REPORT

AIR QUALITY APPRAISAL TOOL (AQAT) – FINAL REPORT

NSW Environment Protection Authority – Air Policy

Job No: 6620

4 April 2013

A PEL Company

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EXECUTIVE SUMMARY

The improvement of transport infrastructure is one of the priorities of the New South Wales (NSW) Government. However, it is essential that any adverse impacts of transport developments - as well as land use changes near transport corridors - are minimised. One of the main considerations in this respect is air quality, as air pollution from transport is associated with detrimental effects on human health, natural ecosystems and climate.

Monetary valuation is commonly used when evaluating the potential benefits of developments or policies and measures, as the diverse range of impacts can be quantified in a simple and consistent manner. An important factor in any economic appraisal of air pollution is the cost of health impacts. The overall costs of air pollution are dominated by costs linked to mortality, which in turn are dominated by the effects of airborne particulate matter (PM). Consideration of the overall exposure of the population to PM is therefore critical when determining health impacts and costs.

This report describes the development of an 'Air Quality Appraisal Tool' (AQAT) for quantifying and monetising the air quality impacts of transport and land use developments in NSW. AQAT will allow planners to consider actions relating to transport and land use alongside other measures that are designed to improve air quality and reduce population exposure as part of the planning process. In addition, it will support the assessment of air pollutant emissions in Environmental Impact Statements and economic appraisals.

The report describes the development of AQAT. It includes the context and scope of the work, a review of existing approaches for estimating emissions and health costs in NSW, the development of the methodology, guidance on implementation, and recommendations for improvement. Several case studies are examined to demonstrate the functionality of AQAT and its application to local and State government projects.

The methodology used in AQAT builds upon existing models. The Tool itself takes the form of a spreadsheet with relatively simple inputs such as road traffic flows, rail freight activity, and local population density (defined in terms of 'Significant Urban Areas'). The outputs are annual emissions of criteria pollutants and the damage costs associated with $PM_{2.5}$ emissions.

The single most important consideration in the development of AQAT was the selection of a method for quantifying the health costs of air pollution, as this dictated the outputs that would be required for other elements of AQAT. Damage costs are calculated using unit costs (in A$ per tonne) for primary $PM_{2.5}$ emissions from transport, based on a method derived for NSW EPA by PAEHolmes in which the unit costs are a function of population density. Damage costs for other sectors of activity and for secondary particles are not included at present.

This therefore meant that the changes in emissions from road and rail for a given development had to be quantified. For large developments, data on transport activity and emissions will generally have been obtained, especially where an Environmental Impact Statement has been compiled, or could be estimated from the available data, and therefore damage cost values can be applied directly. For smaller local developments there are generally very few data, and therefore algorithms are incorporated into AQAT to enable emissions to be calculated.

The Roads and Maritime Services Tool for Roadside Air Quality (TRAQ) was considered to be the most suitable approach for modelling road traffic emissions in AQAT. The level of the approach in

TRAQ is in keeping with the need for simple calculations in AQAT, and the calculation methods are consistent with those used in the 2008 NSW GMR air emissions inventory

The capabilities for modelling rail emissions in Australia are rather limited, and there is a heavy reliance upon emission factors from the USEPA. Given that most of the rail diesel consumption in NSW relates to the haulage of freight and that passenger trains are predominantly electrified, a decision was made to exclude passenger transport from AQAT. Based on a consideration of the available options, it was concluded that the method used in the 2008 GMR inventory would be the most suitable approach for use in AQAT.

The tool takes the form of an Excel spreadsheet which calculates changes in emissions and damage costs based on conditions before and after a development. The required inputs are the type(s) of affected road, road length, road gradient, traffic flow, traffic speed, traffic composition, and the local population density. Guidance on developing the base case and assessment scenarios is provided.

An indicative sensitivity analysis was conducted using the user-defined model parameters for road transport. The analysis was based on a Monte Carlo simulation, with the fractional contribution of each input variable to the variance in the output being determined. For the assumptions used, road gradient was found to be an important parameter for emissions of some pollutants, but less so for PM emissions. For PM emissions and damage cost, road length was an important variable, and population density was also an important variable for damage costs. It is therefore important to characterise these as accurately as possible when using AQAT. The number of HDVs and traffic speed were less important. The analysis could be refined using more appropriate data prior to any specific case study being undertaken.

The report also provides guidance on the use of AQAT in the economic appraisal of developments, some useful sources of information and data, and recommendations for future improvement.

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1 INTRODUCTION

1.1 Background

The improvement of transport infrastructure is one of the priorities of the New South Wales (NSW) Government, as expressed in the *NSW 2021* plan[1]. However, it is essential that any adverse impacts of transport developments - as well as land use changes near transport corridors - are minimised. Planning authorities must therefore assess development applications against various social, economic and environmental criteria, and one of the main environmental considerations is air quality[2]. To ensure that new developments do not exacerbate the impacts of air pollution, development applications need to be accompanied by an air quality assessment, including mitigation measures where appropriate.

Air pollution from transport is associated with detrimental effects on human health, natural ecosystems and climate. When evaluating the potential benefits of developments or pollution-reduction policies it is desirable to quantify impacts in a simple and consistent manner. Whilst this is difficult given the diversity of the impacts, approaches based on monetary valuation are the most common, and these have several advantages. They make explicit the real cost of pollution impacts on society, and enable alternative proposals to be compared directly using a single index (money). A framework for the valuation of costs and benefits of policies, including the economic assessment of environmental impacts, has been established in Guidelines published by the **NSW Treasury (2007).** The Guidelines aim to ensure that all public sector agencies undertake economic appraisals on a consistent basis. Economic appraisal is also an important prerequisite of any new statutory instrument.

An important factor in any economic appraisal of air pollution is the cost of health impacts. The health costs of air pollution are dominated by its effects on mortality, which in turn are dominated by the effects of airborne particulate matter (PM) **(Jalaludin *et al*., 2011)**.

The current approach to air quality management in Australia focuses on reducing exceedances of ambient air quality standards at specific locations. The standards are designed to protect human health. However, for PM there is no evidence of a threshold concentration below which adverse health effects are not observed **(Pope and Dockery, 2006**; **Brook *et al*., 2010; USEPA, 2009a; COMEAP, 2009)**. The evidence indicates that long-term exposure to the prevailing background PM concentration is the most important determinant of health outcomes relating to air quality. Therefore, whilst PM concentrations in Australian cities are significantly below the standards for most of the time[3] **(Commonwealth of Australia, 2010)**, the health impacts are actually driven by large-scale exposure to relatively low pollution levels[4]. Consideration of the overall exposure of the population is therefore critical when determining the effects of policies, measures and developments on health and costs. This is rather different to the current assessment approach for developments, in which air pollution is given a low priority when there is unlikely to be an exceedance of air quality standards.

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[1] http://2021.nsw.gov.au/renovate-infrastructure

[2] Influencing the outcomes of transport and planning decisions is also a priority in the development of the national strategy to improve air quality, as well as the NSW Government's 25-Year Air Quality Management Plan *Action for Air*.

[3] High observed PM concentrations are typically a result of bushfires and dust storms.

[4] The development of an exposure-reduction framework for PM was an important recommendation of a review of the National Environment Protection Measure for Ambient Air Quality ('Air NEPM') (**NEPC, 2011**), and the NSW government is currently in the process of developing such a framework.

Against this background, in February 2012 the Air Policy division of the NSW Environment Protection Authority (EPA) (then Office of Environment and Heritage, OEH) commissioned PAEHolmes to develop an 'Air Quality Appraisal Tool' (AQAT) for quantifying and monetising the air quality impacts of transport and land use developments in the State. The tool will allow planners to consider actions relating to transport and land use alongside other measures that are designed to improve air quality and reduce population exposure as part of the planning process.

This report describes the development of AQAT. It includes the context and scope of the work, a review of existing approaches for estimating transport emissions and health costs, the development of the methodology, and guidance on implementation.

A glossary of the terms and abbreviations used in the report is provided in **Appendix A**.

1.2 Objectives

The main objective of the study was to develop a methodology and tool for monetising the likely health impacts of changes in air pollutant emissions associated with transport and land use developments in NSW, and in particular in the Sydney Greater Metropolitan Region (GMR). For the reasons mentioned earlier, priority was given to valuing the impacts of PM.

NSW EPA requested the following:

- An appraisal methodology which:
  - Would build upon existing NSW approaches.
  - Would be based on sound principles, with any assumptions being clearly stated.
  - Would give reproducible results.
  - Would address a wide variety of planning projects.
- A tool that was very simple, easy to use and not resource-intensive.
- Clear guidance and instructions on its use.
- Examples to demonstrate the use of the method for local and State government projects.
- Advice on how best to incorporate the methodology and tool within planning law, as any tools need to be acceptable to all affected departments.
- An indication of the potential for extending the methodology to other Australian jurisdictions.

1.3 Development approach

The approach used to develop AQAT is summarised in **Figure 1**. In order to achieve the objectives of the project it was necessary to consider a number of different aspects.

Firstly, there had to be clear understanding of the context. This required consideration of: (i) the NSW planning requirements for transport and land use developments (and how these relate to air quality), (ii) the types of development being considered by local and State governments, and (iii) any existing guidelines on appraisal and assessment. Secondly, there was a need to review the methods and models used in NSW for estimating transport emissions and health-related costs. Thirdly, it was important to understand the data and resources available to those responsible for air quality assessments and potential end users of AQAT.

During the project information was collected through a combination of literature reviews and discussions with stakeholders. PAEHolmes consulted with several different authorities at the State and local levels, as well as with specialists in the monetisation of health impacts. The consultees are listed in **Appendix B**.

The content of AQAT was then based on the collected information, and the first draft of AQAT was developed using existing models and data. The draft tool was applied to a number of case studies, and then a final version was implemented. Guidance on the use and application of AQAT was also compiled.

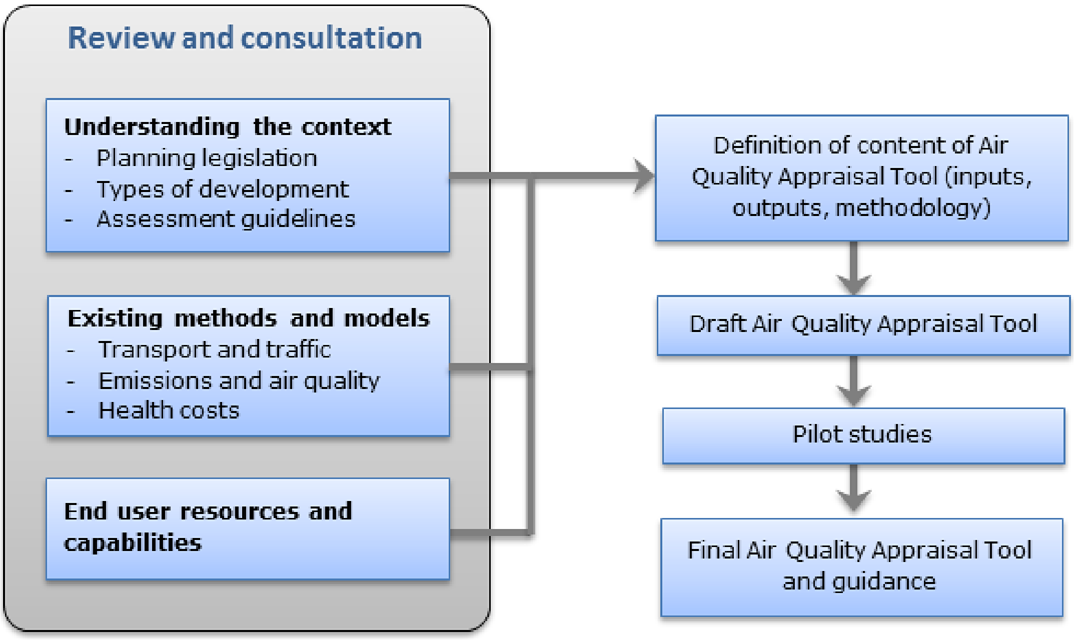

Figure 1: Development process for AQAT

A stakeholder workshop was held at the end of the project to determine whether any further refinements to AQAT were required and to establish precisely how and when it should be used.

2 UNDERSTANDING THE CONTEXT

This Chapter of the report describes the context within which AQAT was developed. It summarises the following:

- Section 2.1: The regulatory framework in NSW in relation to planning and air quality.
- Section 2.2: The planning process and requirements for environmental assessment.
- Section 2.3: The process for economic appraisal of capital projects in NSW.
- Section 2.4: Guidelines for air quality appraisal, assessment and mitigation.
- Section 2.5: Specific examples of developments which can require an environmental assessment.

In terms of the impacts of developments, the emphasis in the report is on air quality and external health costs. The aims are to understand how AQAT would fit into the planning process, and to ensure that the methodology would be consistent, as far as possible, with the overall process in terms of ethos, tone, level of detail and terminology.

2.1 The regulatory framework

There are three main elements to the planning and development legislation in NSW:

- ***Environmental Planning and Assessment (EP&A) Act 1979***. This is the primary legislation governing land use, development and environmental assessment in NSW. It sets out the major concepts and principles involved.
- ***Environmental planning instruments*** *(EPIs).* EPIs can relate to either a local government area (Local Environment Plans - LEPs) or to the whole or part of the State (State Environmental Planning Policies - SEPPs)[5]. LEPs and SEPPs define when development consent is required, and the consent authority for specific types of development. LEPs are usually prepared by local councils and divide areas into 'zones' such as 'rural', 'residential', 'industrial', 'recreational', and 'business'. SEPPs address planning issues within the State, often making the Planning Minister the consent authority for developments. As an example, *State Environmental Planning Policy (Infrastructure) 2007* simplifies the process for providing infrastructure in areas such as education, hospitals, roads, railways, emergency services, water supply and electricity supply.
- ***Environmental Planning and Assessment Regulation 2000***. This addresses the practical implementation of the 1979 Act, and contains many of the details for the various processes.

Other relevant legislation includes:

- The ***National Environment Protection Measure (NEPM) for Ambient Air Quality***, which sets air quality standards and goals to ensure adequate protection of health and wellbeing.
- The ***Protection of the Environment Operations (POEO) Act 1997***. The POEO Act regulates commercial, industrial and domestic activities. The Act also contains provisions

[5] Development control plans (DCPs) are also used to support LEPs by providing specific, comprehensive requirements for certain types of development or locations. Unlike LEPs and SEPPs, DCPs are not legally binding. However, a consent authority must take a DCP into account when considering a development application.

concerning air pollution arising from motor vehicles and open burning. It is supported by the *Protection of the Environment Operations (General) Regulation 1998* and the *Protection of the Environment Operations (Clean Air) Regulation 2002*.

2.2 The planning process and environmental assessment

In NSW there are a number of different systems for the assessment of development proposals. These systems are specifically tailored to cater for the varying size, nature and complexity of different projects. These factors will determine which assessment system applies to a particular development. Under the legislative scheme of the EP&A Act, development proposals can fall into one of the following categories:

- ***Part 3A projects***. These are major public or private projects of State or regional significance which require approval by the Minister for Planning. However, the NSW Government announced in April 2011 that it will not be accepting any new applications under the Part 3A system, and Part 3A will be replaced with two separate regimes:
  - ***State-significant development*** (SSD). This will apply to private sector development and some classes of public sector development.
  - ***State-significant infrastructure*** (SSI). This will apply to other classes of public sector development.
- ***Part 4 development proposals***. These are dealt with through the local council development application process.
- ***Part 5 development proposals***. These are proposals which do not fall under either Part 3A or Part 4, and are usually infrastructure projects.

Any environmental assessment will generally include air quality impacts, with the level of detail depending on the pathway which is followed. More information on the planning pathways – and the role of air quality - is provided below.

2.2.1 State-significant developments and infrastructure

There are a small number of projects whose scale, significance or potential impacts mean they are of State, rather than just local, significance. The NSW Department of Planning and Infrastructure (DoPI) is usually responsible for dealing with applications under the state-significant assessment system. The system has been established to allow planning decisions on major developments or infrastructure proposals which do not require consent but which could have a significant environmental impact. Some examples are given in **Table 1**. A full list of SSD development types and specified sites can be found in Schedules 1 and 2 of the *State and Regional Development SEPP 2011*.

In assessing a development application the consent authority must take into consideration a number of factors under section 79C of the EP&A Act, including impacts on both the natural and built environments, as well as social and economic impacts.

Table 1: Examples of state-significant development and infrastructure

State-significant development		State-significant infrastructure
Large mines	Timber processing	Railways
Ports	Water supply	Roads
Quarries	Processing plant	Water supply works
Aquaculture	Electricity generation	Pipelines
Marinas	Chemical industries	Sewerage systems
Hospitals	Distribution facilities	Telecommunications
Rail facilities	Correctional facilities	Soil conservation works
Education facilities	Medical research facilities	Flood mitigation works
Manufacturing industries	Sporting facilities	Ports, wharf or boating facilities
Film and television facilities	Intensive livestock industries	Electricity transmission or distribution
Tourism and entertainment facilities	Sewage, pipelines & waste facilities	Public parks or reserves management
Petroleum oil or gas production		Stormwater management systems
		Waterway or foreshore management

The planning process for SSD and SSI is summarised in **Figure 2**. Different levels of air quality assessment are required at different stages. State-significant developments and infrastructure demand a full and detailed Environmental Impact Statement (EIS), whereas relatively simple assessments are required during the strategic and concept stages. Economic appraisal (see **Section 2.3**) usually forms part of the concept phase, and increases in rigour as the project progresses.

The EIS is usually a very complex document, and should give a detailed analysis of all potential areas of concern in relation to a development. Schedule 2, Part 2, Clause 7 of the *Environmental Planning and Assessment Regulation 2000* describes the general content of an EIS. The EIS must have regard to the specific Director-General's Requirements (DGRs).

However, the Regulation is not prescriptive in terms of the specific requirements for emissions and air quality (*e.g.* which time periods are to be assessed, which models are to be used, which pollutants are to be modelled, *etc.*). The *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in New South Wales* (**DEC, 2005a**) (see section 2.4.1) should be referred to when considering air quality in the consent assessment process for developments with air pollution potential.

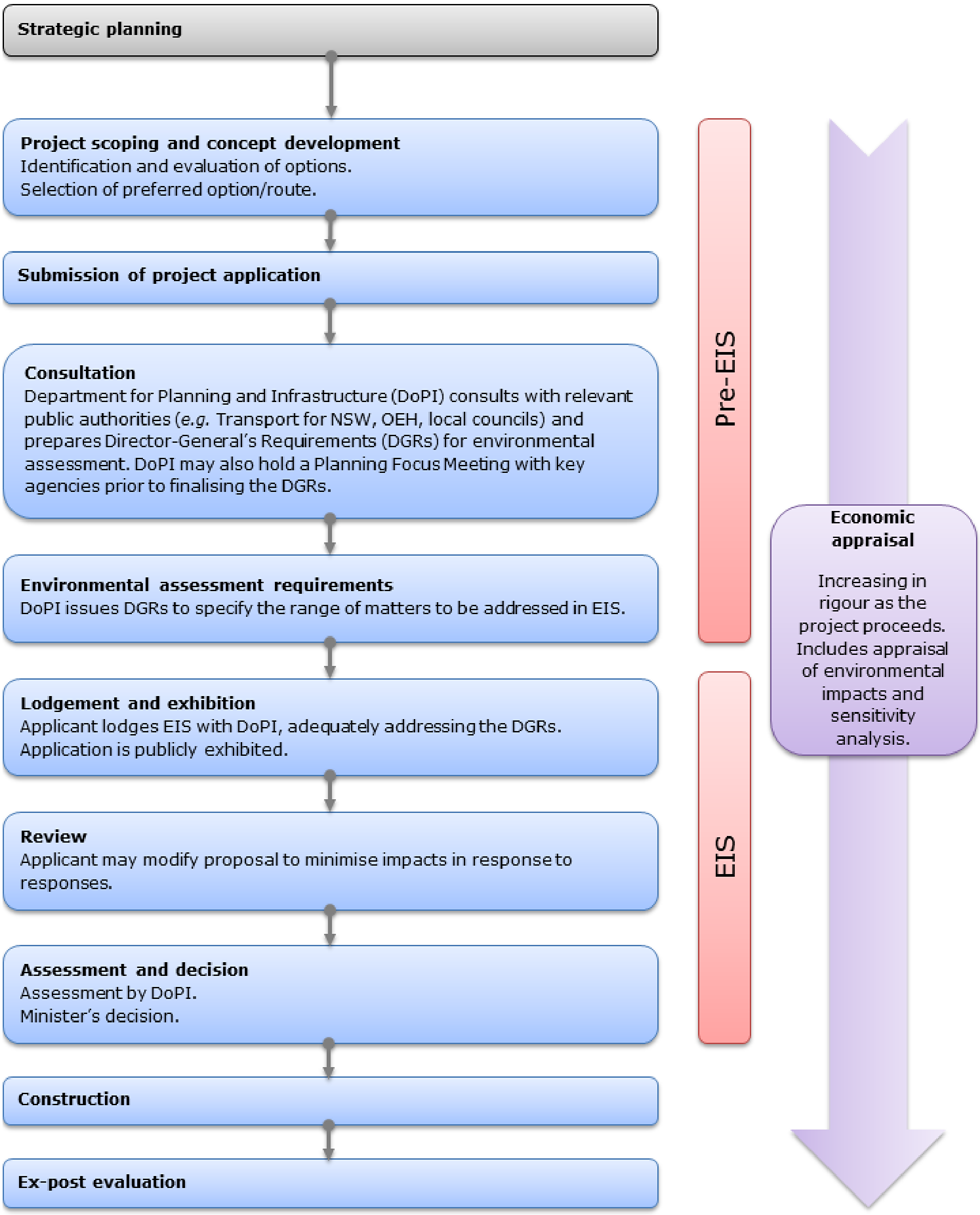

Figure 2: Planning process for State-Significant Development and State-Significant Infrastructure

2.2.2 Part 4 developments

The overwhelming majority of development applications in NSW are for local and regional projects, and are assessed by local councils under Part 4 of the EP&A Act 1979. A number of different types of development fall under the Part 4 assessment system. To be approved under the Part 4 system, a development must be permitted with consent in the relevant land-use zone, and is assessed against local and State planning controls.

2.2.2.1 Local developments

Most local development proposals in NSW require lodgement of a development application with the local council. Dependent on council policy, the council will publicly exhibit the application, and then make a decision on it. When assessing development applications, local authorities may be required to consult with either environmental or health departments in making a decision, or may choose to do so. Alternatively, developments affecting air quality may be required to be referred directly to regional or national authorities with expertise in air quality, bypassing local authorities (**Scholl, 2006**).

