticipated scale of difference between current ATAP environmental parameter values and Australian-based parameter values.

Table 10-1 Summary of findings of the scoping study

Impact category	Data gap		Data collection cost		Expected scale of difference between European-based and Australian-based parameter values
	Cost factor data	Environmental impact data	Recommended approach	Lower cost alternative	
Air pollution	Partial gap in health cost Complete gap in non-health cost	Partial gap in emission factor for some vehicle classes	$125,000 to $130,000	N/A	Uncertain (Up to 50% higher or lower in Australia)
GHG	Partial gap in abatement cost	Partial gap in emission factor for some vehicle classes	$35,000 to $40,000	N/A	At least 5% higher in Australia
Noise pollution	Complete gap in noise cost	Partial gap in noise mapping in some states Complete gap on noise weighting factor for all vehicle classes	$225,0001 to $330,0001	$50,000 to $60,000	At least 5% lower in Australia
Soil and water pollution	Partial gap in soil pollution cost Complete gap in water pollution cost	Complete gap in total waterways affected	$186,000 to $201,000	N/A	Insignificant difference expected
Biodiversity	Complete gap in biodiversity cost	Partial gap in emission factor for some vehicle classes	$12,000 to $20,000	N/A	At least 10% higher in Australia
Nature and landscape	Significant gap in habitat loss and fragmentation cos	No gap identified	$130,000 to $180,000	N/A	Substantially higher in Australia
Urban barrier effect	Partial gap in value of travel time	Partial gap in average waiting time for pedestrians in some states	$55,000 to $88,000	$10,000 to $13,000	Uncertain (10% higher or lower in Australia)
Upstream and downstream cost	Partial gap in health cost Complete gap in non-health cost	Partial gaps in energy consumption rate for some vehicle classes Complete gap in WTT air pollutant emission factors for all vehicle classes	$36,000 - $50,000	N/A	50-150% higher in Australia.

Appendix A. Australian sources for environmental impact data

Table A-1 Details of Australia sources for environmental impact data

Data source code	Author and Date	Data medium	Data type	Impact category	Mode	Name and Description	Note	Data quality
A	Emisia (2018)	Software	Emission factor	Air pollution GHG emission	Road	Name: COPERT Australia[12] COPERT is a globally used software tool used to calculate air pollutant and greenhouse gas emissions produced by road transport. Scientific development is managed by the European Commission. CE Delft et al. (2019) sourced the emission factors for air pollutants from COPERT. COPERT Australia is a dedicated Australian version of COPERT was developed in 2012-13 to properly reflect the Australian fleet mix, fuel quality and driving characteristics and to provide vehicle emission estimates for the Australian situation. The National Pollutant Inventory recommends COPERT Australia for motor vehicle emission inventories and it has been used to estimate motor vehicle emissions for all states and territories in Australia. COPERT Australia only provides emission factors of automobiles and not for trains.	COPERT Australia can be downloaded from https://www.emisia.com/utilities/copert-australia/ License fee for the software is 350 Euros per year. Included in this price are emission factors based on Australian fleet composition in 2010 Additional fees apply for emission factors based on more recent Australian fleet composition	High

[12] COPERT stands for COmputer Program to calculate Emissions from Road Transport

Data source code	Author and Date	Data medium	Data type	Impact category	Mode	Name and Description	Note	Data quality
B	ACG (2007)	Report	Emission factor Energy consumption rate	Air pollution GHG emission Upstream and downstream	Rail	Title: Australian Rail Transport Facts Report commissioned by the Australian Transport Energy Data and Analysis Centre. The purpose of this report is to provide various facts of the Australian rail industry. The report provides energy intensity factor in rail transport units and emission factors in energy units for both passenger and freight rail trains for a variety of air pollutants	Emission factors in transport units can be calculated by multiplying energy intensity in transport units to emission factors in energy units. The report can be accessed via https://ara.net.au/sites/default/files/Australian%20Rail%20Transport%20Facts%202007.pdf	Medium
C	ENVIRON (2013)	Report	Emission factor	Air pollution	Rail	Title: Scoping Study of Potential Measures to Reduce Emissions from New and In-Service Locomotives in NSW and Australia The report was commissioned by EPA NSW. This study was undertaken to identify measures to reduce particulate matter emissions and NOx emissions from new and in-service locomotives in NSW and Australia. Freight rail emission factors for particulate matters and NOx is provided in this report	Emission factors based on Canadian study Report can be accessed via https://www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/air/locoemissrep.ashx	Low
D	LCRA (2016)	Report	Emission factor	Air pollution	Rail	Title: Air Quality Assessment – Caufield to Dandenong Report is prepared by the Level Crossing Removal Authority in Victoria. This report has been prepared to assess air quality for the proposed design of the Caulfield to Dandenong Level Crossing Removal Project.	Emission factors based on diesel engine passenger trains in Victoria Report can be accessed via https://levelcrossings.vic.gov.au/__data/assets/pdf_file/0019/213292/CTD-Air-Quality-Report-October-2016.pdf	Medium