2.2.2.2 Regional developments

Regional developments are those which are notified and assessed by a local council and then determined by the relevant Joint Regional Planning Panel. Regional developments include:

- Developments with a capital investment value (CIV) of more than $20 million.
- Developments with a CIV over $5 million which are council-related, lodged by or on behalf of the Crown (State of NSW), involve private infrastructure and community facilities, or involve eco-tourist facilities.
- Extractive industries, waste facilities and marinas that are 'designated' developments (see below).
- Certain coastal subdivisions.
- Developments with a CIV between $10 million and $20 million which are referred to the regional panel by the applicant after 120 days.
- Crown development applications (with a CIV under $5 million) referred to the regional panel by the applicant or local council after 70 days from lodgement as undetermined, including where recommended conditions are in dispute.

Developments that meet the specific CIV - or other criteria to be state-significant development - are excluded from being regional development. For example, manufacturing industries, hospitals and education establishments with a CIV over $30 million are considered to be state-significant. It is also worth noting that the principle of regional development does not apply in the City of Sydney Council area.

2.2.2.3 Designated developments

Developments classed as 'designated' require particular scrutiny because of their potential to have adverse environmental impacts on account of their scale or their location near sensitive environmental areas. These designated developments are listed in Schedule 3 of the *Environmental Planning and Assessment Regulation 2000* or in planning instruments such as SEPPs. Examples include chemical factories, large marinas, quarries and sewerage treatment works. For designated developments applicants need to submit an EIS with the development application.

All applications must be accompanied by a Statement of Environmental Effects (SEE), unless the development is designated, in which case an EIS is required automatically. The SEE must identify the environmental impacts of the development, and the steps which will be taken to protect the environment or reduce the impact. However, road traffic is not usually considered in the SEE, although SEEs can be influenced by consent authority requirements.

Some jurisdictions have waived the assessment process based on the size of the development (*e.g.* small residential developments). Buffer zones are also being applied for development close to major roads, based on health studies relevant to the jurisdiction (**Scholl, 2006**).

2.2.3 Part 5 developments

Certain developments and activities do not fall under the state-significant or Part 4 systems and do not require development consent. Examples include the construction of roads, railways or electricity infrastructure by public authorities, and mining exploration. The purpose of the Part 5 system is to ensure that public authorities fully consider environmental issues before they undertake or approve such activities.

For this reason, Part 5 of the EP&A Act contains a separate environmental assessment procedure which applies to these types of development and activity. Part 5 projects are usually assessed through a preliminary 'Review of Environmental Factors' (REF), which precedes the granting of an approval for an activity. The REF examines the significance of likely environmental impacts of a proposal, and the measures required to mitigate any adverse impacts to the environment. A REF has no statutory basis, but is required as part of the standard practice of the DoPI and other public authorities.

A REF can be very short or very detailed depending on the nature of the activity, the sensitivity of the environment and the proposed environmental safeguards. **DECC (2008)** specifies the issues that need to be covered in a REF, and these include 'any environmental impact on a community', 'any degradation of the quality of the environment' and 'any pollution of the environment'. Air quality is mentioned specifically, and the REF may include a specialist air quality report. Each impact should be estimated on its extent, size, scope, intensity and duration in order to categorise the impacts ('negligible', 'low', 'medium', 'high adverse' or 'positive'). If the activity is likely to have a significant effect on the environment, then an EIS must be prepared.

For road projects a relatively simple screening assessment will be required as part of the REF (**RTA, 2007**). A more detailed assessment would be required for an EIS. The detailed air quality assessment will also need to present a number of management measures to minimise impacts from the project both in terms of construction and operation. These measures will form the basis for the implementation phase of the project. Therefore, the measures need to be achievable, practical and formulated in conjunction with the project team (**RTA, 2007**).

2.3 Economic appraisal

In 1988 the NSW Government decided that economic appraisal techniques should be applied to all capital works proposals, and appraisal Guidelines have been published by the **NSW Treasury (2007)**. The Guidelines indicate that various methodologies can be employed for the economic appraisal of impacts, including cost-benefit analysis, risk benefit analysis and multi-criteria analysis, and outline the advantages and disadvantages of each approach. The techniques require as many as possible of the benefits and costs to be quantified in monetary terms.

Annex 4 of the Guidelines deals specifically with the economic appraisal of environmental impacts. It is stated that economic appraisal is separate from, and does not replace, the EIS process. It may rely on input from, and in turn provide input to, the EIS process.

The methodologies and techniques used are strongly influenced by the stage of a project. Generally, the closer a project is to being commissioned, the more involved and exacting the economic appraisal needs to be. Ex-Post evaluation is also encouraged so that forecasts can be compared with observed outcomes (**NSW Treasury, 2007**).

The Guidelines do not address road and rail projects specifically, and do not provide a method for monetising air pollution impacts. Nevertheless, it was important that the Air Quality Appraisal Tool was consistent as far as possible with the Guidelines, and could assist with their implementation.

2.4 Guidelines for air quality assessment and mitigation

2.4.1 NSW 'Approved Methods'

The document *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (**DEC, 2005a**) lists the statutory methods that are to be used in NSW. The approved methods are designed to address stationary sources, and contain little information on the assessment of transport schemes and land use changes. However, the document does introduce an overall approach for assessment in which two 'levels' are specified:

- Level 1 – A simple screening level assessment using worst-case input data.
- Level 2 – A detailed assessment using refined modelling techniques and site-specific input data.

The assessment levels are designed so that the results from the second level are more accurate than those from the first. If a Level 1 assessment conclusively demonstrates that adverse impacts will not occur, there is no need to progress to Level 2. The Level 1 assessment therefore needs to be sufficiently conservative. In other words, it needs to ensure that the predicted impacts are likely to be greater than the actual impacts, but not so great that projects unnecessarily require the more expensive and time-consuming Level 2 process.

2.4.2 RTA guidelines for road projects

Although there are currently no approved methods which specifically address the assessment of road transport (and land use) developments in NSW, the two-level approach is also relevant to such developments.

In 2007 Roads and Maritime Services (RMS)(then the Roads and Traffic Authority – RTA) developed a set of guidelines for assessing the air quality impacts of significant new road projects or changes to existing roads. These guidelines were not formally adopted; at the time of writing it is understood that they are being revised by RMS.

The relevant assessment pathway for a proposed road will largely depend on the local planning provisions, the scale of the development and/or on the level of environmental impact posed by the road itself. RTA projects are usually assessed in one of two ways – through the state-significant system or through the Part 5 system. State-significant projects will require detailed air quality assessment and modelling (see below) at the EIS stage. For Part 5 projects the REF may include an air quality assessment report. Part 4 projects (which require local council consent) do occur, but are less common and will generally be assessed in a SEE. The process is similar to that for Part 5, although the council is the consent authority rather than RTA (**RTA, 2007**).

A threshold screening process was provided by **RTA (2007)** to determine whether any quantitative assessment of air quality impacts is required. Roadway projects which are considered to be unlikely to have significant air quality impacts do not require a quantitative air quality assessment. In the RTA guidelines, these projects are categorised as 'low-impact' projects. **Table 2** summarises the criteria for new or existing roads that determine whether a project is categorised as low-impact. For projects including a number of interlinked roadways, all roads being considered must meet the criteria in **Table 2** for the project to be classified as low-impact.

Table 2: Summary of 'low-impact' criteria (**RTA, 2007**)

Parameter	New road	Existing road
Road type	Construction of minor residential or Secondary roadway	Changes to minor residential or secondary roadway.
Traffic volume	Maximum of 20,000 vehicles per day.	Unchanged alignment and less than 10% increase in traffic flows and no change to traffic mix.
	Maximum of 1,200 vehicles per hour.	
Receptor proximity	No receptor within 200 metres for all traffic flows.	Unchanged traffic volume and composition. Realignment decreases distance to receptors by less than 5 m with no receptor closer than 10 m.

The 'two-level' approach is also described in the RMS Guidelines. The Level 1 methodology uses relatively simple estimation techniques and conservative meteorological conditions to estimate the air quality impact of a particular section of road. If the Level 1 assessment indicates that the concentration contributed by the source may result in exceedances of the air quality criteria, then the Level 2 methodology should be applied. The Level 2 methodology involves a more detailed treatment of physical and chemical atmospheric processes, requires more detailed and precise input data, and provides more specialised emission estimates. The Level 2 assessment will also need to present a number of measures to minimise impacts from the project, both in terms of construction and operation. **Table 3** shows the likely NSW planning assessment level and RMS air quality assessment level for different types of road project.

Table 3: Likely assessment level under the NSW Planning Process (**RTA, 2007**)

Project type	Likely assessment level	
	Planning	Air quality
Ventilated road tunnel	Part 3A	2
Non-ventilated road tunnel	Part 3A	2
Major intersection (including signals/roundabouts)	Part 3A/5	2
Area significantly impacted by existing air quality	Part 3A/5	2
Arterial	Part 3A/5	1
Highway / freeway	Part 3A	1
Commercial arterial	Part 3A/5	1
Commercial freeway	Part 3A	1
Residential, minor or secondary roadways	Part 4/5	1 (>20,000 vpd)
Congested conditions	Part 3A/4/5	1

2.4.3 Local Government Air Quality Training Toolkit

The Department of Environment and Climate Change (DECC) (now EPA) has developed a 'Local Government Air Quality Training Toolkit'[6] to provide information to help local government officers better understand and manage the air quality issues under local planning and regulatory control. The Toolkit contains information on the following:

- Air pollution, its sources and impacts.
- The regulatory framework for protecting air quality in NSW.
- General information about air quality management procedures and technologies.
- Specific information in the form of guidelines for managing a number of air polluting activities that have been identified by council officers as priority issues.
- However, the Toolkit does not specifically address road or rail transport.

2.4.4 Interim guideline on development near rail corridors and busy roads

The NSW **Department of Planning (2008)** has produced an Interim Guideline to help planners reduce the health impacts of rail noise, road noise and adverse air quality on sensitive adjacent developments. The Guideline supports the specific rail and road provisions of the 2007 Infrastructure SEPP and provides a number of recommendations, including:

- Minimising the formation of urban canyons that reduce dispersion.
- Incorporating an appropriate separation distance between sensitive uses and the road.
- Ventilation design for developments located adjacent to roadway emission sources.
- Using vegetative screens, barriers or earth mounds.

2.5 Types of development

To optimise the usefulness of AQAT it was important to understand the specific types of land use and transport development in NSW, and which planning procedures apply to which developments. This was important for two main reasons. Firstly, there was a need to determine the nature of the emission calculations required in AQAT, as the calculation methods were likely to be dependent upon the types of development being assessed. Secondly, there was a need to identify suitable examples for the case studies. Although hypothetical, these needed to be as representative as possible, with realistic scenarios and data.

State-level projects include major transport and building developments. **Table 4** provides some examples of SSDs and SSIs which were considered to be relevant to the project, based on the consultation with NSW authorities. The Table also identifies the current requirements for environmental assessment, the role of NSW EPA, and where the assessment and economic evaluation of air quality impacts might be improved.

[6] http://www.environment.nsw.gov.au/air/aqt.htm

Where transport projects are assessed, AQAT could be used to value the impacts of the changes in pollutant emissions. The DGRs would then need to include a request for provision in the EIS of the change in emissions and the location of the change. When choosing where to site new homes, AQAT could be used to value the differences in emission impacts for alternative locations. In this case, the likely population and likely travel patterns will need to be assumed. The changes in the traffic on specific roads could be entered into the tool to determine alternative values of the air emission impacts, and to enable a comparison between alternative proposals.

Some examples of relevant Part 4 and Part 5 developments are given in **Table 5**. Local council and regional planners assess developments costing up to $30 million. At a local level, AQAT could be used to value the impacts of alternative traffic-generating developments, such as hospitals and shopping centres. For larger developments, council planners can request that the proponents use the tool as part of an Environmental Impact Statement. For smaller developments, council planners can request changes in traffic movements on affected roads in the Statement of the Environmental Effects, and assess the changes using AQAT when the SEE is submitted. Local councils might also wish to value the benefits of schemes that reduce motor vehicle use. In this case, the council would need to estimate changes in vehicle movements and enter these into the spreadsheet to value the changes.

Table 4 and **Table 5** show that there is some scope for more detailed information on changes in emissions, population density and associated health costs to be included in the requirements for SEE, REF and EIS.

Following consultation with local planning authorities it was concluded that AQAT would probably be applicable to the following types of local government project:

- Traffic-generating developments, such as new residential areas, shopping centres and commercial/industrial areas.
- The construction of new facilities with sensitive populations (*e.g.* hospitals, schools) near busy roads.
- Transport proposals to reduce motor vehicle travel, such as light rail developments. In these cases the quantification of the air quality benefits could help make the case for the project.

The costs associated with the impacts of air pollutant emissions could be used to justify expenditure on mitigation measures.

Table 4: Examples of state-significant developments and infrastructure

Type of development (SSD)	Example	EIA requirements	EPA role	Potential improvements to EIA process
Commonwealth projects	Moorebank intermodal terminal facility to handle container traffic from interstate rail freight and Port Botany.	EIS required. Australian Government cannot intervene if a project has no significant impact on one of eight matters of 'national environmental significance' (World Heritage Sites, RAMSAR sites, *etc.*). The consent authority becomes the State Government.	DGR requests sent to EPA. EPA can request information/ assessment through the DGRs.	Clear guidelines on method, assumptions, base case conditions, extent and output of transport models. Identification of mitigation measures.
Land use change (rezoning)		Currently no formal environment or health impact assessment.		Clear guidelines on method, assumptions, extent and output. Tools are required for calculating health impacts and costs.
New facilities	Hospitals, education facilities, sport, tourism and entertainment facilities (CIV >$30 million).	EIS required. DoPI specifies requirements of DGRs.	EPA can request that specific information be included in DGRs.	Clear guidelines on method, assumptions, base case conditions, extent and output of transport models. Identification of mitigation measures.
Industrial developments	Chemical plant.	EIS required. DoPI specifies requirements of DGRs.	Considering formally requesting Health Impact Assessment.	
Type of infrastructure (SSI)	**Example**	**EIA requirements**	**EPA role**	**Potential improvements to EIA process**
Transport infrastructure	Major roads or railway lines which cross council boundaries.	EIS required. Preferred route is normally decided at concept stage prior to DoPI approval. DGRs define type and level of assessment. DoPI consults with authorities (*e.g.* DfT, RMS, Railcorp) to determine content of DGRs.	EPA can request that specific information be included in DGRs.	Guidance required on level of air quality impact assessment for different road projects (*e.g.* changes in emissions, changes in population density, how outputs from transport models are used). RMS is currently revising its guidelines. Tools are required for calculating emissions, health impacts and costs. Identification of mitigation measures.

Table 5: Examples of Part 4/5 developments

Type of development	Example	EIA requirements	Potential improvements to EIA process
Traffic-generating developments (land use change)	Shopping centres, residential developments (*e.g.* Macquarie Fields)	Covered by LEP and assessed by Council. Council can specify information requirements in pre-DA meeting, such as changes in traffic movements on surrounding roads. Applicant must state potential impacts, including traffic/parking generation and environmental impacts (but not necessarily air quality).	Definition of criteria and thresholds for triggering assessment. Require developers to include calculation of changes traffic, PM emissions, population density and health costs. Identification of mitigation measures.
New facilities near busy roads	Hospitals, schools, childcare centres, nursing homes (CIV <$30 million)	As above.	Definition of criteria and thresholds for triggering assessment. Inclusion of calculation of changes PM emissions, population density and health costs. Traffic and air quality measurements.
Travel-reduction	Light rail system	As above.	In these cases the quantification of the air quality benefits could help make the case for the project.
Residential, minor or secondary roads	New road or modification to existing road.	Currently go to traffic committee, including proposals for pedestrian crossings. Proposed developments not formally assessed, even for active transport projects.	

3 REVIEW OF METHODS AND MODELS

This Chapter of the report contains a review of the methods, models and data which are used in Australia and other countries to estimate transport/traffic activity, emissions, and health-related costs. The implications for AQAT are also considered.

3.1 Road transport emission models

The models which have been used in NSW for estimating emissions from road and rail transport are summarised below. It does not specifically deal with models commonly used elsewhere, such as COPERT 4[7] and the Handbook of Emission Factors[8] in Europe, and MOBILE 6[9] and CMEM[10] in the United States, although the Australian methods have, in some cases, drawn heavily upon these. It is worth noting that the move to European emission standards in Australia makes the European models increasingly relevant.

3.1.1 National Pollutant Inventory

The Australian Government compiles and maintains a National Pollutant Inventory (NPI). Manuals are also provided to enable emissions from each sector of activity to be calculated. For road vehicles **Environment Australia (2000a)** provides the emissions estimation techniques for the relevant NPI substances, as well as guidance on the spatial allocation of emissions.

Hot running emissions from motor vehicles are estimated by multiplying vehicle-kilometres travelled (VKT) by emission factors (in g/km), taking into account the structure and composition of the vehicle fleet. The emission factors vary for different road types, vehicle/fuel type combinations, vehicle ages, and emission processes (*i.e.* exhaust, evaporative, tyre and brake wear).

However, the NPI manual is now well out of date. For example, it only includes emission factors for the reporting year 2000, and only covers the vehicle technologies up to that date. In addition, whilst some of the emission factors are based on tests on Australian vehicles, most are taken from USEPA models (MOBILE 5a and PART5) and vehicles. The NPI method could not therefore be recommended for use in AQAT.

3.1.2 NSW GMR emissions inventory model

3.1.2.1 2003 inventory

An emissions inventory for the Greater Metropolitan region of NSW was compiled for the calendar year of 2003 (**DECC, 2007a**). The 2003 inventory superseded the existing official inventory – the Metropolitan Air Quality Study (MAQS) for 1992 (**Carnovale *et al.*, 1996**).

Improvements relative to MAQS included the redevelopment of the emission factors for petrol and diesel cars, incorporating test data obtained under Australian conditions as well as information from overseas. The data on VKT were also completely redeveloped using the Sydney Strategic Transport Model (STM) and Household Travel Survey. The number of inventoried substances increased from five criteria pollutants (VOC, NO_x, CO, PM and SO_2) in the MAQS inventory to over 220, including specific PAHs and other air toxic substances.

[7] http://www.emisia.com/copert/

[8] http://www.hbefa.net/e/index.html

[9] http://www.epa.gov/otaq/m6.htm

[10] http://www.cert.ucr.edu/cmem/

According to **DECC (2007a)**, aggregated (fleet-weighted) emission factors were developed for five road types defined in the MAQS inventory – highway, arterial road, commercial highway, commercial arterial road and local/residential road, as well as two traffic flow conditions – free-flow and congested – for each type of road. Emission projections for future years were also made.

3.1.2.2 2008 inventory

The 2003 inventory has recently been superseded by the 2008 inventory. At the time of writing the description of the road methodology had not been published and no software was available.

The method for calculating hot running emissions involves the use of base 'composite' emission factors for various vehicle types (CP, CD, LDCP, LDCD, HDCP, RT, AT, BusD and MC)[11], with the emission factor for each vehicle type taking into account VKT by age (and associated emission factors by sub-type). Five road types (residential, arterial, commercial arterial, commercial highway, highway/freeway), are specified in the emissions inventory. In the development of the emission factors EPA has taken various real-world effects into consideration, including the deterioration in emissions performance with mileage, the effects of tampering or failures in emission-control systems, and the use of ethanol in petrol. For each case, the base emission factor is defined for a VKT-weighted average speed (the base speed) associated with the corresponding road type. Correction factors – in the form of 6th-order polynomial functions - are then applied to the base emission factors taking into account the actual speed on a road (**Jones, 2012**). The data show that some types of road – notably arterial roads – are associated with higher emissions for a given average speed than others (**Figure 3**).

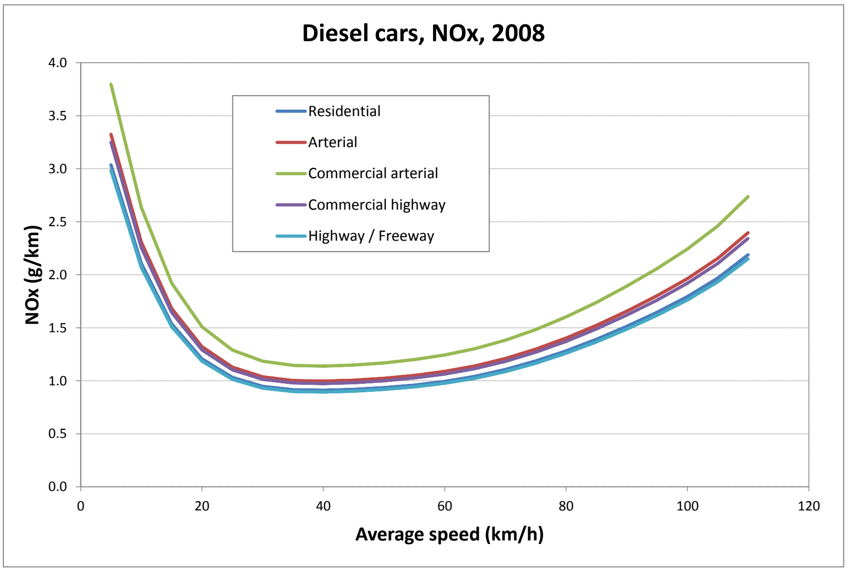

Figure 3: NO_X emission factors vs speed for diesel cars (2008 fleet)

[11] CP = petrol passenger vehicles; CD = diesel passenger vehicles; LDCP = light-duty commercial petrol vehicles (<=3500 kg); LDCD = light-duty commercial diesel vehicles (<=3500 kg); HDCP = heavy-duty commercial petrol vehicles (>3500kg); RT = rigid trucks (3.5-25 tonnes, diesel only); AT = articulated trucks (> 25 tonnes, diesel only); BusD = heavy public transport buses (diesel only); MC = motorcycles.

3.1.3 TRAQ

TRAQ[12] is a tool for assessing the air quality and greenhouse gas impacts of a new or existing roadway in NSW. TRAQ was initially developed on behalf of the RTA (now RMS) by Holmes Air Sciences (now PAEHolmes) in 2008, and was updated by Sinclair Knight Merz (SKM) for RMS in February 2012 to reflect a number of recent developments.

TRAQ has been designed as a 'first-pass' screening assessment to facilitate a Level 1 assessment (see section 2.4.1), and uses a relatively simple approach which should generally provide conservative results. The tool has been designed to assess air quality associated with a single segment of road, and is not suitable for complex situations such as roads through urban canyons, intersections or tunnels (**RMS, 2012**).