Data source code	Author and Date	Data medium	Data type	Impact category	Mode	Name and Description	Note	Data quality
						Passenger rail emission factors for particulate matters and NOx is provided in this report		
E	Brown (1994)	Journal article	Number of people exposed to transport noise	Noise pollution	Road	Title: Exposure of the Australian Population to Road Traffic Noise A research article published in 1994 Provides an estimation on the percentage of Australian population exposed to road traffic noise by five noise bins above 55 dB.	The estimation is based on statistical extrapolation from a random sample of 264 urban dwellings and not based on noise modelling Estimation based on spatial noise modelling and updated more data is preferred	Low
F	Australian Government (2018)	Report	Number of people exposed to transport noise	Noise pollution	Rail	Title: The health effect of environmental noise The report is prepared and published by the Commonwealth Department of Health in 2018. Provides the percentage of people exposed to train operations in noise bins	Exposure is estimated for residents who live along two metropolitan railway lines in Sydney in 2002.	Low
G	Australian Government (2016)	Geographic Information System (GIS) data	Total land mass affected Total network length	Soil and water Nature and landscape	Road Rail	Name: Dynamic National Map Transport Infrastructure Geoscience Australia is the custodian of national GIS topological data on road and rail networks Total land mass effected and total network length can be computed using the GIS data using a GIS software such as ArcMap or QGIS	The GIS data for total road and rail network length can be downloaded via http://services.ga.gov.au/gis/rest/services/NM_Transport_Infrastructure/MapServer	High
H	ABS (2020)	MS Excel file	Total number of people	Urban barrier effect	Road Rail	Name: Population Estimates by Significant Urban Area, 2009 to 2019 ABS (2020) provides data on the number of residents living in urban and rural areas.	The ABS data population in significant urban areas can be downloaded via https://www.abs.gov.au/statistics/people/population/regional-population/2018-19/32180ds0003_2009-19.xls	High

Data source code	Author and Date	Data medium	Data type	Impact category	Mode	Name and Description	Note	Data quality
						Significant Urban Areas (SUAs) represent concentrations of urban development with a population of 10,000 or more using whole Statistical Areas Level 2 (SA2s).		
I	ATAP (2018)	Guideline	Average value of time for pedestrians	Urban barrier effect	Road Rail	Name: Worked Examples: W4 Active Travel – 4.1 Pedestrian / cycle signalised crossing or overpass A sample cost-benefit analysis produced by ATAP Provides an average value of travel time for active travellers (walkers and cyclists)	Average value of travel time is provided on page 4 of the report The report can be downloaded via https://www.atap.gov.au/sites/default/files/w4-active-travel-4.1-ped-crossing-overpass.pdf	High
J	TMR (2020)	Report	Average waiting time per pedestrian	Urban barrier effect	Road	Title: Options for reducing pedestrian delays at traffic signals Guidelines for reducing pedestrians delays at traffic signals prepared by the Queensland Department of Transport and Main Roads Provides estimated average waiting time of pedestrians walking in the CBS	The average waiting time is estimated as a fraction of travel time for an average walking trip completed within Brisbane and Sydney CBDs due to road traffic Average journal time on foot in high-use area is also provided – around 10 minutes Report can be accessed via https://www.tmr.qld.gov.au/-/media/busind/techstdpubs/Cycling/Guideline-Options-for-reducing-pedestrian-delays-at-traffic-signals-.pdf?la=en	Medium
K	Jusayan (2015)	Report	Average waiting time per pedestrian	Urban barrier effect	Rail	Title: Delay Due to Level Crossing A VicRoads report that documented the traffic delay caused by the level-crossings in Victoria Provides average waiting time at the boom gate in minutes	Differentiated waiting time by day type (weekday vs weekend) and time-of-day (AM peak, off peak and PM peak) The report can be accessed via https://levelcrossings.vic.gov.au/__data/assets/pdf_file/0004/216337/APPENDIX-C-Assessment-of-Delays-at-Level-Crossings.PDF	Medium