The original version of TRAQ contained two different emission estimation techniques: NSW Motor Vehicle Emission Projection System (MVEPS) and PIARC (the World Road Association), and estimated pollutant concentrations using the USEPA dispersion model CALINE4. The revised model incorporates the following changes to the emission calculation method:

- Updated emission factors for criteria pollutants from the aforementioned 2008 GMR emissions inventory model.
- The speed-correction method from the 2008 inventory model.
- An alternative method for estimating gradient effects.
- A new cold-start emission calculation methodology.
- A new routine to calculate greenhouse gas emissions.
- Custom traffic mix profiles.

The required inputs for running TRAQ for calculating emissions on a given road are:

- The road type (*e.g.* residential, arterial, highway)
- The number of lanes.
- For each lane:
- The traffic volume
- The peak hour speed
- The road gradient
- The road length
- The traffic mix
- The year of assessment
- The season (which influences cold-start emissions)

Additional inputs are required for estimating pollutant dispersion.

12 Tool for Roadside Air Quality (TRAQ).

The TRAQ model was considered to be appropriate for use in the EPA Air Quality Appraisal Tool, as it is relatively simple and contains up-to-date emission factors which have been specifically designed for use in NSW.

It is worth noting that VicRoads has also developed a screening Tool to enable project engineers to assess air quality impacts of roads using a worst case approach (**Murphy and Shen, 2011**). There is little documentation on the tool, but it appears to be very similar in concept to TRAQ.

3.1.4 PIARC

PIARC provides emission factors for different vehicle types, emission standards, speeds and road gradients. Prior to the development of emission factors designed specifically for use in NSW and elsewhere in Australia the PIARC emission factors were widely used. Because the PIARC emissions data are based on European studies, the emission factors have usually been modified to take account of the vehicle age profile, vehicle mix and emission standards of the Australian vehicle fleet (*e.g.* **SKM and Connell Wagner, 2005**). PIARC emission factors were also used in the 2008 version of TRAQ.

Given the recent development of emission factors based on Australian data, there is no longer a need for the PIARC emission factors to be used.

3.2 Road transport data

3.2.1 Data requirements

All transport emission modelling requires the use of data on activity. For road transport, in simple terms this includes data on traffic volume (or VKT), composition and speed. Whilst the direct measurement of traffic may be possible for some assessments, it is not practical for complex networks. Moreover, traffic characteristics vary with time, and hence long-term measurements are needed to give a representative picture. Measurements cannot be used to provide data for alternative (future) scenarios, or the potential impacts of the construction of a roadway. The use of traffic and transport models is therefore usually essential for an air quality assessment for a proposed roadway.

For this project the most important point was to ensure that AQAT could accept the outputs from different traffic models.

3.2.2 Types of model

In road traffic models the network is represented by zones, links, nodes and lanes. A zone is the source or sink of traffic where vehicles enter or leave the network. A link is a roadway between two nodes, and consists of one or more lanes. A node is either an external connection to a zone or a junction between links inside the network.

According to **Akcelik and Associates (2006)**, models seldom fall into clear-cut categories. Nevertheless, generally speaking there are three main types of model:

- Junction-based models
- Traffic assignment models
- Micro-simulation models

The boundaries between these types of model are increasingly blurred. Many models also have built-in functionality for estimating emissions and fuel consumption.

3.2.2.1 Junction-based models

Some specialist traffic modelling tools are used to analyse individual junctions and roundabouts. There are several models in the UK, such as PICADY[13], ARCADY[14], OSCADY[15], TRANSYT[16] and LINSIG[17]. These models typically estimate queuing delays and fuel consumption for a given traffic demand and junction configuration, but the impacts of junction changes on the network as a whole cannot be estimated. Travel patterns (*i.e.* the numbers of trips per time-period) and the routing of traffic through the network are fixed. An Australian junction model is SIDRA INTERSECTION[18]. Unlike the other models, this treats various features (different types of signalised intersection and roundabout) in one package.

Junction models provide an aggregated representation of demand, employing empirical algorithms. It can be difficult to apply such models to complex types of junction, such a signalised roundabouts and gyratory systems, and micro-simulation models are now often used for such applications.

3.2.2.2 Traffic assignment models

Where the wider implications of transport policies and infrastructure changes need to be analysed it is normal to construct a 'traffic assignment' model. Such models predict traffic volumes and delays on the network using travel demand and aggregate relationships between volume, speed and density. Travel routes are determined by minimising a combination of journey time and cost. The time period covered by assignment models may vary from 30 minutes to 24 hours. In some cases the travel demand routines are quite sophisticated, employing discreet packets of vehicles but still using the same aggregate relationships as simpler models. These are therefore termed 'mesoscopic' models.

Examples of traffic assignment models include:

- CONTRAM (CONtinuous TRaffic Assignment Model)[19].
- SATURN (Simulation and Assignment of Traffic to Urban Road Networks)[20].
- CUBE[21].
- EMME/2[22].
- VISUM[23].

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13 Priority Junction Capacity and Delay
14 Assessment of Roundabout Capacity and Delay
15 Optimised Signal Capacity and Delay
16 Traffic Network Study Tool
17 Traffic Signal Design Tool for Isolated Junctions and Small Networks
18 http://www.sidrasolutions.com/
19 http://www.contram.com/news/developments.shtml
20 http://www.saturnsoftware.co.uk/index.html
21 http://www.citilabs.com/
22 http://www.inro.ca/en/products/emme2/index.php
23 http://www.english.ptv.de/cgi-bin/traffic/traf_visum.pl

The last three models can also be used to assign public transport passengers to different modes. Such models can be used in conjunction with simple emission factors to estimate emissions over a wide area.

3.2.2.3 Micro-simulation models

In recent years increases in computing power have enabled more practical use to be made of micro-simulation traffic models. An essential property of all micro-simulation traffic models is the prediction of the operation of individual vehicles in real time, over a series of short time intervals, and using models of driver behaviour such as car-following, gap acceptance, lane-changing and signal behaviour theories, rather than aggregate relationships. Vehicle operation is usually defined in terms of speed and acceleration for a number of vehicle types. These are the only tools which can be used to assess the impacts of measures on individual types of driver, time-varying policies, and complex junctions and layouts. For example, they can be used to assess the effects of ramp metering, route diversion, variable speed limits and travel information systems.

Different micro-simulation packages vary in their ability to deal traffic situations and behaviour. Some of them were developed to deal with motorway corridors and are unable to represent traffic behaviour in urban centres where there is a high level of interaction between different road users. The best-known models include:

- VISSIM (a German acronym for 'Traffic in Towns – Simulation').
- PARAMICS (PARAllel MICroscopic Simulation).
- DRACULA (Dynamic Route Assignment Combining User Learning and micro-simulation).

Other models are AIMSUN[24], HUTSIM[25], SISTM, TRAF-NETSIM and FRESIM, aaSIDRA and aaMOTION (**TfL, 2003**; **Abbott *et al.* 2000**; **Akcelik and Besley, 2003**).

3.2.3 Comparison of model attributes

The attributes of strategic traffic models and micro-simulation traffic models were summarised and compared by **RTA (2007)**, as shown in **Table 6**. The comparison suggests that emissions based on the output from a traffic micro-simulation model would tend to be more accurate than those based on a strategic traffic model, as the representation of traffic is more site-specific and vehicle operation is treated in more detail. The fuel mix required for estimating emissions is usually exogenous in both instances. However, micro-simulation modelling is restricted to (relatively small) geographical areas, and data may not be available for a particular location. For assessing transport and land use developments, as in AQAT, it is more likely that the traffic data would originate from a strategic traffic assignment model.

[24] Advanced Interactive Microscopic Simulator for Urban and Non-urban Networks. http://www.aimsun.com/site/

[25] http://www.tkk.fi/Units/Transportation/HUTSIM/

Table 6: Traffic model comparison (adapted from **RTA, 2007**)

	Strategic models	Micro-simulation models
Applications	Strategic transport and land use planning, with a focus on main transport corridors to meet regional travel demand – can be multi modal.	Road design and operational requirement assessment with a focus on vehicle dynamic interactions with road geometry – vehicle trip based.
Period	AM peak, PM peak and inter-peak.	AM peak, PM peak and inter-peak.
Key parameters	Volume delay functions, link costs, capacity, speed limits, heavy vehicles and their equivalent PCUs.	Vehicle size and type, heavy vehicle weight, climbing models, road gradients, headway, reaction time, signals and coordination, aggression and awareness behaviour, lane restrictions, vehicle acceleration/deceleration profiles.
Outputs	Average vehicle flow and speed by road link over the modelling period.	Vehicle flow and speed by road link and time interval within the modelling period.
Advantages	Travel demand estimated from land use planning assumptions. Good regional indicators not practical for site-specific impacts. Can examine impacts of changes in travel behaviour.	Sensitive to particular site conditions and driver behaviour. Dynamic vehicle flow, speed and density on a road link. Include various vehicle types and ages. Can test worst-case traffic scenarios for air quality.
Disadvantages	Uniform vehicle volume, speed and density on a road link. Limited vehicle types. Limited road geometry. Limited scenarios for air quality assessment.	Requiring the demand estimation from strategic models. Generate large amounts of data.

3.2.4 Models used in NSW and typical outputs

3.2.4.1 Junction models

A commonly used junction model in NSW is SIDRA INTERSECTION, but the other junction models – including TRANSYT and LINSIG are also used (**Ryan, 2012**). The outputs of SIDRA INTERSECTION include:

- Average delay per vehicle
- Traffic volume and capacity (vehicles/hour)
- Average travel speed and running speed
- Pollutant emissions (CO, HC, NO_X, CO_2) and fuel consumption (estimated using a vehicle path model)

The results are given at various aggregation levels: individual lanes, individual movements, the junction approaches and the junction.

JCT will be releasing a new version of LINSIG in 2012 with features designed to assist users in Australia and New Zealand, including a means of importing data from SCATS[26].

[26] Sydney Coordinated Adaptive Traffic System

3.2.4.2 Assignment models

According to **Taylor (2009)**, most Australian States and Territories have developed strategic transport demand modelling (STDM) tools. Each of the Australian strategic transport models operate on either the CUBE or EMME software platforms (**Taylor, 2009**). The standard outputs of these tools are typically AM peak and PM peak hour vehicle delay, intersection degree of saturation, and 'level of service' (on a scale from A to F which is based on average delay). Traffic volumes and speeds may also be estimated, but these are not always part of the standard output.

A high-profile example is the Sydney STM which is operated by the NSW Bureau of Transport Statistics and is built largely in the EMME software (**BTS, 2012**). This model will be used for most large infrastructure projects in the GMR. The STM projects travel patterns in Sydney, Newcastle and Wollongong under different land use, transport and pricing scenarios. It can be used to test alternative settlement, employment and transport policies, to identify likely future capacity constraints, or to determine potential usage levels of proposed new transport infrastructure or services.

The STM produces travel forecasts for:

- Five yearly intervals from 2006 to 2036.
- Nine travel modes: car driver, car passenger, rail, bus, light rail, ferry, bike, walking and taxi.
- Seven trip purposes: work, business, primary/secondary/tertiary education, shopping, other.
- 24-hour and average workday (Monday to Friday, excluding public holidays) travel.
- Travel during the AM peak (07:00-09:00), PM peak (15:00-18:00), the inter-peak (09:00-15:00) and the rest of the day.
- Road assignment statistics (*e.g.* total vehicle travel time and distance) by time period - as 'passenger car units' (PCUs).
- The Bureau of Transport Statistics also has a separate commercial vehicle model forecasting system (**Milthorpe, 2012**).

3.2.4.3 Micro-simulation models

Micro-simulation tools are also in use in NSW, including PARAMICS (**Ryan, 2012**).

3.2.5 Models used in environmental impact assessment in NSW

A number of EISs were examined to determine the traffic models used. The findings are summarised in **Table 7**.

Table 7: Models used in environmental impact assessment

Project	Type of assessment	Reference	Road traffic model
Pacific Highway, Ballina Bypass.	EIS	**Connell Wagner (1998)**	EMME/2
Bulahdelah Upgrading the Pacific Highway.	EIS	**RTA (2004)**	Tranplan
Upgrade of Cowpasture Road – North. Liverpool Road to Westlink M7.	REF	**RTA (2005)**	EMME/2
Great Western Highway Upgrade. Wentworth Falls East Tableland Road to Station Street.	REF	**RTA (2006)**	SIDRA
Pacific Highway, Banora Point Upgrade.	EIS	**Parsons Brinckerhoff (2008)**	EMME/2
M2 Upgrade.	EA	**Transurban (2010)**	TSUTM, SCATES, SIDRA
North-West Rail Link.	EIS	**Transport for NSW (2012)**	SIDRA

3.3 Rail transport emission models

Emissions from rail transport are a function of:

- The type of transport (passenger or freight).
- The type of locomotion (*e.g*. diesel or electric).
- The different types of locomotive in use (*e.g.* locomotives used for line haul[27] are typically larger and more powerful than those used for shunting operations).
- Operating mode (*e.g.* speed or 'notch' settings), and the time spent in different modes.
- The overall level of activity (*e.g.* hours of operation, amount of fuel consumed or distance travelled).

Rail emission models have different levels of complexity. For inventories it is usually sufficient to use aggregated emission factors for each pollutant, and these are usually fuel-specific (*i.e.* grammes emitted per litre of diesel fuel consumed). More complex models are based on empirical correlations between emissions, train type, and other variables. The energy consumption of a particular train (or train type) is typically calculated using driving resistances, taking into account the technical characteristics of the train, a load factor for the train type, the characteristics of the railway line, and the speed profile. Where emissions from electric trains are allocated to the rail sector, the location of the emission will be the power station, and therefore a function of power consumption and power plant emission factors.

As with road transport there are a number of different rail emission models. Examples of methods and models in use in Europe include the EMEP/EEA Guidebook (**EEA, 2009**), the ARTEMIS rail model (**Lindgreen and Sorenson, 2005**), PRORIN (**Gijsen and van den Brink, 2002**) and

[27] The movement of cargo over long distances.

RAILI[28]. In addition, several relatively simple web-based tools have been developed to compare road and rail emissions, a good example being EcoTransIT[29]. However, there has been relatively little development of rail emission models in Australia, and calculation approaches have tended to rely upon data from other countries. Some methods which have been used in Australia are briefly summarised below.

3.3.1 National Pollutant Inventory

A manual for estimating emissions from railways for the NPI was published by **Environment Australia (1999)**. The method is based on a national locomotive fleet mix and average fuel consumption figures developed by the USEPA. Emissions are calculated by multiplying the amount of fuel consumed in the inventory area by the appropriate fuel-specific emission factors (expressed in grammes per litre of fuel burned) for NPI substances. A distinction is made between line haul locomotives and yard locomotives, and some examples of the emission factors are provided in **Table 8**.

Table 8: Locomotive emission factors in the NPI (**Environment Australia, 1999**)

Pollutant	Emission factor (g/l)	
	Line haul locomotives	Yard locomotives
CO	7.5	10.7
NO_x	59.1	60.4
PM_{10}	1.39	1.65
SO_2	2.59	2.59
VOC	2.54	6.09

3.3.2 NSW GMR emissions inventory model

3.3.2.1 2003 inventory

In the 2003 inventory for the NSW GMR, emissions from railways were estimated using the NPI method described above. Data on the volume of fuel consumed and gross tonne-kilometres (GTK)[30] were obtained from ABARE and the rail operators (**DECC, 2007b**).

3.3.2.2 2008 inventory

As noted earlier, the 2003 inventory has recently been superseded by the 2008 inventory. At the time of writing the description of the rail methodology had not been published. However, a spreadsheet containing the rail calculations was supplied to PAEHolmes by EPA (**Agapides, 2012**). Again, emissions are calculated using the amount of fuel consumed and fuel-specific emission factors from the US (**USEPA, 2009b**; **USEPA, 2009c**), which are similar to those used in the 2003 inventory. The fuel consumption and emissions are spatially disaggregated by Local Government Area (LGA), and also by line, by applying a top-down calculation method.

[28] http://lipasto.vtt.fi/railie/index.htm

[29] http://www.ecotransit.org/

[30] One gross tonne-km represents the movement over a distance of one kilometre of one tonne of rail vehicle, including the weight of the tractive vehicle and the load.

3.3.3 Other models

Other models have been for specific studies in Australia. For example, in an emissions inventory for the Port of Brisbane, **Smit *et al.* (2010)** used the EMEP/EEA Guidebook approach to estimate emissions from locomotives. In an air quality assessment of the Koolbury Rail Loop, **Kellaghan (2010)** used emission data for class 81 and class 90 locomotives from **Lilley (1996)** and data for class 82 and 90 locomotives from manufacturer specifications.

3.4 Rail transport data

Data on diesel fuel consumption can usually be obtained from the rail operators. Other activity data for passenger trains, where required, are available from timetables, but information on freight traffic scheduling and activity data are more difficult to obtain. Indeed, freight trains, although subject to timetabled movements, routinely deviate from schedules to allow priority to late-running passenger services.

3.5 Methods for monetising air pollution impacts

3.5.1 General approaches

The following Sections provide brief descriptions of the two main approaches to valuing changes in air pollution: the 'impact pathway' approach and the 'damage cost' approach. For more detail on these approaches the reader is referred to the report by **Aust *et al.* (2012)**.

3.5.1.1 Impact pathway approach

The approach taken for the detailed valuation of the health impacts of air pollution is often referred to as the impact pathway approach. This approach was developed through a series of joint EU-US research projects in the 1990s, and involves the following steps:

- Step 1: Quantification of emissions, with disaggregated road-based or grid-based source apportionment.
- Step 2: Analysis of pollutant dispersion and chemistry across different spatial scales. This includes the consideration of primary pollutants and secondary pollutants (secondary particles such as sulphates, or gaseous pollutants such as ozone), and the assessment of changes in pollutant concentrations.
- Step 3: Quantification of the exposure of people, the environment and buildings that are affected by air pollution (*i.e.* linking pollution with the 'stock at risk' using, for example, population data).
- Step 4: Quantification of the impacts of air pollution using relationships from studies that link pollutant concentrations with physical impacts such as health outcomes. The outcomes are typically based on epidemiological studies, which may have been undertaken in the country of interest or may be transferred from other countries.
- Step 5: Valuation of the impacts. This is usually undertaken using a 'willingness to pay' (WTP) approach based on stated and revealed preference techniques. It requires analysis of three components, each of which captures a different element of the total effect: the resource costs (*i.e.* medical treatment costs), the opportunity costs

in terms of lost productivity, and dis-utility (*i.e.* pain or suffering, concern and inconvenience to family and others).

The impact-pathway approach is recommended best practice for monetising the impacts of air quality policies as it uses a more detailed location-specific approach to quantifying and valuing the impact of air pollution changes. However, it is important to note that there are uncertainties associated with each step of the pathway, particularly relating to the quantification of emissions, the health and non-health impacts of changes in air quality, and the valuation of these impacts. The impact pathway approach is also resource intensive – and prohibitively so for many policy impact assessments - with a large volume of information being required (**Defra, 2007**). As a consequence, some simplified approaches have been developed.

In some cases - such as standard setting - Steps 1 and 2 may not be required as changes in the exposure of the stock at risk is estimated using current and predicted future air quality for the base case, and the assumed standard for the alternative case for which benefits are evaluated.

3.5.1.2 Damage cost approach

Some countries have adopted tables or models to allow a valuation of the marginal costs of air quality impacts based solely on emissions, whereby the only information available is the change in the amount of pollutant emitted. These are frequently referred to as 'damage cost' or 'unit cost' methods, and use approximate monetary values per tonne of pollutant. Examples include the damage costs from the UK Interdepartmental Group on Costs and Benefits (IGCB) and the EU Clean Air for Europe (CAFE) programme. It is worth noting that the specific damage costs for a particular country or region are usually developed using the impact pathway approach and location-specific inputs (*e.g*. population density, life expectancy). However, this is not always possible.

In the UK a simple decision tree is used to determine when it is appropriate to use the more detailed impact pathway approach or damage costs. For cases that involve state (or national) level policies that affect air quality, an impact pathway approach is probably needed. For individual policy proposals a damage cost approach may be sufficient.

In the UK the damage cost approach is used when the estimated impacts of a proposal on air quality are less than £20 million, when the impacts will last for less than 20 years, or where air quality impacts are ancillary to the policy or policies (**Defra, 2011**). The use of damage costs is not, however, considered a replacement for detailed modelling and analysis. Damage costs are more appropriate as part of a filtering mechanism to narrow down a wide range of policy options into a smaller number that are then taken forward for more comprehensive assessment.

3.5.2 Australian examples

An international review of the approaches used for valuing the health impacts of PM emissions and concentrations was recently completed on behalf of EPA[31] by **Aust *et al.* (2012)**. The review covered work undertaken by overseas jurisdictions - including the EU, the US, Canada and New Zealand - and also Australian jurisdictions. For the international methodologies the reader is referred to the original review. The Australian studies are briefly summarised below. Again, further details on the methodologies are available from the review. The damage cost values from the Australian studies are given in **Table 9**.

[31] EPA project (OEH-1072-2011 – Methodology for Valuing the Health Impacts of Changes in Particle Emissions).

Table 9: Summary of damage cost values from Australian studies (adjusted to 2010 prices)

Study	Details	Unit damage cost (A$/tonne)				
		PM_{10}	NOx	THC	SO_2	CO
NSW EPA (1997)		3,747	3,085	1,987	-	52
NSW EPA (1998)		642	141	-	-	-
Environment Australia (2000b)		23,659	1,862	1,936	-	16
Beer (2002)	Ozone included	184,326[b]	1,088[b]	24,169[b]	-	4[b]
	Ozone excluded	184,326[b]	14[b]	23,404[b]	-	4[b]
Watkiss (2002)	Band 1: Inner areas of larger capital cities	427,155	2,188	1,094	14,228	-
	Band 2: Outer areas of larger capital cities	116,500	2,188	1,094	5,476	-
	Band 3: Other capital cities and urban areas	116,500	325	219	3,501	-
	Band 4: Non-urban areas	1,550	-	-	66	-
Coffey (2003)	Capital cities	282,243	10,341[a]	2,676	-	16
CIE (2005)	Sydney	293,185	-	-	-	-
DEC (2005b)	Sydney	273,242[b]	-	-	-	-
	Hunter	72,941[b]	-	-	-	-
	Illawarra	54,416[b]	-	-	-	-
DIT (2010)	Capital cities	241,955[b]	-	-	-	-
	Rest of Australia	57,415[b]	-	-	-	-

(a) Ozone formation
(b) Central estimate

Early valuations of the health impacts of air pollution were presented by **NSW EPA (1997, 1998)** and **Environment Australia (2000b)**. The damage costs from these studies were summarised by **Coffey (2003)** – though it was noted that many of these will not have taken chronic mortality into account, and so cannot be directly compared with more recent estimates. This would explain in part the much lower values obtained in these earlier studies.

Beer (2002) used published Australian transport-related health costs to estimate the costs associated with the road transport contribution to ambient PM_{10}. The work by Beer is cited as being the only valuation study based on Australian data, although it uses an equation developed to represent US conditions in the early 1990s.

Damage costs were derived for Australia as part of the Fuel Taxation Inquiry by **Watkiss (2002)**. Unit damage costs for criteria air pollutants were obtained from the international literature and adjusted to reflect Australian conditions. Unit costs were determined for areas in four population density bands.

Coffey (2003) used marginal abatement benefit values ($/tonne avoided) for VOCs reductions. The savings per tonne of emission varied from location to location according to population and meteorological factors. However, the values did not appear to take account of the role of NO_x and SO_2 in secondary PM formation. The report also summarised earlier values (also shown in **Table 9**)

– though it was noted that many of these will not have taken chronic mortality into account, and so cannot be directly compared with more recent estimates.

In 2005, the Centre for International Economics undertook an evaluation of Sydney's existing and future transport infrastructure. As part of the study, CIE assessed damage costs for PM_{10} (**CIE, 2005**).

DEC (2005) derived damage costs for the NSW GMR (defined as 'Hunter', 'Sydney' and 'Illawarra'), and obtained values for PM_{10} of A$236,000 per tonne for Sydney, falling to A$47,000 for Illawarra.

The NSW Department of Infrastructure and Transport (**DIT, 2010**) undertook a review of health benefits as part of a Regulatory Impact Statement for adopting the Euro 5 and Euro 6 emissions standards for light-duty vehicles. The study used an avoided health cost approach, whereby monetary values (in $/tonne) were assigned to HC, NO_x and PM. The studies by **Coffey (2003)**, **Watkiss (2002)** and **Beer (2002)** were used to calculate the total health benefit. Unit damge cost values for capital cities were calculated by taking the simple average of the estimates from the three studies. Unit values for the rest of Australia were based on the simple average of the estimates for Band 3 and Band 4 contained in **Watkiss (2002)**.

The most recent cost-benefit analysis of air pollution in the GMR was completed by **Jalaludin *et al.* (2011)**. The authors estimated the number of adverse health effects that could be avoided (and the associated monetary benefit) by reducing concentrations of $PM_{2.5}$, PM_{10} and O_3 to near-background levels. It was found that the associated health benefit for the GMR equated to A$5.7 billion, the greatest proportion of which was due to avoiding premature deaths due to long-term exposure to $PM_{2.5}$. However, unit damage costs for emissions were not determined.

3.5.3 Updated Australian methodology

Aust *et al.* (2012) concluded that the most robust method for valuing health impacts from air pollution follows the impact pathway approach, and the most advanced and detailed studies have been those undertaken in Europe and the US. These studies have also captured the complexity associated with chronic health effects. This is not reflected in the earlier Australian studies, though this is in part due to their age.

The report by **Aust *et al.* (2012)** also included as analysis of Australian needs and conditions, and the availability of data and information to support the use of potential methodologies, a review of the literature on secondary particles, and a proposed methodology for estimating the health costs associated with changes in PM emissions in NSW and Australia.

The authors proposed a new methodological framework based on a two-level approach, as used in the UK, in which the impact pathway or damage cost approach is recommended based on the type of application and the anticipated effects of the changes. However, it was concluded that Australia currently lacks sufficient and readily available PM emission modelling information to permit a full impact pathway process and, by extension, to generate a set of accurate, location-specific damage costs. Consequently, a method was provided for calculating damage costs for primary $PM_{2.5}$ emissions based on UK data which can be used until more reliable data are available for Australia. The approach relates unit damage costs for $PM_{2.5}$ emissions to population density, and provides specific unit damage costs for the 'Significant Urban Areas' (SUAs) defined by the Australian Bureau of Statistics.

4 DEVELOPMENT OF AIR QUALITY APPRAISAL TOOL

This Chapter summarises the development of AQAT based on the information presented in the previous Chapters. The calculation methodology is described in more detail in **Appendix C**, and a User Guide is provided in **Appendix D**. The User Guide also includes further guidance on the application of AQAT, and potential sources of input data.

4.1 Overall approach

The single most important consideration in the development of AQAT was the selection of a method for quantifying the health costs of air pollution, as this dictated the outputs that would be required for other elements of AQAT. In fact, the impact pathway approach is a resource intensive process, and was not considered to be a realistic option for deriving Australian air pollution costs for AQAT. The complexity and cost of the approach precluded its use for evaluation at the level envisaged by EPA. An approach based on damage costs (in A$ per tonne of pollutant emitted) was therefore considered to be more appropriate for use in AQAT.

This therefore meant that the changes in emissions from road and rail for a given development had to be quantified. As noted earlier, varying levels of data and resources will be available to the potential end user of AQAT. The availability of data will differ for different types of development, and in particular whether an EIS has been compiled. For large developments, data on transport activity and emissions will generally have been obtained, or could be estimated from the available data, and therefore damage cost values could be used directly. For smaller, local developments there are generally very few data, and therefore algorithms had to be incorporated into AQAT to enable emissions to be calculated.

The selection of the methods and models for monetising impacts and quantifying emissions is described in the following sections. No resources were available for the development of new emission models, and therefore existing models were adapted for use in AQAT.

Microsoft Excel was selected as the platform for AQAT because it is widely available and can be used with little training.

4.2 Selection of approach for monetising impacts

The different approaches to quantifying the health impacts of air pollution have recently been reviewed in the EPA project *Methodology for Valuing the Health Impacts of Changes in Particle Emissions* (**Aust *et al*., 2012**), and the findings from this informed the development of AQAT. More specifically, **Aust *et al.* (2012)** provided Australia-specific unit damage costs for pollution from transport sources[32]. The damage costs correspond to the effects of air pollution on chronic mortality, acute mortality, and all respiratory and all cardiovascular hospital admissions.

These unit damage costs for transport have been included in AQAT. These are specified in terms of population density (which acts as a surrogate for exposure to air pollution), and include relevant uplifts and discounts for future years (an explanation of these terms is provided in **Section C3.1** of **Appendix C**).

[32] On a cost-per-tonne basis, the non-transport damage costs are substantially lower than those for transport.

Aust *et al.* (2012) did not provide damage costs for secondary PM, as it is more difficult to accurately transfer these between countries. Further modelling and analysis of Australian conditions was recommended to develop a set of appropriate values. Once this work has been undertaken, the possibility of including secondary PM in AQAT should be re-evaluated.

It should also be noted that the unit damage costs provided by **Aust *et al.* (2012)** exclude several key effects, as the quantification and valuation of these was not possible or was highly uncertain. The key effects that have not been included are:

- Effects on ecosystems (through acidification, eutrophication, *etc.*).
- Impacts of trans-boundary pollution.
- Effects on cultural or historic buildings from air pollution.
- Potential additional morbidity from acute exposure to PM.
- Potential mortality effects in children from acute exposure to PM.
- Potential morbidity effects from chronic (long-term) exposure to PM or other pollutants.
- Effects of exposure to ozone, including both health impacts and effects on materials.
- Change in visibility (visual range).
- Macroeconomic effects of reduced crop yield and damage to building materials.
- Non-ozone effects on agriculture.

4.3 Selection of emission modelling approaches

4.3.1 Road transport

Based on a consideration of the available options, it was decided that the TRAQ model was the most suitable approach for modelling road traffic emissions in AQAT for the following reasons:

- The level of the approach in TRAQ is in keeping with the need for simple calculations in AQAT, and it is easy to update the model.
- TRAQ offers sufficient flexibility for the assessment of road transport developments.
- It is relatively straightforward to adapt the TRAQ databases for use in AQAT.
- The TRAQ emission factors are consistent with those used in the 2008 NSW emissions inventory.

Importantly, NSW Roads and Maritime Services (RMS) also agreed for TRAQ to be used in the EPA Air Quality Appraisal Tool.

Road traffic emissions are therefore calculated using the aggregated emission factors developed by EPA for the 2008 GMR inventory and supplied to RMS for use in the TRAQ model (Version 2, release date 12 April 2012)[33]. The emission factors in TRAQ are not available through the user interface (the calculations are managed using macros), and therefore in AQAT the emission factors are reconfigured using Excel functions.

[33] RMS granted PAEHolmes permission to use the data and algorithms from TRAQ in the Air Quality Appraisal Tool.

TRAQ does, however, have some limitations at present. For example, calculations can only be made for specific years (2008, 2011, 2016, 2021 and 2026), due to the fleet data only being included for these years. However, it is assumed that EPA could provide fleet data for other years if needed. The calculations in TRAQ are also managed using macros in Visual Basic for Applications (VBA), and therefore these were converted to functions in Excel.

4.3.2 Rail transport

The capabilities for modelling rail emissions in Australia are rather limited, and there is a heavy reliance upon emission factors from the USEPA. The existing calculation methods also require knowledge of actual fuel consumption. However, it is unlikely that the user of AQAT will have ready access to train fuel consumption data. Based on a consideration of the available options, it was concluded that the method used in the 2008 GMR inventory would, with some adaptation, be the most suitable approach for use in AQAT.

In NSW most rail passenger services are electrified, whereas diesel locomotives are used for line haul and shunting operations. Including electricity generation complicates the analysis in AQAT (and in particular the selection of appropriate damage costs), since the location of energy use is not the same location as where emissions are being produced. Electricity generation does not therefore directly affect the local area under consideration. If emissions are to be allocated spatially and temporally then the locations of power stations must be known (or otherwise a general 'area type' must be defined for the air pollution health costs associated with power stations). However, a number of assumptions may be required, such as power distribution losses, the use of regenerative braking systems, *etc*.

A spreadsheet summarising the calculation of rail emissions for the 2008 GMR inventory was supplied to PAEHolmes by EPA (**Agapides, 2012**). The EPA spreadsheet contained activity data in gross tonne-kilometres for all trains in the GMR (31,940,182 tonne-km) during 2008, as well as total diesel consumption by freight (128,836,774 litres) during the same period. Given that most of the rail diesel consumption in NSW relates to the haulage of freight and that passenger trains are predominantly electrified, a decision was made to exclude passenger transport from AQAT. It was therefore assumed that the gross tonne-km value related to freight trains only, giving a single average unit fuel consumption value of 4.03 litres per thousand gross tonne-km for freight trains. This is very similar to values reported in the literature (*e.g.* **Pacific National, 2006**; **ARTC, 2010**). No further disaggregation was possible.

4.4 Use of models within AQAT

The calculation of damage costs for the health impacts associated with air pollution requires data on both emissions from road and/or rail transport, as well as population density. Without one or the other the calculation is not possible. A given development could affect costs through a change transport emissions, a change in population density, or both.

For example, the construction of a new road will result in a change in road transport emissions, but not necessarily a change in nearby population density. Nevertheless, the population density must still be quantified. Other developments (*e.g.* construction of a new housing estate) will result in a change in land use and population density. The change in land use alone will have implications in terms of the damage costs of air pollution. There may or may not be a change in the activity on the transport corridor and local roads, and there may also be some new roads.

In AQAT the potential damage costs for different types of development are accommodated by allowing the user to specify road transport emissions, rail transport emissions and population density (through the use of SUAs).

The damage cost methodology is similar to that described by **Defra (2008, 2011)**. However, whereas the Defra approach involves calculating damage costs for policies which have a timescale of several years, for AQAT it was assumed that the air pollution impacts of a development would be considered for a specific year. The user needs to select the particular year for which air pollution is being considered (the options being 2008, 2011, 2016, 2021 or 2026). AQAT is restricted to these years because they are the only ones covered by the road traffic emission model.

The changes in emissions of CO, HC, NO_x, $PM_{2.5}$ and CO_2-e, and also the changes in damage costs, are presented separately for road and rail traffic, as well as in combination.

5 CASE STUDIES

5.1 Overview

It was important to demonstrate that AQAT could deal with different types of development. In this Chapter the functionality of AQAT has been demonstrated through application in four case studies:

- A local transport development involving a road bypass
- A local land use development involving a growth centre
- A state-significant transport development involving a rail freight link
- A comparison between two local land use developments

It should be noted that the examples are only designed to show how AQAT could be used and to identify some of the issues that may be encountered. The assessments are not meant to be comprehensive and are not designed to address all aspects of the developments. They are not substitutes for EIA, nor are they designed to replicate the results of EIAs.

5.2 Study 1: Local transport - road bypass

5.2.1 Description of case study

This case study illustrates how AQAT could be used to evaluate the change in the exposure of a local population to air pollution following the introduction of a road bypass scheme.

The Ballina Bypass project[34] will provide 12 km of dual carriageway on the Pacific Highway, extending from south of Ballina at the intersection of the Bruxner and Pacific highways to north of Ballina at the intersection of Ross Lane at Tintenbar. The NSW Minister for Planning approved the Ballina bypass project on 22 May 2003. Construction began in May 2008, and the bypass opened to traffic in 2012.

The project is designed to improve traffic and environmental conditions within Ballina by removing through traffic, improving road safety, providing uninterrupted traffic flow on the Highway, and providing easy access to and from the Highway for local traffic. The location and alignment of the Bypass are shown in **Figure 4**.

The reduction in the volume of traffic on the roads in Ballina should result in a reduction in emissions on those roads and a reduction in overall exposure to air pollution.

[34] http://www.rta.nsw.gov.au/roadprojects/projects/pac_hwy/ballina_tweed_heads/ballina_bypass/index.html

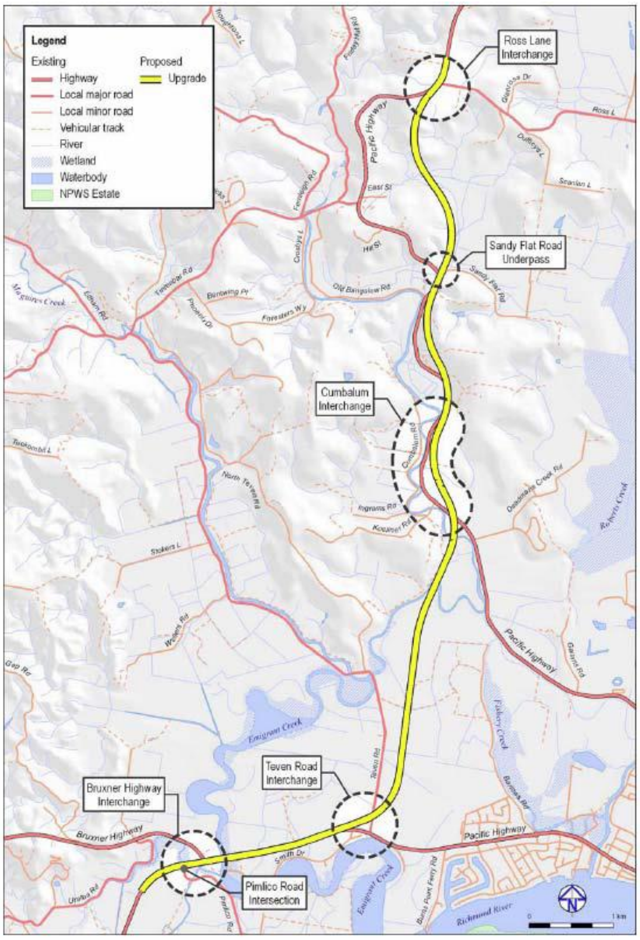

Figure 4: Ballina Bypass location and alignment (**RTA, 2008a**)

5.2.2 Input data

In order to evaluate the Ballina Bypass (or any similar scheme), the following information was required for each affected road in the study area before and after the development:

- The road type
- The road gradient
- The road length
- The daily traffic volume
- The traffic mix
- The traffic speed
- The local population density (i.e. the SUAs affected)

The data for each road are entered on a separate line in the AQAT spreadsheet, which then estimates the emissions from the traffic and the associated damage costs.

The actual inputs used in the Ballina case study are summarised below.

5.2.2.1 Road and traffic data

The roads affected by the Ballina Bypass – as defined in the EIS (**Connell Wagner, 1998**) - are shown in **Figure 5**. It should be noted that links 1, 2 and 14 extended some way beyond the town of Ballina. For the purpose of this example, it would have been necessary to assume that the bypass had an influence on the traffic on these roads over a fixed distance. However, the results would have been dependent upon the actual distance used. Therefore, these road links were excluded from the calculations to maintain a 'closed' system.

Road lengths were determined using Google Earth. In addition, the road type in each case was based on a visual inspection in Google Maps. The traffic volume data were taken from the EIS and from **RTA (2008b)**. For each road the traffic speed was assumed to be the same as the speed limit, which was obtained using Google Maps. The default traffic composition data for each road type were taken from AQAT.

The road and traffic data are summarised in **Table 10**. The data with and without the bypass were available for the year 2022 (including expected traffic growth), and therefore the closest year to this in AQAT, 2021, was used in the assessment.

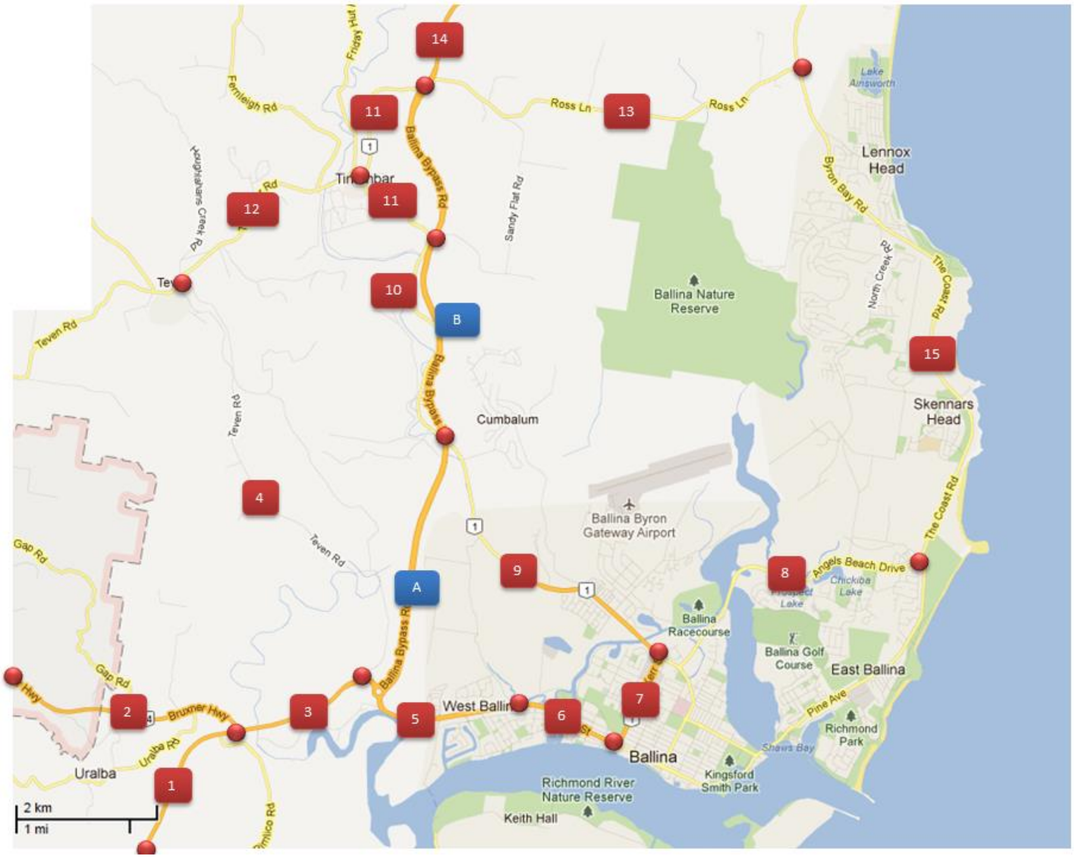

Figure 5: Roads affected by the Ballina Bypass. The Bypass itself is identified by sections A and B (Background image from Google Maps).

Table 10: Traffic data for roads affected by Ballina Bypass (2021)

Road	Road name	Road type	Grade (%)	Length (km)	Daily traffic (vpd)	Traffic mix (%) CP	CD	LDCP	LDCD	HDCP	RT	AT	BusD	MC	Speed (km/h)
Before development															
3	Pacific Highway, east of Bruxner Highway	Highway/freeway	0%	2.1	23,208	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	50
4	Teven Road	Arterial	0%	7.5	7,288	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	80
5	Pacific Highway, east of Teven Road	Highway/freeway	0%	2	35,132	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
6	Pacific Highway Fishery Creek	Highway/freeway	0%	1.6	39,319	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
7	Kerr Street	Arterial	0%	1.4	26,938	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	60
8	Angels Beach Drive	Arterial	0%	4.6	16,566	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	80
9	Pacific Highway, east of industrial area	Highway/freeway	0%	4.7	29,732	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
10	Pacific Highway, north of Cumbalum Interchange	Highway/freeway	0%	3.2	13,800	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
11	Pacific Highway, Tintenbar	Highway/freeway	0%	3.4	12,910	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
12	Tintenbar Road	Arterial	0%	3.5	20,356	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	80
13	Ross Lane	Arterial	0%	5.7	12,180	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	80
15	The Coast Road	Arterial	0%	8	15,282	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	100
A	Bypass, south of Cumbalum	Highway/freeway	-	-	-	-	-	-	-	-	-	-	-	-	-
B	Bypass, south of Cumbalum	Highway/freeway	-	-	-	-	-	-	-	-	-	-	-	-	-
After development															
3	Pacific Highway, east of Bruxner Highway	Highway/freeway	0%	2.1	26,736	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	50
4	Teven Road	Arterial	0%	7.5	2,290	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	80
5	Pacific Highway, east of Teven Road	Highway/freeway	0%	2	32,702	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
6	Pacific Highway Fishery Creek	Highway/freeway	0%	1.6	36,834	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
7	Kerr Street	Arterial	0%	1.4	23,752	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	60
8	Angels Beach Drive	Arterial	0%	4.6	13,786	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	80
9	Pacific Highway, east of industrial area	Highway/freeway	0%	4.7	29,486	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
10	Pacific Highway, north of Cumbalum Interchange	Highway/freeway	0%	3.2	5,734	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
11	Pacific Highway, Tintenbar	Highway/freeway	0%	3.4	10,268	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
12	Tintenbar Road	Arterial	0%	3.5	12,300	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	80
13	Ross Lane	Arterial	0%	5.7	14,896	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	80
15	The Coast Road	Arterial	0%	8	11,200	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	100
A	Bypass, south of Cumbalum	Highway/freeway	0%	3.8	12,740	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
B	Bypass, south of Cumbalum	Highway/freeway	0%	5.4	23,100	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100

5.2.2.2 SUA allocation

In this case study it was necessary to distinguish between two NSW SUAs: 'Ballina' and 'Not in any significant urban area'. The Boundary of the Ballina SUA is shown in **Figure 6**. The SUA covers the 'A' section of the bypass area, but not the 'B' section. However, for the purpose the case study it was assumed that the SUA did not include the bypass, and that development will occur around the bypass in future years. It was therefore concluded that road links 5, 6, 7, 8, 9 and 15 were inside the SUA and the remaining links were not in any significant urban area (**Table 11**). In a rigorous assessment more accurate data could be obtained using a geographical information system (GIS). A future population growth rate of 1% per annum was used.