Data source code	Author and Date	Data medium	Data type	Impact category	Mode	Name and Description	Note	Data quality
L	Australian Government (2019a)	Guidelines	Emission factor	Upstream and downstream	Road Rail	Title: National Greenhouse Accounts (NGA) Factors The NGA Factors are prepared by the Department of Environment and Energy and is designed for use by companies and individuals to estimate greenhouse gas emissions. Scope 3 GHG emission factors are included for a variety of transport fuel and electricity for end users. Scope 3 emission factors reported in NGA Factors are indirect emissions attributable to the extraction, production and transport of fossil fuels consumed; indirect emissions from the extraction, production and transport of fuel burned at generation and the electricity lost in delivery in the T&D network for electricity consumed	Emission factors for GHG are measured in units of CO2-equivalent per energy units (GJ for fossil fuel and kWh for electricity) Hence, energy content of fossil fuel are needed to convert emission factors to units of fuel consumption rate – provided in table 4 of NGA Factors The guideline can be accessed via https://www.industry.gov.au/sites/default/files/2020-07/national-greenhouse-accounts-factors-august-2019.pdf	High
M	Green Vehicles Guide	Database	Emission factor Fuel consumption rate	GHG Upstream and downstream	Road	Name: Green Vehicles Guide Green Vehicle Guide is an online database of energy efficiency and emission information for all passenger vehicles and light commercial vehicles sold in Australia Energy consumption rate is provided for both fossil fuel and electric vehicles GHG emission factor is provided for both tailpipe emission and lifecycle emission	Data is disaggregated provided for each specific model of vehicles May need account for fleet composition to derive fuel/energy consumption rate at the vehicle class level Link to the online database is via https://www.greenvehicleguide.gov.au/	High

Data source code	Author and Date	Data medium	Data type	Impact category	Mode	Name and Description	Note	Data quality
N	ATAP (2016)	Guideline	Fuel consumption rate	Upstream and downstream	Road	Name: PV2 Road Parameter Values Provides fuel consumption for base fuel and coefficients to adjust for road conditions Estimates are provided for 20 vehicle classes	Does not specify the type of fuel associated with the estimates Estimates are for rural roads only The guideline is currently undergoing updates Link to the guideline: https://www.atap.gov.au/sites/default/files/pv2_road_parameter_values.pdf	High
O	ABS (2019)	MS Excel file	Transport performance data Fuel consumption rate	Noise pollution Soil and water Nature and landscape Urban barrier effect Upstream and down stream	Road	Name: Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2018 ABS (2019) provides vehicle-kilometre-travelled data disaggregated by vehicle type, location and fuel type For commercial vehicles, freight volume moved in tonne-kilometre-travelled is disaggregated by vehicle size and fuel type. Fuel consumption rate is disaggregated by fuel type and fuel type	Passenger vehicles data are not disaggregated by size Microdata – more disaggregated data are available for purchase from ABS ABS (2019) can be accessed via https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/12-months-ended-30-june-2018/92080do001_1202201810.xls	High
P	Australian Government (2019b)	Report and MS Excel file	Transport performance data	Noise pollution Soil and water Nature and landscape Urban barrier effect	Road Rail	Title: Australian Infrastructure Statistics—Yearbook 2019 Transport performance data is provided for in vkt, pkm and tkm Data is disaggregated by mode and not by vehicle size, fuel type or location	Data can be accessed via https://www.bitre.gov.au/publications/2019/yearbook_2019	High
Q	Smit (2020)	Software	Transport performance data	Noise pollution Soil and water	Road	Name: The Australian Fleet Model (AFM) is a proprietary software that provides estimates of vkt for a wide range of vehicle classes	A fee is required to use the transport performance data generated by the AFM	High