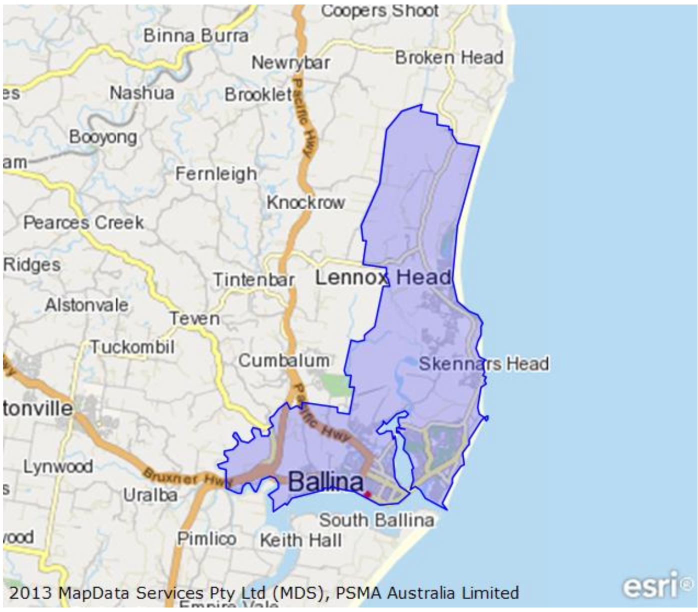

Figure 6: Boundary of Ballina SUA (REF)

Table 11: Assumed SUAs for roads affected by Ballina Bypass

Road	Road name	Significant urban area	Unit damage cost for $PM_{2.5}$ in SUA (A$/tonne, 2011)
3	Pacific Highway, east of Bruxner Highway	Not in any Signif. Urban Area	$360
4	Teven Road	Not in any Signif. Urban Area	$360
5	Pacific Highway, east of Teven Road	Ballina	$90,000
6	Pacific Highway Fishery Creek	Ballina	$90,000
7	Kerr Street	Ballina	$90,000
8	Angels Beach Drive	Ballina	$90,000
9	Pacific Highway, east of industrial area	Ballina	$90,000
10	Pacific Highway, north of Cumbalum I'change	Not in any Signif. Urban Area	$360
11	Pacific Highway, Tintenbar	Not in any Signif. Urban Area	$360
12	Tintenbar Road	Not in any Signif. Urban Area	$360
13	Ross Lane	Not in any Signif. Urban Area	$360
15	The Coast Road	Ballina	$90,000
A	Bypass, south of Cumbalum	Not in any Signif. Urban Area	$360
B	Bypass, south of Cumbalum	Not in any Signif. Urban Area	$360

5.2.3 Results

The results from AQAT are shown in **Table 12** and **Table 13**. The results show that in 2021 there will be increases in emissions of CO, NO_x, $PM_{2.5}$ and CO_2 from road traffic as a result of the bypass. However, despite these increases in emissions the lower population density alongside the bypass will lead to a net reduction of 5% in the health-related costs associated with air pollution (based on primary PM emissions only).

Table 12: Emissions from road traffic – Ballina Bypass

Traffic emissions	CO	NOx	$PM_{2.5}$	HC	CO_2-e
Before development (tonnes/year)	775	218.9	8.83	21.6	89,977
After development (tonnes/year)	809	243.3	9.37	21.6	98,888
Change (tonnes/year)	*34.3*	*24.4*	*0.54*	*-0.06*	*8,911*
Change (%)	*4.4%*	*11.2%*	*6.1%*	*-0.3%*	*9.9%*

Table 13: Damage costs for Ballina Bypass (primary $PM_{2.5}$ emissions only, A$ in 2011 prices)

Case	Cost
Before development (A$/year)	$349,739
After development (A$/year)	$310,578
Change (A$/year)	*$-39,160*
Change (%)	*-11.2%*

5.3 Study 2: Local land use – growth centre

5.3.1 Description of case study

This case study illustrates how AQAT can be configured to process general travel data rather than traffic data for specific road links.

The Leppington North Precinct was released for planning by the Minister in October 2009. It is a 1,090-hectare precinct in the South West Growth Centre (**Figure 7**, **Figure 8**). The Precinct currently comprises small rural holdings, farming lands, market gardens and some residential areas. Leppington North is expected to accommodate around 12,000 dwellings and 30,000 new residents[35]. The South West Structure Plan shows a Major Centre in Leppington North Precinct and a number of neighbourhood centres along major roads. The South West Rail link is proposed to run through the Precinct, with a station at the proposed new Leppington Major Centre.

Because the population and level of development in Leppington North are currently very low, any 'before and after' comparison that is limited to the site itself would inevitably lead to large increases in both emissions and exposure. However, this would not take into account the real exposure of people before they move to the site. This case study was therefore used to illustrate

[35] http://www.gcc.nsw.gov.au/leppington_north-103.html

how AQAT might be used to evaluate, in broad terms, the effects of such developments on emissions and pollution-related health costs.

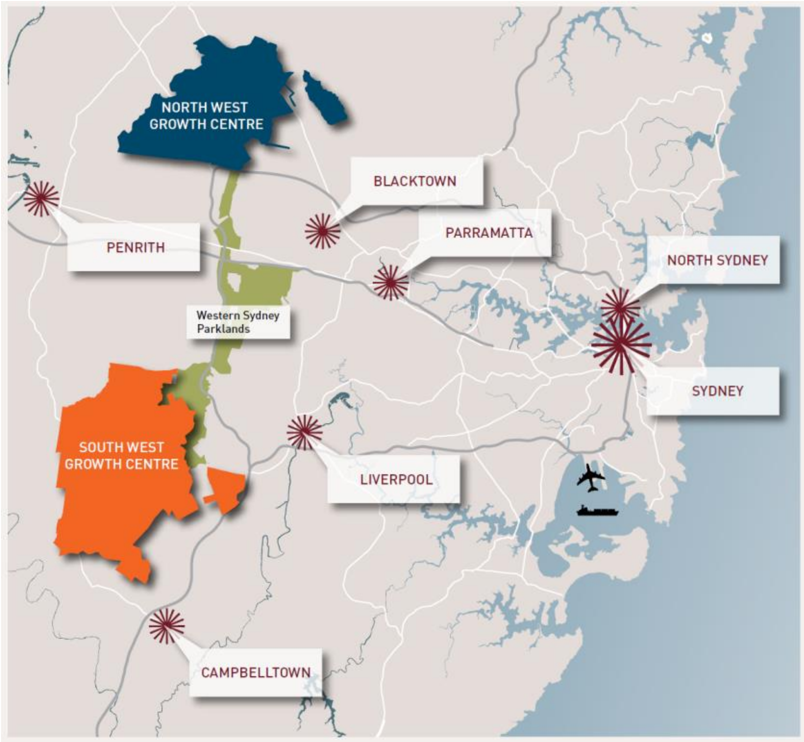

Figure 7: NSW Growth Centres (**Department of Planning, 2009**)

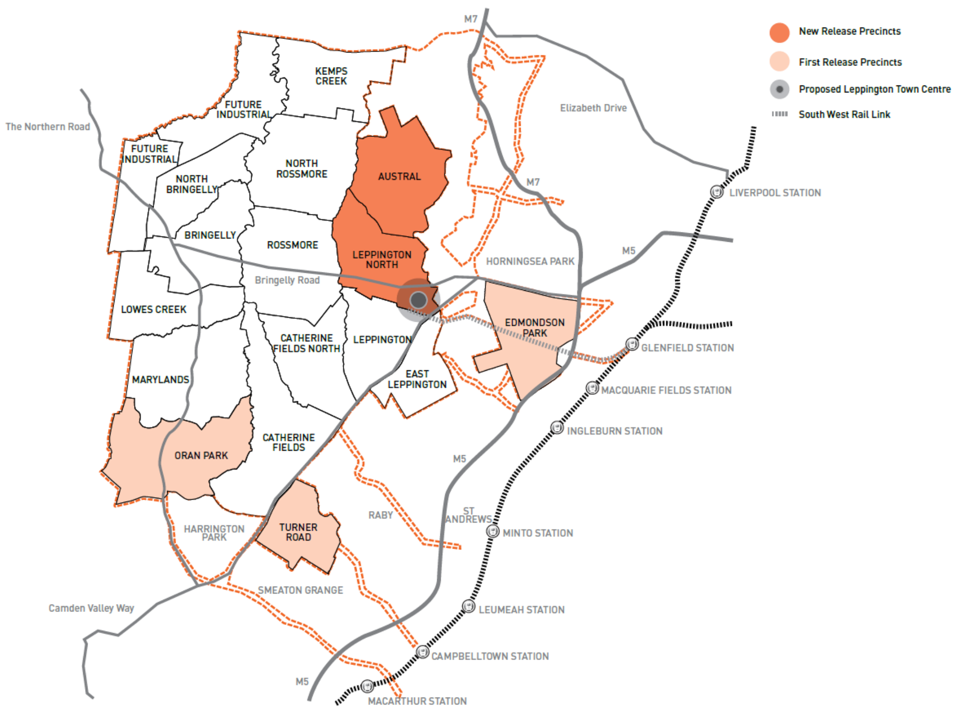

Figure 8: Leppington North location (**Department of Planning, 2009**)

5.3.2 Scenarios and input data

Essentially, the case study examined the effects of two travel scenarios relative to a baseline. As noted above, the Leppington North Development will accommodate 30,000 new residents. Although the new residents will be relocating from various different places, for the purpose of this example it was assumed that they would be moving from a single inner-city area (the example selected was Leichhardt) with high population density.

The study focussed on the number of people being relocated who were of working age, and assumed that the place of work would be either local or in an urban centre (involving a longer trip). It was also assumed that all trips to work would be made either by car or by public transport. The assessment year was 2016.

A baseline and three scenarios were developed, representing the following situations:

- **Baseline**: This situation represented people living in Leichhardt prior to the Leppington North development. It was assumed that 50% of the people of working age would travel to a local place of work, and the remaining 50% would travel to Sydney. The distances to work were relatively short and the proportion of travel by bus was relatively high. The population density was also relatively high.
- **Scenario 1**: This scenario represented a situation in which people had moved to Leppington North, but there was no local employment and no public transport. Consequently, the distances to work were relatively high and all work trips were made by car. However, the population density was lower than in the baseline case.
- **Scenario 2**: In this scenario local employment and public transport (bus only) were available in Leppington North. The distance to local employment was therefore lower than in scenario 1, and the proportion of travel by bus was higher.
- **Scenario 3**: One of the main features of the Leppington North development is that it will be situated on the line of the South-West Rail Link. In this scenario the assumptions are the same as those in scenario 2, with the exception that all public transport travel is by train rather than by bus. Because the emission factor for passenger rail in AQAT is effectively zero, there was no need to calculate the number of train journeys.

Assumptions concerning modal split were based on Household Travel Survey[36] data for Leichhardt and Campbelltown (a centre near to Leppington which would be likely to have similar demographics). Further assumptions were made concerning the road types in each case, and default speed data were taken from TRAQ. The data used for the baseline and scenarios are summarised in **Table 14**. The Sydney SUA area map (**Figure 9**) excludes the Leppington area. As Leppington is an urban growth area, it was classified here as 'Outer Sydney'. Leichhardt was classified as 'Inner Sydney' and Ryde 'Mid Sydney'. A population growth rate of 2% per year was used.

The transport input data for AQAT are shown in **Table 15**.

[36] http://www.bts.nsw.gov.au/Statistics/HTS/default.aspx#top

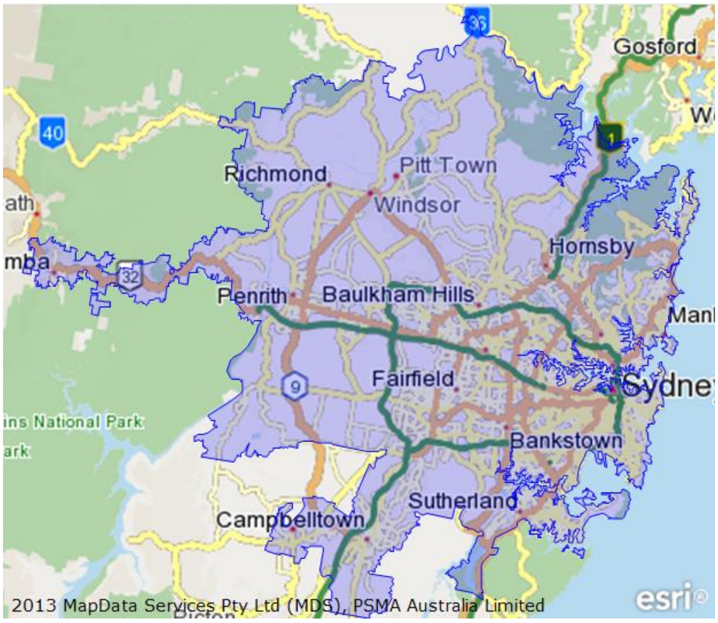

Figure 9: Boundary of Sydney SUA (REF)

Table 14: Baseline and scenario assumptions – Leppington North

	Baseline (Leichhardt)	Scenario 1 (Leppington North, no local employment or public transport)	Scenario 2 (Leppington North, with local employment and public transport - bus)	Scenario 3 (Leppington North, with local employment and public transport - train)
Population				
Population affected	33,000	33,000	33,000	33,000
% of population in work	60%	60%	60%	60%
People in work	19,800	19,800	19,800	19,800
Local work trips				
Proportion of local work trips	50%	50%	80%	80%
Number of round trips day	9,900	9,900	15,840	15,840
Length of round trip (km)	4	10	4	4
% of trips by car	50%	100%	80%	80%
Car movements per day(c)	3,300	6,600	8,448	8,448
% of trips by bus	10%	0%	5%	5%
% of trips by train/non-motorised mode	40%	0%	15%	15%
Bus movements per day(d)	33	0	26	26
Work trips to city				
Proportion of work trips to city	50%	50%	20%	20%
Number of round trips day	9,900	9,900	3,960	3,960
Length of round trip (km)	7	30	30	30
% of trips by car	30%	100%	60%	60%
Car movements per day(c)	1,980	6,600	1,584	1,584
% of trips by bus	70%	0%	40%	0%
% of trips by train	0%	0%	0%	40%
Bus movements per day(d)	231	0	53	0

(a) Approximate value.
(b) Assuming 33,000 people in 1,000 ha (10 $km/^2$).
(c) Assuming an average occupancy of 1.5.
(d) Assuming an average occupancy of 30.

Table 15: Travel data for Leppington North case study (2016)

Road	Road name	Road type	Grade (%)	Length (km)	Daily traffic (vpd)	Traffic mix (%) CP	CD	LDCP	LDCD	HDCP	RT	AT	BusD	MC	Speed (km/h)[b]
Before development															
B-1	Local trips by car	*Arterial*	*0%*	4	3,300	97[a]	3[a]	0	0	0	0	0	0	0	36.3
B-2	City trips by car	*Commercial arterial*	*0%*	7	1,980	97[a]	3[a]	0	0	0	0	0	0	0	34.2
B-3	Local trips by bus	*Arterial*	*0%*	4	33	0	0	0	0	0	0	0	100	0	36.3
B-4	City trips by bus	*Commercial arterial*	*0%*	7	231	0	0	0	0	0	0	0	100	0	34.2
After development – Scenario 1															
S1-1	Local trips by car	*Arterial*	*0%*	10	6,600	97[a]	3[a]	0	0	0	0	0	0	0	36.3
S1-2	City trips by car	*Commercial arterial*	*0%*	30	6,600	97[a]	3[a]	0	0	0	0	0	0	0	34.2
S1-3	Local trips by bus	*Arterial*	*0%*	10	0	0	0	0	0	0	0	0	100	0	36.3
S1-4	City trips by bus	*Commercial arterial*	*0%*	30	0	0	0	0	0	0	0	0	100	0	34.2
After development – Scenario 2															
S2-1	Local trips by car	*Arterial*	*0%*	4	8,448	97[a]	3[a]	0	0	0	0	0	0	0	36.3
S2-2	City trips by car	*Commercial arterial*	*0%*	30	1,584	97[a]	3[a]	0	0	0	0	0	0	0	34.2
S2-3	Local trips by bus	*Arterial*	*0%*	4	26	0	0	0	0	0	0	0	100	0	36.3
S2-4	City trips by bus	*Commercial arterial*	*0%*	30	53	0	0	0	0	0	0	0	100	0	34.2
After development – Scenario 3															
S3-1	Local trips by car	*Arterial*	*0%*	4	8,448	97[a]	3[a]	0	0	0	0	0	0	0	36.3
S3-2	City trips by car	*Commercial arterial*	*0%*	30	1,584	97[a]	3[a]	0	0	0	0	0	0	0	34.2
S3-3	Local trips by train	Not applicable – zero emissions assumed													
S3-4	City trips by train	Not applicable – zero emissions assumed													

(a) Calculated from default values in TRAQ.

(b) Default values from TRAQ.

5.3.3 Results

The results from AQAT are shown in **Table 16** and **Table 17**. The results show the effects of the trade-offs between trip length and travel mode on emissions, and the additional effect of population density on damage costs due to PM emissions. Scenario 1 led to a large increase in emissions and damage costs due to the combined effect of long trips to work and the absence of public transport. However, scenario 2 shows that - with local employment and public transport becoming available – even though there is still an increase in emissions the overall damage costs are hardly affected. In Scenario 3 there is a further reduction in emissions and damage costs when bus travel is replaced by train travel.

Table 16: Emissions from road traffic - Leppington North

Traffic emissions	CO	NO_X	$PM_{2.5}$	HC	CO_2-e
Baseline					
Before development (tonnes/year)	9.9	10.1	0.31	1.2	2,873
Scenario 1					
After development (tonnes/year)	95.9	32.9	1.55	9.9	18,995
Change (tonnes/year)	*86.1*	*22.8*	*1.24*	*8.7*	*16,122*
Change (%)	*874%*	*227%*	*396%*	*743%*	*561%*
Scenario 2					
After development (tonnes/year)	28.6	16.4	0.63	3.1	6,687
Change (tonnes/year)	*18.7*	*6.4*	*0.31*	*1.9*	*3,814*
Change (%)	*190%*	*63%*	*100%*	*168%*	*133%*
Scenario 3					
After development (tonnes/year)	*27.7*	*9.7*	*0.5*	*2.9*	*5,733*
Change (tonnes/year)	*17.9*	*-0.3*	*0.2*	*1.8*	*2,861*
Change (%)	*181%*	*-3%*	*53%*	*150%*	*100%*

Table 17: Damage costs for Leppington North (primary $PM_{2.5}$ emissions only, A$ in 2011 prices)

Case	Cost
Baseline	
Before development (A$/year)	$111,527
Scenario 1	
After development (A$/year)	$276,412
Change (A$/year)	$164,885
Change (%)	*148%*
Scenario 2	
After development (A$/year)	$111,721
Change (A$/year)	$194
Change (%)	*0.2%*
Scenario 3	
After development (A$/year)	$85,090
Change (A$/year)	$-26,437
Change (%)	*-24%*

5.4 Study 3: State transport – rail freight link

5.4.1 Description of case study

This study shows how AQAT can be used to compare the impacts of transporting freight by road and by rail.

A dedicated rail freight line exists between Port Botany and Enfield/Chullora, a distance of approximately 18 kilometres (**Figure 10**). This case study examined the effects of transferring different amounts of freight from rail transport to road transport along the same corridor (and hence the cost savings associated with the rail freight link).

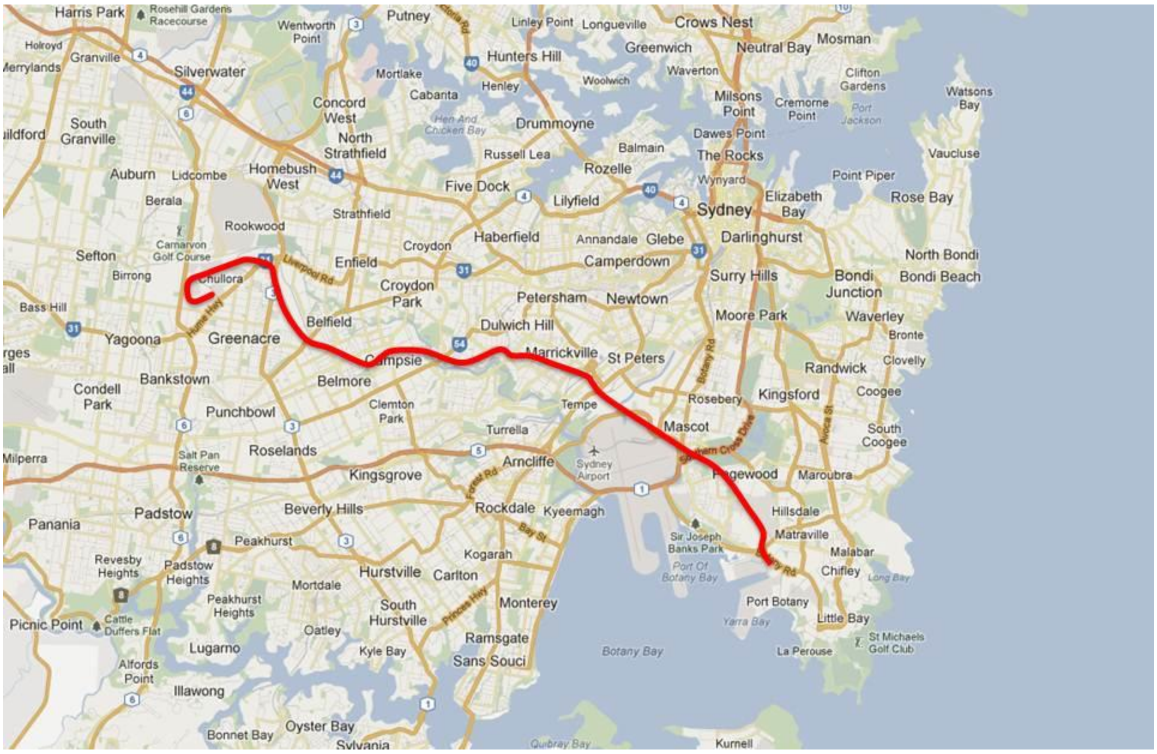

Figure 10: Botany-Enfield/Chullora freight rail link

5.4.2 Scenarios and input data

Emissions and costs were estimated for transporting an additional one million tonnes of freight annually along the full length of the rail link (in 2016). The change in population density along the rail link was also taken into account in the calculations by considering the SUAs through which it passes.