Data source code	Author and Date	Data medium	Data type	Impact category	Mode	Name and Description	Note	Data quality
				Nature and landscape Urban barrier effect		AFM is developed by the same company managing COPERT Australia		
R	Queensland Government (2020)	Online tool	Total number of people exposed to transport noise	Noise pollution	Road Rail	Name: Transport noise corridors mapping tool A noise exposure tool developed by the Queensland Government. Can be used with ABS census population data at the mesh block level to determine the total number of people exposed to transport noise in Queensland	The tool can be accessed via https://www.business.qld.gov.au/industries/building-property-development/building-construction/laws-codes-standards/queensland-development-code/transport-noise-corridor-search	Medium

Appendix B. Detailed coverage by Australian environmental impact data

Appendix B.1 Air pollution

Data sources represented by letter keys can be looked up in Table A-1 and "?" indicates no Australian data source has been identified.

Table B-1 Data coverage for air pollution emission factors

Mode	Size	Fuel	Air pollutant emission factors									
			Urban					Rural				
			VOC	SO_2	NO_x	$PM_{2.5}$	PM_{10}	VOC	SO_2	NO_x	$PM_{2.5}$	PM_{10}
2-wheelers	e-bike	Electric	-	-	-	-	-	-	-	-	-	-
	Scooters/Mopeds	Petrol	A	A	A	A	A	A	A	A	A	A
		Electric	-	-	-	-	-	-	-	-	-	-
	Motorcycle	Petrol	A	A	A	A	A	A	A	A	A	A
		Electric	-	-	-	-	-	-	-	-	-	-
Passenger cars	Small	Petrol	A	A	A	A	A	A	A	A	A	A
		LPG	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]
		Diesel	A	A	A	A	A	A	A	A	A	A
		Hybrid	?	?	?	?	?	?	?	?	?	?
		Electric	-	-	-	-	-	-	-	-	-	-
	Medium	Petrol	A	A	A	A	A	A	A	A	A	A
		LPG	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]
		Diesel	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]
		Hybrid	?	?	?	?	?	?	?	?	?	?

Mode	Size	Fuel	Air pollutant emission factors									
			Urban					Rural				
			VOC	SO_2	NO_x	$PM_{2.5}$	PM_{10}	VOC	SO_2	NO_x	$PM_{2.5}$	PM_{10}
		Electric	-	-	-	-	-	-	-	-	-	-
	Large	Petrol	A	A	A	A	A	A	A	A	A	A
		LPG	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]
		Diesel	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]
		Hybrid	?	?	?	?	?	?	?	?	?	?
SUV	Compact	Petrol	A	A	A	A	A	A	A	A	A	A
		LPG	?	?	?	?	?	?	?	?	?	?
		Diesel	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]
		Hybrid	?	?	?	?	?	?	?	?	?	?
		Electric	-	-	-	-	-	-	-	-	-	-
	Large	Petrol	A	A	A	A	A	A	A	A	A	A
		LPG	?	?	?	?	?	?	?	?	?	?
		Diesel	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]	A[1]
		Hybrid	?	?	?	?	?	?	?	?	?	?
		Electric	-	-	-	-	-	-	-	-	-	-
Buses and coaches	Light (Urban buses and busway)	Diesel	A	A	A	A	A	A	A	A	A	A
		CNG	?	?	?	?	?	?	?	?	?	?
		Electric	-	-	-	-	-	-	-	-	-	-
	Heavy (Coaches)	Diesel	A	A	A	A	A	A	A	A	A	A
		CNG	?	?	?	?	?	?	?	?	?	?
		Electric	-	-	-	-	-	-	-	-	-	-

Mode	Size	Fuel	Air pollutant emission factors									
			Urban					Rural				
			VOC	SO_2	NO_x	$PM_{2.5}$	PM_{10}	VOC	SO_2	NO_x	$PM_{2.5}$	PM_{10}
Passenger rail	Tram	Electric	-	-	-	-	-	-	-	-	-	-
	Metro Single-Decker	Electric	-	-	-	-	-	-	-	-	-	-
	Metro Double-Decker	Electric	-	-	-	-	-	-	-	-	-	-
	Regional /Inter-City	Diesel	B	B	B,D[3]	B,D	B,D	B	B	B,D[3]	B,D	B,D
Freight rail	-	Diesel	B	B	B,C	B,C	B,C	B	B	B,C	B,C	B,C
Road Freight	Small – Freight	Petrol	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]
		Diesel	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]	A[4]
	Rigid trucks	Petrol	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]
		Diesel	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]
	Articulated trucks	Diesel	A	A	A	A	A	A	A	A	A	A

Notes:

1. Emission factor LPG-engine cars is not disaggregated by vehicle size
2. Assumes same emission factor is for medium to large diesel-engine cars
3. Emission factor is estimated as NO_2
4. Corresponding vehicle class in COPERT Australia is Light Commercial Vehicle (LCV)
5. Corresponding vehicles classes in COPERT Australia are Medium Commercial Vehicle (MCV) and Heavy Commercial Vehicle (HCV). Petrol- and diesel-engine emission factors are separately available for Medium Commercial Vehicle (MCV). For HCV, only diesel-engine emission factor is available.

Appendix B.2 GHG emissions

Data sources represented by letter keys can be looked up in Table A-1 and “?” indicates no Australian data source has been identified.

Table B-2 Data coverage for GHG emission factors

Mode	Size	Fuel	Urban				Rural			
			CO_2	N_2O	CH_4	$CO_{2\text{-}eq}$	CO_2	N_2O	CH_4	$CO_{2\text{-}eq}$
2-wheelers	e-bike	Electric	-	-	-	-	-	-	-	-
	Scooters/Mopeds	Petrol	A	A	A	M	A	A	A	M
		Electric	-	-	-	-	-	-	-	-
	Motorcycle	Petrol	A	A	A	M	A	A	A	M
		Electric	-	-	-	-	-	-	-	-
Passenger cars	Small	Petrol	A	A	A	M	A	A	A	M
		LPG	A[1]	A[1]	A[1]	M	A[1]	A[1]	A[1]	M
		Diesel	A	A	A	M	A	A	A	M
		Hybrid	M	M	M	M	M	M	M	M
		Electric	-	-	-	-	-	-	-	-
	Medium	Petrol	A	A	A	M	A	A	A	M
		LPG	A[1]	A[1]	A[1]	M	A[1]	A[1]	A[1]	M
		Diesel	A[2]	A[2]	A[2]	M	A[2]	A[2]	A[2]	M
		Hybrid	M	M	M	M	M	M	M	M
		Electric	-	-	-	-	-	-	-	-
	Large	Petrol	A	A	A	M	A	A	A	M
		LPG	A[1]	A[1]	A[1]	M	A[1]	A[1]	A[1]	M
		Diesel	A[2]	A[2]	A[2]	M	A[2]	A[2]	A[2]	M
		Hybrid	M	M	M	M	M	M	M	M
SUV	Compact	Petrol	A	A	A	M	A	A	A	M
		LPG	?	?	?	M	?	?	?	M
		Diesel	A[1]	A[1]	A[1]	M	A[1]	A[1]	A[1]	M
		Hybrid	?	?	?	M	?	?	?	M
		Electric	-	-	-	-	-	-	-	-
	Large	Petrol	A	A	A	M	A	A	A	M
		LPG	?	?	?	M	?	?	?	M
		Diesel	A[1]	A[1]	A[1]	M	A[1]	A[1]	A[1]	M
		Hybrid	?	?	?	M	?	?	?	M
		Electric	-	-	-	-	-	-	-	-
Buses and coaches	Light (Urban buses and busway)	Diesel	A	A	A	?	A	A	A	?
		CNG	?	?	?	?	?	?	?	?
		Electric	-	-	-	-	-	-	-	-

Mode	Size	Fuel	Urban				Rural			
			CO_2	N_2O	CH_4	$CO_{2\text{-eq}}$	CO_2	N_2O	CH_4	$CO_{2\text{-eq}}$
	Heavy (Coaches)	Diesel	A	A	A	?	A	A	A	?
		CNG	?	?	?	?	?	?	?	?
		Electric	-	-	-	-	-	-	-	-
Passenger rail	Tram	Electric	-	-	-	-	-	-	-	-
	Metro Single-Decker	Electric	-	-	-	-	-	-	-	-
	Metro Double-Decker	Electric	-	-	-	-	-	-	-	-
	Regional/ Inter-City	Diesel	B	B	B	?	B	B	B	?
Freight rail	-	Diesel	B	B	B	?	B	B	B	?
Road Freight	Small – Freight	Petrol	A[2]	A[2]	A[2]	?	A[2]	A[2]	A[2]	?
		Diesel	A[2]	A[2]	A[2]	?	A[2]	A[2]	A[2]	?
	Rigid trucks	Petrol	A[3]	A[3]	A[3]	?	A[3]	A[3]	A[3]	?
		Diesel	A[3]	A[3]	A[3]	?	A[3]	A[3]	A[3]	?
	Articulated trucks	Diesel	A	A	A	?	A	A	A	?