A baseline case and four scenarios were evaluated:

- **Baseline**: The additional amount of freight is transported by rail.
- **Scenario 1**: The additional amount of freight is transported by articulated trucks, each carrying a load of 20 tonnes.

- **Scenario 2**: The additional amount of freight is transported by articulated trucks, each carrying a load of 30 tonnes.
- **Scenario 3**: The additional amount of freight is transported by articulated trucks, each carrying a load of 40 tonnes.
- **Scenario 4**: The additional amount of freight is transported by articulated trucks, each carrying a load of 50 tonnes.

For each scenario the number of trucks required per year was calculated by dividing the additional amount of freight (one million tonnes) by the truck load (*e.g.* 20 tonnes). For example, in this case the number of trucks required per year would have been 50,000, or 137 per day (as the daily flow is required in AQAT). There are no adjustments to the emission factors in AQAT to account for changes in vehicle load[37], and therefore the same emission factors were used for all articulated trucks. In each scenario the road type was assumed to be 'Commercial Arterial' (the worst-case in terms of emission factors).

The rail and population data and SUAs used in the calculations are given in **Table 18**. The road transport inputs are summarised in **Table 19** (note – only the daily traffic flows were changed). An annual population growth rate of 2% was assumed for all SUAs.

Table 18: Rail transport and population data for rail freight link case study

LGAs through which line passes	Length of line in LGA (km)	Thousand gross tonne-km per year of freight transported	SUA	Unit damage cost for $PM_{2.5}$ in SUA (A$/tonne, 2011)
Randwick	0.71	706	Mid-Sydney	$300,000
Botany Bay	3.18	3,177	Mid-Sydney	$300,000
Marrickville	4.94	4,941	Inner Sydney	$400,000
Canterbury	6.00	6,000	Mid-Sydney	$300,000
Strathfield	3.18	3,177	Mid-Sydney	$300,000
Total	18.00	18,000	Mid-Sydney	$300,000

5.4.3 Results

The results from AQAT are shown in **Table 20** and **Table 21**. It can be seen that the transfer of freight from rail to road would lead to large increases in emissions of some pollutants, but decreases in emissions of others. The attractiveness of road transport increases as the weight carried per road vehicle increases, and in terms of damage costs road becomes more beneficial than rail when the load per truck approaches 40 tonnes. Further refinements to the damage cost calculations could be made by considering alternative routes by road through areas of lower population density. Importantly, CO_2 emissions from road transport were much higher than those from rail in all scenarios. The different behaviour of CO_2 and the air quality criteria pollutants is due to the fact that for road transport the latter are controlled, whereas at present no pollution controls are assumed for rail transport.

[37] Vehicle load is not included in TRAQ.

Table 19: Road transport data for rail freight link case study

Link	Link name	Road type	Grade (%)	Length (km)	Daily traffic (vpd)	Traffic mix (%)									Speed (km/h)[b]
						CP	CD	LDCP	LDCD	HDCP	RT	AT	BusD	MC	
Scenario 1: Transport by articulated truck, 20 t load															
S1-1	Randwick	*Commercial arterial*	*0%*	0.7	137	0	0	0	0	0	0	100	0	0	36.3
S1-2	Botany Bay	*Commercial arterial*	*0%*	3.2	137	0	0	0	0	0	0	100	0	0	36.3
S1-3	Marrickville	*Commercial arterial*	*0%*	4.9	137	0	0	0	0	0	0	100	0	0	36.3
S1-4	Canterbury	*Commercial arterial*	*0%*	6.0	137	0	0	0	0	0	0	100	0	0	36.3
S1-5	Strathfield	*Commercial arterial*	*0%*	3.2	137	0	0	0	0	0	0	100	0	0	36.3
Scenario 2: Transport by articulated truck, 30 t load															
S2-1	Randwick	*Commercial arterial*	*0%*	0.7	91	0	0	0	0	0	0	100	0	0	36.3
S2-2	Botany Bay	*Commercial arterial*	*0%*	3.2	91	0	0	0	0	0	0	100	0	0	36.3
S2-3	Marrickville	*Commercial arterial*	*0%*	4.9	91	0	0	0	0	0	0	100	0	0	36.3
S2-4	Canterbury	*Commercial arterial*	*0%*	6.0	91	0	0	0	0	0	0	100	0	0	36.3
S2-5	Strathfield	*Commercial arterial*	*0%*	3.2	91	0	0	0	0	0	0	100	0	0	36.3
Scenario3: Transport by articulated truck, 40 t load															
S3-1	Randwick	*Commercial arterial*	*0%*	0.7	69	0	0	0	0	0	0	100	0	0	36.3
S3-2	Botany Bay	*Commercial arterial*	*0%*	3.2	69	0	0	0	0	0	0	100	0	0	36.3
S3-3	Marrickville	*Commercial arterial*	*0%*	4.9	69	0	0	0	0	0	0	100	0	0	36.3
S3-4	Canterbury	*Commercial arterial*	*0%*	6.0	69	0	0	0	0	0	0	100	0	0	36.3
S3-5	Strathfield	*Commercial arterial*	*0%*	3.2	69	0	0	0	0	0	0	100	0	0	36.3
Scenario3: Transport by articulated truck, 50 t load															
S4-1	Randwick	*Commercial arterial*	*0%*	0.7	55	0	0	0	0	0	0	100	0	0	36.3
S4-2	Botany Bay	*Commercial arterial*	*0%*	3.2	55	0	0	0	0	0	0	100	0	0	36.3
S4-3	Marrickville	*Commercial arterial*	*0%*	4.9	55	0	0	0	0	0	0	100	0	0	36.3
S4-4	Canterbury	*Commercial arterial*	*0%*	6.0	55	0	0	0	0	0	0	100	0	0	36.3
S4-5	Strathfield	*Commercial arterial*	*0%*	3.2	55	0	0	0	0	0	0	100	0	0	36.3

Table 20: Emissions from road and rail traffic (2016)

Traffic emissions	CO	NOx	$PM_{2.5}$	HC	CO_2-e
Baseline: Transport by rail					
Before development (tonnes/year)	0.58	3.88	0.11	0.22	220.5
Scenario 1: Transport by articulated truck, 20 t load					
After development (tonnes/year)	0.91	7.91	0.18	0.18	1,532.3
Change (tonnes/year)	*0.33*	*4.03*	*0.08*	*-0.04*	*1,311.8*
Change (%)	*58%*	*104%*	*74%*	*-19%*	*595%*
Scenario 2: Transport by articulated truck, 30 t load					
After development (tonnes/year)	0.60	5.25	0.12	0.12	1,017.8
Change (tonnes/year)	*0.03*	*1.38*	*0.02*	*-0.10*	*797.3*
Change (%)	*5%*	*36%*	*16%*	*-46%*	*362%*
Scenario3: Transport by articulated truck, 40 t load					
After development (tonnes/year)	0.46	3.98	0.09	0.09	771.8
Change (tonnes/year)	*-0.12*	*0.11*	*-0.01*	*-0.13*	*551.2*
Change (%)	*-21%*	*2%*	*-12%*	*-59%*	*250%*
Scenario3: Transport by articulated truck, 50 t load					
After development (tonnes/year)	0.37	3.17	0.07	0.07	615.2
Change (tonnes/year)	*-0.21*	*-0.70*	*-0.03*	*-0.15*	*394.6*
Change (%)	*-37%*	*-18%*	*-30%*	*-68%*	*179%*

Table 21: Damage costs (primary $PM_{2.5}$ emissions only, A$ in 2011 prices)

Case	Cost (A$)
Baseline: Transport by rail	
Before development (A$/year)	$30,780
Scenario 1: Transport by articulated truck, 20 t load	
After development (A$/year)	$53,608
Change (A$/year)	$22,828
Change (%)	74.2%
Scenario 2: Transport by articulated truck, 30 t load	
After development (A$/year)	$35,608
Change (A$/year)	$4,829
Change (%)	15.7%
Scenario 3: Transport by articulated truck, 40 t load	
After development (A$/year)	$27,000
Change (A$/year)	$-3,780
Change (%)	-12.3%
Scenario 4: Transport by articulated truck, 50 t load	
After development (A$/year)	$21,521
Change (A$/year)	$-9,258
Change (%)	-30.1%

5.5 Study 4: Comparison between two local land use developments

5.5.1 Description of case study

This case study involved a comparison between two rather different growth centres. The first growth centre was the Leppington North development described earlier. The second growth centre was Macquarie Park. Whilst Leppington North will eventually have a higher population density than Macquarie Park, the levels of traffic will be lower.

Macquarie Park is located 12 km north-west of the Sydney CBD in the local government area of the City of Ryde. It is bounded in the north by Culloden Road and the perimeter of Macquarie University, in the east by Lane Cove River, in the south by Delhi Road, and in the west by Epping Road (**Figure 11**)[38]. The M2 motorway passes through Macquarie Park, and the Epping-Chatswood Rail Link provides direct rail access.

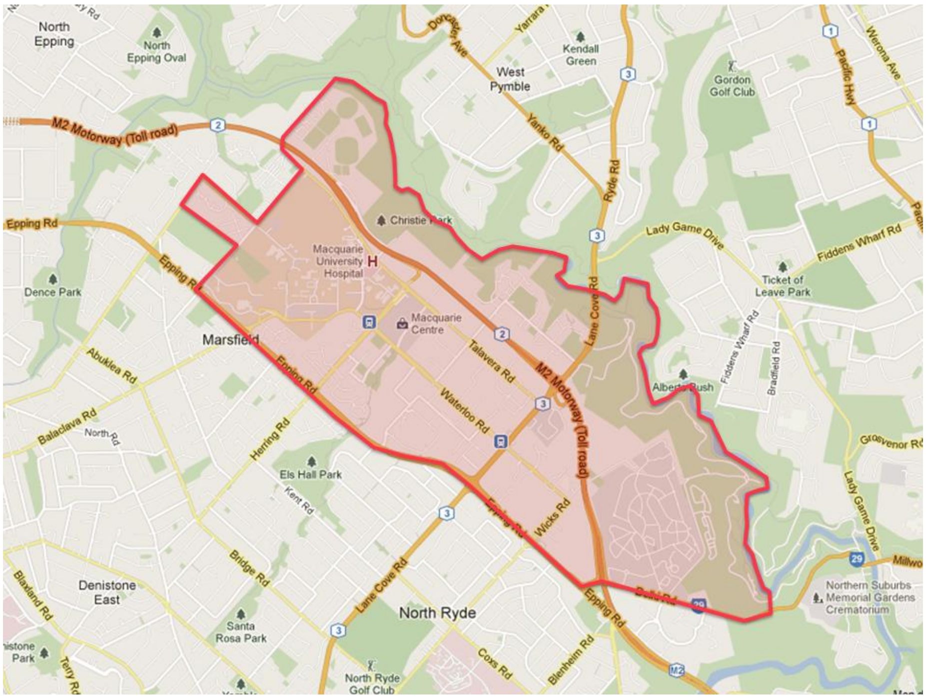

Figure 11: Macquarie Park area

The Macquarie Park Corridor is a major (and growing) centre for business and employment in NSW. Macquarie Park is nominated as a 'Specialised Centre' under the State Government's Metropolitan Strategy. Macquarie Park's existing and future development land use activity is outlined in Ryde Local Environmental Plan 2010[39]. The Corridor will include new housing, business and retail areas, new roads, and three railway stations.

[38] http://forecast2.id.com.au/default.aspx?id=306&pg=5230&gid=130

[39] http://www.ryde.nsw.gov.au/Development/Planning+Controls/Local+Environmental+Plan

5.5.2 Scenarios and input data

Damage costs for Leppington North and Macquarie Park were based on traffic data for the main roads in the two areas and assumptions concerning population. The calculations were conducted for the year 2026, by which time the developments will have been completed. The input data used in the calculations are shown in **Table 22** and **Table 23**.

For the Leppington North development very little information on projected traffic volume was available. For Bringelly Road the traffic volume in 2026 was assumed based on the Review of Environmental Factors[40]. The volumes of traffic on the other main roads in the area were estimated based on likely road type. The default values in TRAQ for traffic mix and speed were applied.

For Macquarie Park the traffic implications of the existing and future land use activity to 2031 are available in the Macquarie Park Corridor Traffic Study[41], and traffic data for the M2 upgrade are given by the RTA[42]. These sources were used to estimate the traffic volumes on the main roads in the area. The default values in TRAQ for traffic mix and speed were applied.

The 'Outer Sydney' SUA was assumed for Leppington North, whereas 'Mid-Sydney' was assumed for Macquarie Park.

An annual growth rate of 1% was assumed for both areas.

5.5.3 Results

The impacts of the two areas on emissions and damage costs are shown in **Table 24** and **Table 25** respectively. Due the much larger traffic activity at Macquarie Park, emissions are considerably higher than at Leppington North. There was a smaller difference in total damage costs due to the lower population density on Macquarie Park. However, the affected population in Leppington North was higher. Consequently, damage costs were also estimated on a per person basis. As noted above, the Leppington North Development will accommodate 30,000 new residents. For Macquarie Park the population in 2026 (around 9,750) was taken from the projections on the City of Ryde web site[43].

This showed that costs per person at Macquarie Park were several times higher than those at Leppington North. The difference may be less pronounced in the future if more major roads are built in Leppington North than currently forecast.

[40] http://www.rta.nsw.gov.au/roadprojects/projects/sydney_region/south_west_sydney/bringelly_road/documents/ref/br_ref_section_2.pdf

[41] http://www.ryde.nsw.gov.au/_Documents/Dev-Macquarie+Park/Traffic+Study+-+Coverpage+and+TOC.pdf

[42] http://www.rta.nsw.gov.au/roadprojects/projects/building_sydney_motorways/m2/m2_upgrade/index.html

[43] http://forecast2.id.com.au/default.aspx?id=306&pg=5230&gid=130

Table 22: Assumed road traffic data

Link	Link name	Road type	Grade (%)	Length (km)	Daily traffic (vpd)	Traffic mix (%) CP	CD	LDCP	LDCD	HDCP	RT	AT	BusD	MC	Speed (km/h)(b)
Leppington North															
S1-1	Bringelly Road	*Commercial highway*	*0%*	3	45,000	72.8	2.1	10.2	3.5	0.2	6.5	3.6	0.5	0.6	34
S1-2	Fourth Avenue	*Arterial*	*0%*	2	30,000	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	36
S1-3	Edmondson Avenue	*Arterial*	*0%*	2	30,000	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	36
Macquarie Park															
S2-1	M2	*Highway / freeway*	*0%*	4.1	110,000	64	1.8	9.5	3.2	0.4	10.8	9.6	0.2	0.5	100
S2-2	Epping road	*Commercial highway*	*0%*	3.5	45,000	72.8	2.1	10.2	3.5	0.2	6.5	3.6	0.5	0.6	70
S2-3	Herring Road	*Arterial*	*0%*	1	20,000	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	60
S2-4	Lane Cove Road	*Arterial*	*0%*	0.8	60,000	75.6	2.2	9.6	3.2	0.2	5.3	2.7	0.6	0.6	60

Table 23: Assumed SUAs

Area	SUA	Unit damage cost for $PM_{2.5}$ in SUA (A$/tonne, 2011)
Leppington North	Outer Sydney	$200,000
Macquarie Park	Mid-Sydney	$300,000

Table 24: Emissions from road traffic

Traffic emissions	CO	NO_x	$PM_{2.5}$	HC	CO_2-e
Leppington North (tonnes/year)	47.8	39.2	2.2	4.8	24,650
Macquarie Park (tonnes/year)	610.6	138.0	6.1	11.2	75,476

Table 25: Damage costs (primary $PM_{2.5}$ emissions only, A$ in 2011 prices)

Case	Cost (A$ per year)	Population in 2026	Cost (A$ per person per year)
Leppington North	$267,705	30,000	$9
Macquarie Park	$1,123,174	9,750	$115

6 SENSITIVITY ANALYSIS

6.1 Overview

Any mathematical model represents the relationships between input and output variables using functions (which are often non-linear), data and assumptions, and at each step in the calculation there are a number of uncertainties. In the context of AQAT these include, for example, uncertainties in the emission factors, uncertainties in the internal model data, and uncertainties in the user input. The chain of uncertainties results in an overall uncertainty in the model output.

Sensitivity analysis identifies the variation in model output resulting from the collective variation in the model inputs, and exposes the relative importance of different variables and assumptions within the model. This allows prioritisation in data collection and, if needed, further research. For the variables which have little effect on the overall results, less emphasis can be placed on data collection or they can be discarded altogether.

In this part of the work a basic sensitivity analysis was conducted using just the user-defined model parameters for road transport and an assessment year of 2011. This work should be considered to be indicative rather than definitive, given that some arbitrary assumptions were required (*e.g.* road length, traffic flow).

6.2 Method

Rather than examining the sensitivity of the model output to changes in one input variable at a time – which cannot be used to explore the entire range of possible outcomes and does not indicate the likelihood of achieving any particular outcome - the analysis involved an approach based on Monte Carlo simulation.

The Crystal Ball software package was used to run the Monte Carlo simulation and to decompose the output variance (the software estimates the fractional contribution of each input variable to the variance in the output). A similar - but much more detailed - approach has been used in the past to characterise the uncertainty in European road transport emission inventories (*e.g.* **Kioutsioukis *et al.*, 2004**).

In the Monte Carlo simulation, Crystal Ball generates a random number for every input variable, according to the pre-defined range of values and an idealised probability distribution (which can take any one of several forms (*e.g.* normal, log-normal, uniform, gamma, *etc.*). The inputs are entered into the model, and the outputs are recalculated. This process is repeated a large number of times; in this example 10,000 iterations were used.

The characterisation of the full chain of uncertainties, from errors in primary data down to model selection and use, is an important part of the analysis. For the purpose of illustration, in this example a simplified approach was used for AQAT. Only user-defined values were considered. The sensitivity of the results to internal parameters (such as emission factors, cold-start adjustments, petrol/diesel splits, *etc.*) was not considered, as supporting data (*e.g.* standard deviations of datasets used to develop emission factors) were not readily available. The rail transport part of AQAT was also excluded, as there is effectively only one input variable (gross tonne-km).

The probability distributions of the input variables shown in **Table 12** were characterised. For simplicity, the only vehicle types used were light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs). Apart from road type, which was assumed to have a uniform distribution, each variable was assumed to be distributed normally. This is not actually the case in reality (*e.g.* population density for the LGAs does not follow a normal distribution), but was considered to be a reasonable assumption for this example. In an intermediate step, the data were prepared for entry into AQAT (*e.g.* LDVs and HDVs were disaggregated according to the vehicle types in AQAT).

Table 26: Assumptions for variables included in the simulation

Variable	Units	Distribution	Mean	Standard deviation
Road type	-	Uniform (each road type equally likely)	-	-
Road gradient	%	Normal	0	3
Road length	km	Normal	10	2
Number of LDVs	vpd	Normal	18,000[a]	1,800
Number of HDVs	vpd	Normal	2,000[a]	200
Speed	km/h	Normal	50[b]	10
Local population density	people/km^2	Normal	2,000[c]	500

(a) Based on an assumed traffic volume of 20,000 vpd, and 90% LDV.
(b) Close to the average of the default values for all road types in TRAQ.
(c) Close to the average population density of the LGAs in the NSW GMR.

6.3 Results and discussion

Running Crystal Ball over 10,000 iterations produced the probability distributions for the selected input variables shown in **Figure 12**. The more iterations that are run, the closer the simulated distribution approaches the target distribution. In this case, 10,000 iterations were considered to be more than sufficient, as the target distributions were closely replicated.

The results obtained from the model for emissions of CO, NO_x and $PM_{2.5}$, and also for damage costs, are shown in **Figure 13**. The contribution of each variable to the total variance in the model output is shown in **Table 27**. It can be seen that, for the assumptions used in the example, road gradient is an important parameter for CO and NO_x emissions, but less so for $PM_{2.5}$ emissions. For $PM_{2.5}$ emissions and damage cost, road length is an important variable, and population density is also an important variable for damage costs. It would therefore be important to characterise these as accurately as possible when modelling. The number of HDVs and traffic speed were not important parameters.

As noted earlier, this work should be considered to be indicative rather than definitive. Nevertheless, it illustrates how such an approach can be used to examine model sensitivity more thoroughly than examining simple 'one at a time' changes, and it could be refined using more appropriate data prior to any specific case study being undertaken. This also ties in the with NSW Guidelines for Economic Appraisal (**NSW Treasury, 2007**), which state that sensitivity analysis should be performed in order to identify those factors with the greatest influence on a project's overall net present value (NPV).