Notes:

1. Emission factor LPG-engine cars is not disaggregated by vehicle size
2. Corresponding vehicle class in COPERT Australia is Light Commercial Vehicle (LCV)
3. Corresponding vehicles classes in COPERT Australia are Medium Commercial Vehicle (MCV) and Heavy Commercial Vehicle (HCV). Petrol- and diesel-engine emission factors are separately available for Medium Commercial Vehicle (MCV). For HCV, only diesel-engine emission factor is available.

Appendix B.3 Noise pollution

Data sources represented by letter keys can be looked up in Table A-1 and "?" indicates no Australian data source has been identified.

Table B-3 Data coverage for number of people exposed to transport noise

	Number of people exposed to transport noise	
	Urban	Rural
Road	E,R	R
Rail	F,R	R

Appendix B.4 Soil and water pollution

Data sources represented by letter keys can be looked up in Table A-1 and "?" indicates no Australian data source has been identified.

Table B-4 Data coverage for land mass affected by transport activities

	Land mass affected	
	Urban	Rural
Road	G	G
Rail	G	G

Appendix B.5 Biodiversity

Data sources represented by letter keys can be looked up in Table A-1 and "?" indicates no Australian data source has been identified.

Table B-5 Data coverage for emission factors with biodiversity impacts

Mode	Size	Fuel	NH_3	
			Urban	Rural
2-wheelers	e-bike	Electric	-	-
	Scooters/Mopeds	Petrol	A	A
		Electric	-	-
	Motorcycle	Petrol	A	A
		Electric	-	-
Passenger cars	Small	Petrol	A	A
		LPG	A[1]	A[1]
		Diesel	A	A
		Hybrid	?	?
		Electric	-	-
	Medium	Petrol	A	A
		LPG	A[1]	A[1]
		Diesel	A[2]	A[2]

Mode	Size	Fuel	NH_3	
			Urban	Rural
		Hybrid	?	?
		Electric	-	-
	Large	Petrol	A	A
		LPG	A[1]	A[1]
		Diesel	A[2]	A[2]
		Hybrid	?	?
SUV	Compact	Petrol	A	A
		LPG	?	?
		Diesel	A[1]	A[1]
		Hybrid	?	?
		Electric	-	-
	Large	Petrol	A	A
		LPG	?	?
		Diesel	A[1]	A[1]
		Hybrid	?	?
		Electric	-	-
Buses and coaches	Light (Urban buses and busway)	Diesel	A	A
		CNG	?	?
		Electric	-	-
	Heavy (Coaches)	Diesel	A	A
		CNG	?	?
		Electric	-	-
Passenger rail	Tram	Electric	-	-
	Metro Single-Decker	Electric	-	-
	Metro Double-Decker	Electric	-	-
	Regional/ Inter-City	Diesel	?	?
Freight rail	-	Diesel	?	?
Road Freight	Small – Freight	Petrol	A[2]	A[2]
		Diesel	A[2]	A[2]
	Rigid trucks	Petrol	A[3]	A[3]
		Diesel	A[3]	A[3]
	Articulated trucks	Diesel	A	A

Notes:

1. Emission factor LPG-engine cars is not disaggregated by vehicle size
2. Corresponding vehicle class in COPERT Australia is Light Commercial Vehicle (LCV)
3. Corresponding vehicles classes in COPERT Australia are Medium Commercial Vehicle (MCV) and Heavy Commercial Vehicle (HCV). Petrol- and diesel-engine emission factors are separately available for Medium Commercial Vehicle (MCV). For HCV, only diesel-engine emission factor is available

Appendix B.6 Nature and landscape

Data sources represented by letter keys can be looked up in Table A-1 and "?" indicates no Australian data source has been identified.

Table B-6 Data coverage for transport network lengths

	Total network length	
	Urban	Rural
Road	G	G
Rail	G	G

Appendix B.7 Urban barrier effect

Data sources represented by letter keys can be looked up in Table A-1 and "?" indicates no Australian data source has been identified.