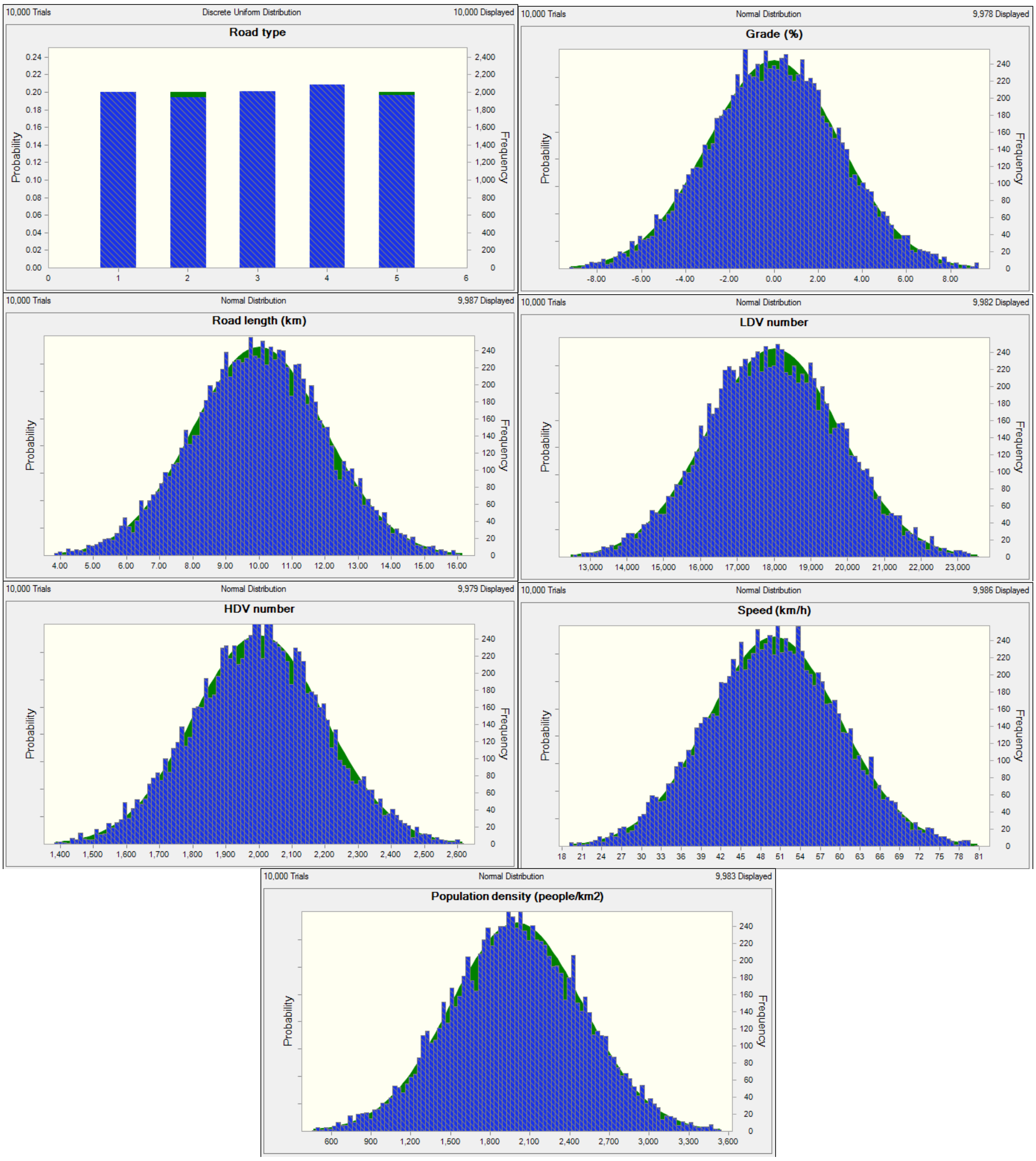

Figure 12: Probability distributions for selected input variables

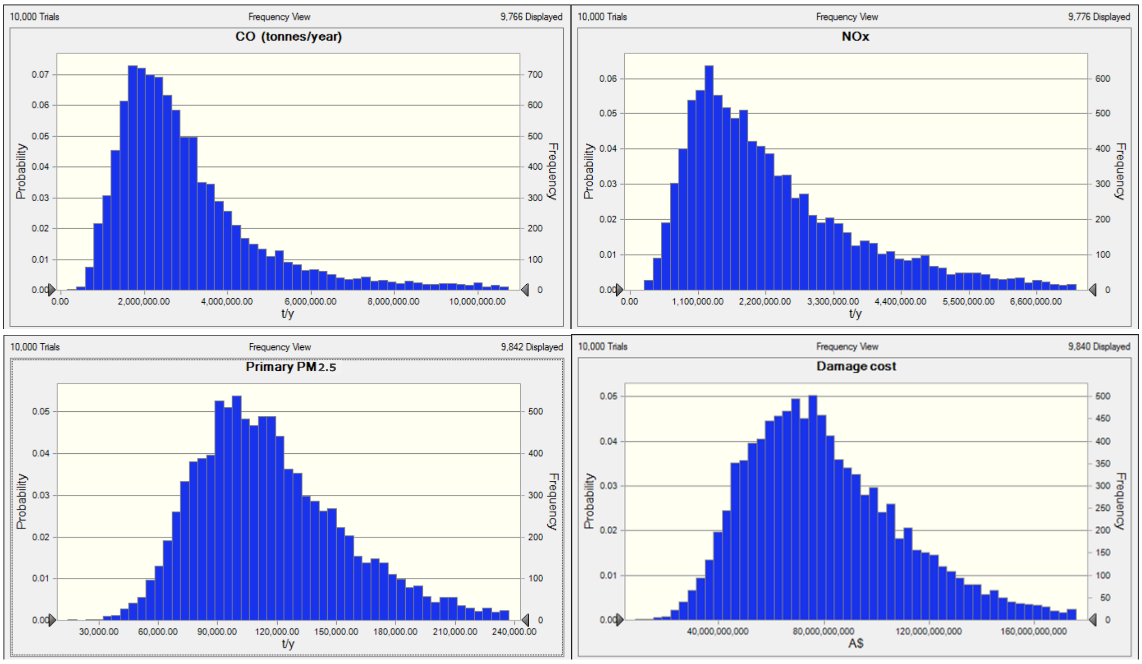

Figure 13: Probability distributions for selected output variables

Table 27: Contributions of variables to variance in model output

Input variable	Contribution to variance in output			
	CO	NO_X	$PM_{2.5}$	Damage cost
Road type	0.3%	13.7%	9.3%	7.3%
Road gradient	65.2%	70.1%	21.4%	15.2%
Road length	19.3%	10.7%	45.0%	31.3%
LDV number	14.9%	4.6%	20.3%	15.2%
HDV number	0.1%	0.8%	3.5%	2.8%
Speed	0.2%	0.1%	0.4%	0.2%
Population density	N/A	N/A	N/A	27.9%

N/A = not applicable

7 IMPLEMENTATION AND FUTURE IMPROVEMENTS

This chapter of the report suggests how AQAT might be implemented, provides some useful sources of information and data, and considers potential ways in which it might be improved in the future.

7.1 Implementation

7.1.1 Role in planning process

7.1.1.1 Capital projects

For large capital projects there is scope for the formal integration of AQAT in Annex 4 of the *NSW Government Guidelines for Economic Appraisal* (**NSW Treasury, 2007**), which deals specifically with environmental impacts. In this sense, there is potential for it to be used at several different stages: within strategic planning, as part of scoping of developments, as part of environmental impact assessment, and within so-called Ex-Post[44] evaluation. Given that the rigour of the appraisal generally increases as a project progresses, this should be reflected in any guidelines which relate specifically to air quality, and some considerations are provided below. These will be discussed in more detail with EPA, the DoPI, other potential users of AQAT, and other stakeholders. A workshop will be held at the end of the project, and this will provide a suitable forum for discussion.

Large transport and land use projects are assessed by NSW DoPI, although such projects are also referred to the Environment Protection Authority (EPA). The EPA could request that DoPI includes a requirement to undertake an air quality assessment using AQAT as part of the EIS, and AQAT could be made available for this purpose.

For rezoning and land release proposals DoPI is responsible for the original assessment. Guidance is required on how to set up the base case and scenarios, and how to develop reasonable assumptions about future travel patterns.

7.1.1.2 Small projects

Smaller one-off, local projects – defined as those costing less than A$1 million - are unlikely to merit a full, formal appraisal (**NSW Treasury, 2007**). Whilst in some cases it may still be useful to characterise economic impacts, the general approach can be much simpler than that for capital projects. The unpublished guidance from the RTA (**Section 2.4.2**) provides examples of screening criteria for road schemes which might be used to determine whether an assessment of emissions and health costs is required.

Local government is responsible for the assessment of new traffic-generating developments. Either the proponents could be required to undertake an assessment using AQAT (for larger projects), or the local authority could ask for a description of the roads affected and the likely changes in traffic movement as part of the SEE. In the latter case, the council planner would need to undertake an assessment. For local traffic schemes (*e.g.* to increase walking/cycling) council planners would need to estimate the changes in traffic movements.

[44] 'Ex-Post' refers to the situation after a project has been implemented or constructed.

7.1.2 General guidance on appraisal of developments

7.1.2.1 Capital projects

When appraising the health impacts of capital transport and land use developments, attention should be paid to the specific requirements of the planning process. As noted above, the rigour of the appraisal generally increases as a project progresses. As a general rule, it is therefore advisable that the effort required of an end user of AQAT should be in proportion to the size or impact of the development being evaluated.

There are three general areas in which guidance is required:

1. Characterisation of the development
2. Application of AQAT
3. Using the results from AQAT

An important first step in the appraisal of any development is the accurate characterisation and definition of the development being investigated, and also the boundary conditions relating to the calculations. For example, there is a need to define the precise objectives of the appraisal, and which roads, railway lines and affected populations are likely to be affected. In most cases this information should be available in increasing detail as the project progresses.

The application of AQAT should essentially follow the steps described in the User Guide, irrespective of the size of the development. However, different procedures could be used to collect the relevant input data during the various stages of the project cycle. Some examples are provided below.

- *Strategic planning*: Here, the inputs (such as the total amount of road or rail transport) could be based on generic estimates or simple calculations for one or two routes, and average population densities for regions could be assumed.
- *Project concept*: At this stage slightly more accurate information would be required. For example, specific routes would need to be more clearly defined and traffic flows would either be predicted based on simple assumptions or obtained from models. Population density could be used at the LGA level.
- *Environmental Impact Statement*: For the EIS, the traffic inputs would have to be based on model predictions for specific road links with detailed information on traffic flow, composition and speed, and an accurate description of rail freight activity. There would also be greater spatial resolution in the population density data.
- *Ex-Post evaluation*: In the Ex-Post evaluation it would be appropriate to undertake measurements. The inputs to AQAT could therefore include real-world measurements of road traffic flow, composition and speed, and/or rail freight activity and fuel consumption.
- The use of the results from AQAT in the economic appraisal process should be made clear.

7.1.2.2 Small projects

In the case of small projects it is difficult to provide general guidance, as the requirements will depend on the nature of the project. However, the level of effort should again be in proportion to the scale of the development, and therefore quite simple calculations would generally be sufficient.

7.2 Sources of information and data

The information which would typically be required for using AQAT to assess different types of development is summarised in the following sections. In each case examples of data sources are also provided.

7.2.1 Road transport

7.2.1.1 Road type

The road type in AQAT is defined in terms of the categories used in the NSW GMR emissions inventory. These categories are shown in **Table 28**. These follow, in general, the definitions from the original 1992 air emissions inventory of the Metropolitan Air Quality Study (**Carnovale *et al.*, 1996**). Further information on the mapping of these categories to the RTA road network road types and the RTA's EMME2 model is provided in the 2008 inventory.

Table 28: Road type definitions **(Jones, 2012)**

NSW GMR inventory road type	RTA functional class	Definition/description
Local/ residential	Local roads	Secondary roads with prime purpose of access to property. Characterised by low congestion and low levels of heavy vehicles. Generally one lane each way, undivided with speed limits of 50 km/h maximum. Regular intersections, mostly unsignalised and with low intersection delays.
Arterial	Sub-arterial and arterial	Provide connection from local roads to arterial roads, and may provide support role to arterial roads for movement of traffic during peak periods. Distribute traffic within residential, commercial and industrial areas. Speed limits 50-70 km/h, 1-2 lanes. Regular intersections, mostly uncontrolled. Lower intersection delays than Residential, but significant congestion impact at high volume to capacity ratios (V/C).
Commercial arterial	Arterial	Major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to high congestion in peak periods. Speed limits 60-80 km/h, typically dual carriageway. Regular intersections, many signalised, characterised by stop-start flow, moderate to high intersection delays and queuing with higher V/C ratios
Commercial highway	Arterial	Major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to moderate congestion in peak periods. Speed limits 70-90 km/h, predominantly dual carriageway. Lesser intersections than commercial arterial with smoother flow, but subject to some congestion at high V/C.
Freeway/ motorway	Motorway	High volume arterial roads with primary purpose of inter-regional traffic movement with strict access control (i.e. no direct property access). Speed limits 80-110 km/h, predominantly 2+ lanes and divided. Relatively free flowing and steady in non-congested, slowing with congestion approaching V/C limit, but minimal stopping

For the user of AQAT, road type therefore needs to be identified based on the following criteria:

- The generic road description.
- The speed limit. This can be the design speed limit for planned roads, or can be determined using RMS or local council records for existing roads (or otherwise using Google Maps).

- The number of lanes.
- The frequency of intersections and the level of signalisation.

7.2.1.2 Road length

For an existing road the length can be determined using the 'Ruler' tool in Google Earth. For a planned road the length can be determined from planning documents held by DoPI, RMS or, council transport/traffic departments.

7.2.1.3 Road gradient

For an existing road the average gradient can be calculated using Google Earth. The 'Ruler' tool can be used to give the road length as above, and the elevation values can be obtained for the start and end points of the road. For planned roads the gradient can be obtained from the relevant planning authority.

7.2.1.4 Traffic volume, composition and speed

It is anticipated that for many developments the road traffic activity data will be produced by a traffic assignment model (such as the Sydney STM). However, there are a number of difficulties associated with using the outputs from a traffic assignment model as inputs to an emission model. The outputs of the former are not usually defined in a manner which is ideal for use in the latter (**Boulter and Turpin, 2007**). The main differences are summarised below.

- ***Road classification:*** Road types tend not to be defined explicitly in traffic assignment models. The distinction made with regards to road type in some types of emission model is typically between 'urban', 'rural' and 'motorway', which is rather ambiguous. AQAT uses a different classification (see section 3.1.3). This does not usually represent a serious problem as, if needed, road type can be assumed or inferred. Nevertheless, slightly different approaches would be required for different types of road/link.

- ***Time periods:*** The time period being covered is one of the principal differences between traffic assignment models and emission models. Because many road schemes are designed for times of maximum travel demand, it is conventional practice to model hourly average traffic flows for the peak and inter-peak periods during an 'average weekday' of a 'neutral month'. The 'average weekday' often relates to four days (Monday to Thursday). Outputs are not usually provided specifically for Fridays, Saturdays and Sundays, or for minor roads. However, in AQAT annual average 24-hour traffic data are required.

- ***Vehicle classification:*** In emission models traffic data are required for large number of vehicle categories, whereas traffic models tend to deal with fewer vehicle categories. An appropriate mapping is therefore required between the categories defined in the two types of model. In some cases, the traffic model may only provide data for 'passenger car units' (PCUs), or for light-duty vehicles and heavy-duty vehicles. To reduce uncertainties in the overall emission estimates, the traffic model needs to maximise the detail in the compositional data. Buses and taxis are significant contributors to air pollution but are often poorly characterised in traffic models.

- ***Vehicle operation:*** Traffic speed is a common output of traffic assignment models, but again the data are for specific time periods. For AQAT there is a need for something simpler (average daily speed). It would be feasible to use speed distributions rather than a daily average value, but this would complicate what is supposed to be a simple tool.

The general implication is that there will be a need for a post-processing of any traffic model data, such as the development of scaling factors for traffic flow, traffic composition and speed. However, this was beyond the scope of the project.

It is also possible that in some cases the traffic activity data for developments will be provided by micro-simulation models. In general the considerations mentioned for traffic assignment models also apply here. The main difficulty is simplifying the large amount of data from such models (unless appropriate summary values are already provided by the model).

Alternative sources of traffic data include:

- Automatic and manual classified traffic counts for specific roads. Data will be available from local authorities and the RTA web site (http://www.rta.nsw.gov.au/trafficinformation/downloads/aadtdata_dl1.html).
- Video surveys for existing roads. These can also be used in conjunction with RTA registration data to give details petrol/diesel splits for cars and light commercial vehicles.
- For travel-based assessments, data are available by LGA from the NSW Bureau of Transport Statistics, Household Travel Survey (http://www.bts.nsw.gov.au/Statistics/HTS/default.aspx#top).
- Road project assessments. A range of information is available for specific road projects from the RMS web site (http://www.rta.nsw.gov.au/roadprojects/projects/index.html).

For assessments in future years, information on traffic growth projections in Australian cities can be found in a BITRE report (http://www.bitre.gov.au/publications/2012/report_127.aspx).

7.2.2 Rail transport

It seems likely that in the near future the required rail activity data will have to be obtained from the sources which are currently used (*e.g.* train operators and infrastructure managers). However, this is probably sufficient for many applications. Locomotive fuel usage activity data may be sourced from the Australian Bureau of Agricultural and Resource Economics (ABARE) and Australian Bureau of Statistics.

7.2.3 Population density

The principal source of population data is the Australian Bureau of Statistics (http://www.abs.gov.au). ABS provides population by LGA. Land area or LGAs is also available from ABS, and can also be estimated using GIS or Google Earth.

7.3 Future improvements

Some considerations for the future improvement of AQAT are presented below.

- *Inclusion of additional model years*. At present AQAT is restricted to appraisals for five model years (2008, 2011, 2016, 2021 and 2026), as road transport emission factors were only available for these years. This limits the applicability of AQAT.
- *Greater disaggregation of vehicle types*. The Tool currently predicts emissions for nine different types of vehicle, but for each model year an aggregated emission factor is used, and the vehicle age/technology distribution and weight distributions are implicit. This

means that the effects of developments, policies and measures which affect these distributions cannot currently be evaluated. Examples of these include:

- Accelerated introduction of the most recent emission standards, low-carbon technologies (such as hybrids) or specific engine or exhaust after-treatment technologies (*e.g.* diesel particulate filters).
- Low-emission zones.
- Accelerated vehicle scrappage schemes.
- Shifting freight between heavy goods vehicles having different load-carrying capacity, or shifting passengers between different types of bus.

  In the future, consideration should be given to extending AQAT so that it incorporates more detail from the full 2008 GMR road emissions inventory model.

- *Improvement of the rail freight emission calculation*. The rail freight calculation is currently very coarse. It could be improved by including specific train types and weights, and allowing for train operation.
- *Inclusion of rail passenger transport*. At the moment it is assumed that there are no emissions from passenger trains, as most trains are electric. However, passenger trains could be included if and when data become available, along with emission factors for power generation and other related assumptions (*e.g.* power losses during transmission). This would improve the accuracy of inter-modal comparisons. Reliable data on train (and bus) occupancy would help to improve the estimation of emissions on a per passenger basis.
- A *module for processing traffic data*. Whilst AQAT will accept the outputs from different traffic models, some post-processing of the traffic model data will be required to ensure that the data are in the correct format, and it is likely that traffic scaling factors will also be required. The possibility of including a specific module in AQAT for processing traffic data could be investigated.
- *Additional damage costs.* Additional costs for secondary particles should be included in AQAT, as and when the scientific understanding is sufficiently robust to permit this.
- *Further sensitivity analyses*. The importance of different model variables will vary depending on the specific type of development being investigated. A procedure for identifying the most important variables for any given type of development would therefore be useful. It would also be of interest to undertake a global sensitivity analysis for the 2008 GMR inventory model for road transport, as this would provide a more general indication of model uncertainty.
- The use of *significance criteria* for indicating the importance of impacts. It may be appropriate to apply such criteria before the results from AQAT are used in economic appraisal (*e.g*. to reduce work where impacts are not likely to be significant).
- *Adaptation to other jurisdictions*. The Tool is designed for use in NSW, and the road and rail emission factors are designed for use in the State. However, there is no reason why AQAT cannot be used in other Australian jurisdictions, and all SUAs are included in AQAT. The confidence in the predictions should improve where State-specific emission factors and model data are used in place of the NSW data.

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APPENDIX A

Glossary of terms and abbreviations

Table A1: Terms and abbreviations

Term	Description
CAFE	(EU) Clean Air for Europe (programme)
CIV	Capital investment value
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalents
DCP	Development Control Plan
Defra	(UK) Department for Environment, Food and Rural Affairs
DGRs	Director General's Requirements
DoPI	(NSW) Department of Planning and Infrastructure
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPI	environmental planning instrument
GMR	(Sydney) Greater Metropolitan Region
IGCB	(UK) Interdepartmental Group on Costs and Benefits
LGA	Local Government Area
LEP	Local Environment Plan
NEPM	National Environment Protection Measure
NH_3	Ammonia
NO_x	Oxides of nitrogen
NSW	New South Wales
OEH	(NSW) Office of Environment and Heritage
PM	Airborne particulate matter
PM_{10}	Airborne particulate matter with an aerodynamic diameter of less than 10 µm.
$PM_{2.5}$	Airborne particulate matter with an aerodynamic diameter of less than 2.5 µm.
REF	Review of Environmental Factors
RMS	(NSW) Roads and Maritime Services
RTA	(NSW) Roads and Traffic Authority
SEPP	State Environmental Planning Policies
SEE	Statement of Environmental Effects
SO_2	Sulphur dioxide
SSD	State-Significant Development
SSI	State-Significant Infrastructure
STM	(Sydney) Strategic Transport Model
TRAQ	Tool for Roadside Air Quality
VKT	Vehicle-kilometres travelled
VOCs	Volatile organic compounds

APPENDIX B

Consultees

Table B1: Consultees.

Consultee			Contacted?	
Organisation	**Contact**	**Position**	**Y/N**	**Notes**
NSW Dept. of Planning and Infrastructure	Principal Assessment Officer (rail)	Manager, Infrastructure Projects Department of Planning	Y	Meeting 13/3/12
	Principal Assessment Officer (road)		Y	Meeting 13/3/12
Transport for NSW	Bruce Dowdell	Manager – Freight Emissions, Transport for NSW	Y	Meeting 19/3/12
City of Ryde	Vince Galletto	Client Manager	Y	Meeting 8/3/12
NSW EPA (2008 GMR Emissions Inventory)	Gareth Jones (road)	Senior Atmospheric Scientist, NSW EPA	Y	Meeting 21/2/12
	Nick Agapides (non-road)	Manager Major Air Projects, Air Policy	Y	Telephone discussion 17/4/12
Transport for NSW Bureau of Transport Statistics	Frank Milthorpe	Transport Model Development Manager	Y	Email
NSW Office of Environment and Heritage	Liam Ryan	Policy officer: Emissions Reduction, Climate Change Air and Noise	Y	Kick-off meeting, email
Paul Watkiss Associates	Paul Watkiss	Director	Y	Contacted through separate EPA project[a]

a EPA project OEH-1072-2011 (Methodology for valuing health impacts of changes in particle emissions).

APPENDIX C

Air Quality Appraisal Tool – Calculation Methodology

C1 Emissions from road transport

AQAT estimates hot running emissions, cold-start emissions and non-exhaust $PM_{2.5}$ emissions, as well as emissions of other pollutants (although these are not used in the damage cost calculation). For these processes the calculations are described below. Evaporative emissions of VOCs are not included in AQAT.

C1.1 Calculation of hot running emissions

C1.1.1 Base emission factors and speed-correction

The method for calculating hot running emissions in AQAT involves the use of base 'composite' emission factors for the following matrix of cases:

- Five pollutants (CO, NO_X, PM_{10}, HC, CO_2)[45].
- Nine vehicle types (CP, CD, LDCP, LDCD, HDCP, RT, AT, BusD and MC)[46], with the emission factor for each vehicle type taking into account the VKT by age (and associated emission factors by sub-type).
- Five road types (residential, arterial, commercial arterial, commercial highway, highway/freeway), as specified in the 2008 GMR emissions inventory.
- Five years (2008, 2011, 2016, 2021, 2026). The year is used to define the vehicle fleet.
- Three seasons (summer, winter, spring/autumn) were used for emission estimation by EPA. In developing AQAT, a worst-case 'season' (using the highest emission factor of the three seasons for each case) is also defined.
- In the development of the emission factors EPA has taken various real-world effects into consideration, including the deterioration in emissions performance with mileage, the effects of tampering or failures in emission-control systems, and the use of ethanol in petrol. These assumptions are built into the base emission factors in AQAT, and cannot be modified by the user.

For each case in the matrix, the base emission factor is defined for a VKT-weighted average speed (the base speed) associated with the corresponding road type. Dimensionless correction factors – in the form of 6th-order polynomial functions - are then applied to the base emission factors taking into account the actual speed on a road. According to EPA, the speed correction factors are valid up to 110 km/h for light-duty vehicles, and up to 100 km/h for heavy-duty vehicles (**Jones, 2012**).

Therefore, the emission factor for a given traffic speed is calculated using Equation C1.

$$EF_{HotSpd} = EF_{HotBasSpd} \times \frac{SCF_{Spd}}{SCF_{BasSpd}} \qquad \text{Equation C1}$$

Where:

[45] It was assumed that $PM_{2.5}$ was equivalent to PM_{10}, which is appropriate for exhaust emissions.

[46] CP = petrol passenger vehicles; CD = diesel passenger vehicles; LDCP = light-duty commercial petrol vehicles (<=3500 kg); LDCD = light-duty commercial diesel vehicles (<=3500 kg); HDCP = heavy-duty commercial petrol vehicles (>3500kg); RT = rigid trucks (3.5-25 tonnes, diesel only); AT = articulated trucks (> 25 tonnes, diesel only); BusD = heavy public transport buses (diesel only); MC = motorcycles.

EF_{HotSpd}	is the composite emission factor (in g/km) for the defined speed
$EF_{HotBasSpd}$	is the composite emission factor (in g/km) for the base speed
SCF_{Spd}	is the speed-correction factor for the defined speed
SCF_{BasSpd}	is the speed-correction factor for the base speed

Each speed-correction factor is a 6th order polynomial: $SCF = aV^6 + bV^5 + ... + fV + g$, where a to g are constants and V is the speed in km/h.

C1.1.2 Road gradient correction factors

Correction factors are also applied to allow for the effects of road gradient on hot running emissions. The gradient correction is introduced as follows:

$$EF_{HotGradCor} = EF_{HotSpd} \times G$$ Equation C2

Where:

$EF_{HotGradCor}$	is the composite emission factor (in g/km) corrected for road gradient
G	is the road gradient correction factor. Different values of G are used for each pollutant, vehicle type and speed.

C1.2 Calculation of cold-start emissions

The method for calculating cold-start emissions involves the application of adjustments to the base speed hot emission factors, to take into account the extra emissions which occur before a vehicle's engine and after-treatment system have reached their full operational temperatures. The method was developed by RMS, SKM and EPA. The adjustments take into account:

- The distance driven from the start of a trip.
- The parking duration.
- The ambient temperature.

Cold-start emissions are only calculated for light-duty vehicles, and are only applied to the base hot running emission factors. No cold-start adjustment is made for PM. The amount of 'cold running' depends on the road type, and no cold running is assumed for residential roads and highways.

Cold-start emissions are therefore calculated as follows:

$$EF_{Cold} = EF_{HotBasSpd} \times (CS - 1)$$ Equation C3

Where:

EF_{Cold}	is the cold-start emission factor (in g/km)
CS	is a cold start adjustment factor (>1). Different values of CS are used for each pollutant, vehicle type, road type and year.

C1.3 Calculation of non-exhaust PM emissions

The method for non-exhaust $PM_{2.5}$ is drawn from the EMEP/EEA Air Pollutant Emission Inventory Guidebook (**EEA, 2009**), and includes tyre wear, brake wear and road surface wear. Emission factors (EF_{NonEx} in g/km) are provided for each vehicle type, road type and year.

C1.4 Calculation of emissions per link

For each vehicle category (v), the total emission factor ($EF_{Tot,v}$) is then calculated by summating the hot running emission, cold-start and non-exhaust emission factors:

$$EF_{Tot,v} = (EF_{HotGradCor,v} + EF_{Cold,v} + EF_{NonEx,v})$$

Equation C4

Again, cold-start emission factors are only used for light-duty vehicles, and non-exhaust emissions are only relevant to $PM_{2.5}$.

For a given road link, pollutant and year, total annual emissions are then calculated using the following equation:

$$e_{L,y} = \frac{365}{10^6} \times F \times \sum_{v=1}^{v=9} EF_{Tot,v} \times P_{L,v}$$

Equation C5

Where:

$e_{L,y}$ is the total annual emission (in tonnes/year) from the traffic on link L in year y, summated over all nine vehicle categories

F_L is the average total daily traffic volume on link L

$P_{L,v}$ is the proportion of the traffic on link L in vehicle category v

C1.5 Summation of link emissions

Total emissions ($e_{Tot,y}$) for the before-development and after-development cases are then calculated as follows:

$$e_{Tot,y} = \sum_{L=1}^{L=n} e_{L,y}$$

Equation C6

C1.6 Calculation of greenhouse gas emissions

A carbon balance method supplied by EPA is used to calculate fuel consumption for petrol and diesel vehicles. The fuel consumption (in litres per 100 km) is calculated from the emission factors for CO, HC and CO_2 (determined using the daily traffic flows and base speeds) and density values for petrol and diesel fuel. The fuel consumption values are then scaled according to the road length in km and restated as a function of time. Finally, annual CO_2-equivalent (CO_2-e) emissions are determined by applying fuel-specific emission factors supplied by the Department of Climate Change and Energy Efficiency (**DCCEE, 2011**).

C1.7 Change in emissions

The final step in the road traffic calculation simply involves calculating the absolute and percentage changes in the emissions associated with the development, using the e_{Tot} values for the before and after cases.

C2 Emissions from rail transport

C2.1 Calculation of emissions per link

For a given pollutant, link and assessment year, total annual emissions from diesel freight trains are calculated using the following equation:

$$e_{rail,p,L,y} = \frac{A_L \times 4.03 \times EF_p}{10^6}$$ Equation C7

Where:

$e_{rail,p,L,y}$	is the total annual rail emission (in tonnes/year) on link L in year y
A_L	is the average total activity on link L (in gross tonne-km per year)
4.03	is an average fuel consumption factor for freight trains in the GMR (in litres per gross tonne-km)
EF_p	is the emission factor for pollutant p (in grammes per litre)

Emission factors from the USEPA for Tier 0 locomotives are used in the calculations. These emission factors were also used in the 2008 GMR inventory. Emissions from diesel passenger trains and electric trains are not calculated.

C2.2 Year adjustment

Fuel consumption (and emissions) for future years is estimated using values supplied by EPA. For a given future year the corresponding factor is applied to the result from Equation C7.

C2.6 Summation of link emissions

Total rail emissions ($e_{rail,Tot,y}$) for the before-development and after-development cases are then calculated as follows:

$$e_{rail,p,Tot,y} = \sum_{L=1}^{L=n} e_{rail,p,L,y}$$

Equation C8

C2.7 Change in emissions

The final step in the rail traffic calculation simply involves calculating the absolute and percentage changes in the emissions associated with the development, using the $e_{rail,p,Tot,y}$ values for the before and after cases.

C3 Damage costs

C3.1 General approach

Damage costs are only calculated from primary $PM_{2.5}$ emissions from transport. Costs are calculated using the unit damage costs for SUAs developed by **Aust *et al.* (2012)**. These unit damage costs are listed in **Tables C1** to **C6** below.

Table C1: Unit damage costs by SAU (rounded to two significant figures) – NSW

SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
1030	Sydney	4,064	4,028,525	991	**See note below**
1009	Central Coast	566	304,755	538	**$150,000**
1035	Wollongong	572	268,944	470	**$130,000**
1027	Port Macquarie	96	41,722	433	**$120,000**
1013	Forster - Tuncurry	50	19,501	394	**$110,000**
1023	Newcastle - Maitland	1,019	398,770	391	**$110,000**
1014	Goulburn	65	21,485	332	**$93,000**
1003	Ballina	73	23,511	320	**$90,000**
1018	Lismore	89	28,285	319	**$89,000**
1016	Griffith	56	17,900	317	**$89,000**
1033	Ulladulla	47	14,148	303	**$85,000**
1010	Cessnock	69	20,262	294	**$82,000**
1034	Wagga Wagga	192	52,043	272	**$76,000**
1025	Orange	145	36,467	252	**$71,000**
1022	Nelson Bay - Corlette	116	25,072	217	**$61,000**
1012	Dubbo	183	33,997	186	**$52,000**
1017	Kurri Kurri - Weston	91	16,198	179	**$50,000**
1015	Grafton	106	18,360	173	**$48,000**
1004	Batemans Bay	94	15,732	167	**$47,000**
1024	Nowra - Bomaderry	202	33,340	165	**$46,000**
1029	St Georges Basin - Sanctuary Point	77	12,610	164	**$46,000**
1031	Tamworth	241	38,736	161	**$45,000**
1005	Bathurst	213	32,480	152	**$43,000**
1032	Taree	187	25,421	136	**$38,000**
1001	Albury - Wodonga	628	82,083	131	**$37,000**
1011	Coffs Harbour	506	64,242	127	**$36,000**
1028	Singleton	127	16,133	127	**$36,000**
1007	Broken Hill	170	18,519	109	**$30,000**
1019	Lithgow	120	12,251	102	**$29,000**
1006	Bowral - Mittagong	422	34,861	83	**$23,000**
1002	Armidale	275	22,469	82	**$23,000**
1020	Morisset - Cooranbong	341	21,775	64	**$18,000**
1026	Parkes	235	10,939	47	**$13,000**

SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
1021	Muswellbrook	262	11,791	45	**$13,000**
1008	Camden Haven	525	15,739	30	**$8,400**
1000	Not in any Significant Urban Area (NSW)	788,116	999,873	1.3	**$360**

Note: In order to discriminate between different areas of Sydney, three damage cost bands were used: 'Inner Sydney' ($200,000/tonne of $PM_{2.5}$), 'Mid-Sydney' ($300,000/tonne of $PM_{2.5}$) and 'Inner Sydney' ($400,000 per tonne of $PM_{2.5}$).

Table C2: Unit damage costs by SAU (rounded to two significant figures) – Victoria

SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
2011	Melbourne	5,679	3,847,567	677	**$190,000**
2016	Sale	46	14,259	313	**$88,000**
2020	Wangaratta	58	17,687	307	**$86,000**
2004	Bendigo	287	86,078	299	**$84,000**
2003	Ballarat	344	91,800	267	**$75,000**
2005	Colac	55	11,776	215	**$60,000**
2010	Horsham	83	15,894	191	**$54,000**
2008	Geelong	919	173,450	189	**$53,000**
2017	Shepparton - Mooroopna	249	46,503	187	**$52,000**
2006	Drysdale - Clifton Springs	65	11,699	180	**$50,000**
2012	Melton	266	47,670	179	**$50,000**
20+22	Warrnambool	183	32,381	177	**$50,000**
2019	Traralgon - Morwell	235	39,706	169	**$47,000**
2014	Moe - Newborough	105	16,675	158	**$44,000**
2018	Torquay	126	15,043	119	**$33,000**
2015	Ocean Grove - Point Lonsdale	219	22,424	103	**$29,000**
2001	Bacchus Marsh	196	17,156	87	**$24,000**
2002	Bairnsdale	155	13,239	85	**$24,000**
2013	Mildura - Wentworth	589	47,538	81	**$23,000**
2007	Echuca - Moama	351	19,308	55	**$15,000**
2009	Gisborne - Macedon	367	18,014	49	**$14,000**
2021	Warragul - Drouin	680	29,946	44	**$12,000**
2000	Not in any Significant Urban Area (Vic.)	216,296	693,578	3	**$900**

Table C3: Unit damage costs by SAU (rounded to two significant figures) - Queensland

SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
3003	Cairns	254	133,912	527	**$150,000**
3008	Hervey Bay	93	48,678	523	**$150,000**
3006	Gold Coast - Tweed Heads	1,403	557,823	398	**$110,000**
3001	Brisbane	5,065	1,977,316	390	**$110,000**
3010	Mackay	208	77,293	371	**$100,000**
3004	Emerald	39	13,219	337	**$94,000**
3012	Mount Isa	63	20,569	328	**$92,000**
3007	Gympie	69	19,511	282	**$79,000**
3016	Townsville	696	162,291	233	**$65,000**
3002	Bundaberg	306	67,341	220	**$62,000**

SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
3015	Toowoomba	498	105,984	213	**$60,000**
3018	Yeppoon	79	16,372	208	**$58,000**
3005	Gladstone - Tannum Sands	240	41,966	175	**$49,000**
3014	Sunshine Coast	1,633	270,771	166	**$46,000**
3011	Maryborough	171	26,215	154	**$43,000**
3013	Rockhampton	580	73,680	127	**$36,000**
3017	Warwick	159	14,609	92	**$26,000**
3009	Highfields	230	16,820	73	**$20,000**
3000	Not in any Significant Urban Area (Qld)	1,718,546	755,687	0.4	**$120**

Table C4: Unit damage costs by SAU (rounded to two significant figures) – South Australia

SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
4001	Adelaide	2,024	1,198,467	592	**$170,000**
4006	Port Pirie	75	14,044	187	**$52,000**
4008	Whyalla	121	21,991	181	**$51,000**
4003	Murray Bridge	98	16,706	171	**$48,000**
4002	Mount Gambier	193	27,754	144	**$40,000**
4005	Port Lincoln	136	15,222	112	**$31,000**
4007	Victor Harbor - Goolwa	309	23,851	77	**$22,000**
4004	Port Augusta	249	13,657	55	**$15,000**
4000	Not in any Significant Urban Area (SA)	980,973	264,882	0.3	**$76**

Table C5: Unit damage costs by SAU (rounded to two significant figures) – Western Australia

SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
5009	Perth	3,367	1,670,952	496	**$140,000**
5007	Kalgoorlie - Boulder	75	30,839	411	**$110,000**
5003	Bunbury	223	65,608	295	**$83,000**
5005	Ellenbrook	105	28,802	276	**$77,000**
5002	Broome	50	12,765	255	**$71,000**
5006	Geraldton	271	35,749	132	**$37,000**
5008	Karratha	134	16,474	123	**$34,000**
5010	Port Hedland	116	13,770	118	**$33,000**
5001	Albany	297	30,656	103	**$29,000**
5004	Busselton	1,423	30,286	21	**$6,000**
5000	Not in any Significant Urban Area (WA)	2,520,513	30,654	0.01	**$3**

Table C6: Unit damage costs by SAU (rounded to two significant figures) - Other

State	SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
Tasmania	6001	Burnie - Wynyard	131	29,050	223	**$62,000**
	6004	Launceston	435	82,222	189	**$53,000**

State	SUA code	SUA name	Area (km^2)	Population	Population density (people/km^2)	Damage cost/tonne of $PM_{2.5}$ (A$, 2011)
	6003	Hobart	1,213	200,498	165	**$46,000**
	6005	Ulverstone	130	14,110	108	**$30,000**
	6002	Devonport	290	26,871	93	**$26,000**
	6000	Not in any Significant Urban Area (Tas.)	65,819	142,598	2	**$610**
Northern territory	7002	Darwin	295	106,257	361	**$100,000**
	7001	Alice Springs	328	25,187	77	**$22,000**
	7000	Not in any Significant Urban Area (NT)	1,347,577	80,504	0.06	**$17**
ACT	8001	Canberra – Queanbeyan	482	391,643	812	**$230,000**
	8000	Not in any Significant Urban Area (ACT)	1,914	1,622	0.85	**$240**
Other	9000	Not in any Significant Urban Area (OT)	218	3,029	14	**$3,900**

As noted above, the damage cost function is only applicable to primary $PM_{2.5}$ emissions from transport. No method was provided for estimating the costs associated with exposure to secondary particles, but in any case these would be rather difficult to quantify in a tool of this kind, given that secondary particle formation occurs over distances of hundreds to thousands of kilometres, and therefore the location of exposure is not known.

It is important that costs are expressed in equivalent terms, so the effects of emission changes in, say, 2021 can be compared with those in, say, 2015. In addition, the costs of any development (which will involve up-front capital costs and operating costs over time) need to be compared with the benefits in the same price year. It is therefore necessary to make two adjustments to the unit damage cost. These are:

- An 'uplift' to reflect the change in per capita GDP growth between the assessment year and 2011. This is currently assumed to be 2.5%, based on the guidance from **Defra (2011)**. This reflects any change in health risk (e.g. the value of a life). In other words, the real cost of air pollution impacts on health will rise in line with economic output.
- A 'discount', based on the principle that future costs are less important than current costs. This is assumed to be 7%.

The unit damage cost for the assessment year is then calculated using the following equation:

$$c_y = c_{2011} \times (1+u)^{y-2011} \times \frac{1}{(1+d)^{y-2011}}$$

Equation C9

Where:

c_y is the unit damage cost for primary PM emissions from transport in the assessment year (A$/tonne)

u is the uplift for the annual rate of economic growth (%) – assumed to be 2.5%

d is the annual discount rate – assumed to be 0.07 (i.e. 7%)[47]

y is the assessment year

Consequently, all costs are expressed in 2011 prices.

[47] The **NSW Treasury (2007)** has suggested an appropriate real discount rate for Australia of 7% which needs to be repeated for each year in the appraisal period.

The total damage cost in the assessment year is the calculated as follows:

$$C_y = c_y \times e_y$$ Equation C10

Where:

C_y is the damage cost in the assessment year y (A$)

c_y is the unit damage cost for the SUA

e_y is the emission of $PM_{2.5}$ in year y.

C3.2 Application to road and rail traffic

For road and rail transport, the damage costs for the before-development and after-development cases are summated over all links as follows:

$$C_{Tot,y} = \sum_{L=1}^{L=n} C_{L,y}$$

Equation C11

$C_{Tot,y}$ is the total damage cost for either the before-development or after-development case in the assessment year y (A$).

$c_{L,y}$ is the damage cost for link L in assessment year y.

The absolute and percentage changes in damage costs associated with the development are then determined using the $C_{Tot,y}$ values for the before and after cases described above.

APPENDIX D

Air Quality Appraisal Tool - User Guide

D1 Tool description

AQAT is a Microsoft Excel spreadsheet (*Air Quality Appraisal Tool - Version 1.1 (locked).xlsx*). The Tool has been tested using a Windows 7 64-bit operating system.

The spreadsheet contains ten worksheets, as described below:

- *Cover*. This sheet gives the title of AQAT, along with the version number and the release date.
- *Versions*. This sheet lists the versions of AQAT and the amendments in each version.
- *Instructions*. This sheet explains how to use AQAT.
- *Data sources*. This lists the sources of data used in AQAT. It gives default values of the traffic mix and speed by road type, and the population density by LGA in the NSW GMR.
- *Planning Guidance*, which explains the role of AQAT in the planning process.
- *References*. This sheet provides the references for the methods and default data used in AQAT.
- *Inputs (A)*. This sheet is used to enter model inputs were emission estimates are not already available.
- *Inputs (B)*. This sheet is used to enter model inputs where emission estimates are already available.
- *Results (A)*. This sheet provides the model results, based on the information entered in the *Inputs (A)* sheet.
- *Results (B)*. This sheet provides the model results, based on the information entered in the *Inputs (B)* sheet.

Additional sheets contain the calculations for road transport, rail transport, although these are hidden from the user.

D2 Instructions

D2.1 Data entry

As noted above, different approaches are used depending on whether emissions data are already available for the development. It may be necessary for the user to follow a combination of approaches (A) and (B) – such as where emissions data are available for road transport, but not for rail.

D2.1.1 Approach A: No emission estimates available

Where emission estimates for a development are not already available, these can be calculated using the *Inputs (A)* sheet. The following steps are required:

Step A1: Generic inputs. The user enters the assessment year - which can be 2008, 2011, 2016, 2021 or 2026 – using the drop-down menu provided. The economic growth rate (applied to all years) can also be modified, though justification for doing so should be provided.

Step A2: The user enters the road transport activity data for the 'before development' and 'after development' cases. In each case data can be entered for up to 20 road links. For each link the following information is required:

- The name of the link (as text, or a combination of numbers and text).
- The road type (selected using the drop-down menu).
- The road gradient (selected using the drop-down menu).
- The road length in km.
- The total daily bi-directional traffic volume (in vehicles per day)
- The traffic mix (% of vehicles in nine categories, as defined earlier). Default values for different road types are provided on the 'Info' sheet of AQAT.
- The average daily traffic speed in km/h.
- Whether cold-start emissions are to be included in the calculations.

Step A3: The user enters the rail transport activity data for the 'before development' and 'after development' cases. In each case data can be entered for up to 10 rail links. Only two inputs are required:

- The name of the rail link.
- The amount of freight transport in gross tonne-km per year (*i.e.* the combined weight of the train and load multiplied by the distance travelled).

Step A4: For all road and rail links included in the 'before development' and 'after development' cases the user enters the local SUA affected. The concept of 'local' is open to some interpretation here, and therefore the user must make an informed decision as to what a sensible value would be, clearly stating the assumptions made when reporting. The average population growth rate for the SUA also needs to be entered, as this is used to adjust the unit damage costs.

D2.1.2 Approach B: Emission estimates already available

Where emission estimates for a development are already available, these can be entered in the appropriate cells of the *Inputs (B)* sheet. The following steps are required:

Step B1: Generic inputs are entered as in Step A1. In this case any year between 2008 and 2036 can be entered.

Step B2: The user enters the road transport emission data (in tonnes per year) for the 'before development' and 'after development' cases. Again, in each case data can be entered for up to 20 road links. For each link the following information is required:

- The name of the link (as text, or a combination of numbers and text)
- The emissions of each pollutant (CO, NO_x, $PM_{2.5}$, HC, CO_2-e) in tonnes per year. **NB**: Only the $PM_{2.5}$ emissions data are currently used in the damage cost calculation.

Step B3: The user enters the rail transport emissions data (in tonnes per year) for the 'before development' and 'after development' cases.

Step B4: For all road and rail links included in the 'before development' and 'after development' cases the user enters the SUA and population growth, as in Approach A.

D2.2 Results

The results for approaches A and B are presented on the *Results (A)* and *Results (B)* sheets respectively. If any of the input data are changed then the results will automatically be updated.