Table B-7 Data coverage for urban barrier effect for waiting time, value of time and number of residents

	Urban		
	Average waiting time per pedestrian at a crossing	Average value of time per person	Total number of residents
Road	J	I	H
Rail	K	I	H

Appendix B.8 Upstream and downstream costs

Data sources represented by letter keys can be looked up in Table A-1 and "?" indicates no Australian data source has been identified.

Table B-8 Data coverage for WTT emission factors

	Well-to-tank emission factor					
	VOC	SO_2	NO_x	$PM_{2.5}$	PM_{10}	GHG
Petrol	?	?	?	?	?	L
LPG	?	?	?	?	?	L
Diesel	?	?	?	?	?	L
CNG	?	?	?	?	?	L
Electricity	?	?	?	?	?	L

Table B-9 Data coverage for fuel/energy consumption rates

Mode	Size	Fuel	Fuel/energy consumption rate	
			Urban	Rural
2-wheelers	e-bike	Electric	?	?
	Scooters/Mopeds	Petrol	A	A
		Electric	?	?
	Motorcycle	Petrol	A	A,N[5]
		Electric	?	?
Passenger cars	Small	Petrol	M	M,N[5]
		LPG	A[1]	A[1],N[5]
		Diesel	A	A,N[5]
		Hybrid	M	M
		Electric	M	M
	Medium	Petrol	A	A,N[5]
		LPG	A[1]	A[1],N[5]
		Diesel	A[2]	A[2],N[5]
		Hybrid	M	M
		Electric	M	M,N[5]
	Large	Petrol	A	A,N[5]

Mode	Size	Fuel	Fuel/energy consumption rate	
			Urban	Rural
		LPG	A[1]	A[1],N[5]
		Diesel	A[2]	A[2],N[5]
		Hybrid	M	M
SUV	Compact	Petrol	A	A,N[5]
		LPG	M	N[5]
		Diesel	A[1]	A[1],N[5]
		Hybrid	M	N[5]
		Electric	M	M
	Large	Petrol	A	A, N[5]
		LPG	M	N[5]
		Diesel	A[1],M	A[1],N[5]
		Hybrid	M	M
		Electric	M	M
Buses and coaches	Light (Urban buses and busway)	Diesel	A	A
		CNG	?	?
		Electric	?	?
	Heavy (Coaches)	Diesel	?	N[5]
		CNG	?	N[5]
		Electric	?	?
Passenger rail	Tram	Electric	?	?
	Metro Single-Decker	Electric	B[4]	B[4]
	Metro Double-Decker	Electric	B[4]	B[4]
	Regional/ Inter-City	Diesel	B	B
Freight rail	-	Diesel	B	B
Road Freight	Small – Freight	Petrol	A[2]	A[2]
		Diesel	A[2]	A[2]
	Rigid trucks	Petrol	A[3]	A[3]
		Diesel	A[3]	A[3]
	Articulated trucks	Diesel	A	A

Notes:

1. Emission factor LPG-engine cars is not disaggregated by vehicle size
2. Corresponding vehicle class in COPERT Australia is Light Commercial Vehicle (LCV)
3. Corresponding vehicles classes in COPERT Australia are Medium Commercial Vehicle (MCV) and Heavy Commercial Vehicle (HCV). Petrol- and diesel-engine emission factors are separately available for Medium Commercial Vehicle (MCV). For HCV, only diesel-engine emission factor is available.
4. Fuel consumption rate for suburban trains is not disaggregated by train size
5. Fuel consumption rate is not separately available by fuel type

Appendix B.9 Transport performance data

Data sources represented by letter keys can be looked up in Table A-1 and “?” indicates no Australian data source has been identified.

Table B-10 Data coverage for transport performance data

Transport type	vkt	pkm	tkm
Passenger transport			
Passenger car – petrol	O,Q	P	-
Passenger car – diesel	O,Q	P	-
Scooters	Q		
Motorcycles	O,Q	P	-
Light bus	O,Q	P	-
Heavy bus	O		
Passenger train – electricity	P	P	-
Passenger train – diesel	P	p	
Freight transport			
LCV	O,Q	-	O
MCV	O,Q	-	O
HCV	O,Q	-	O
Rail	P	-	P

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