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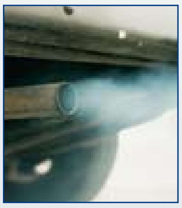
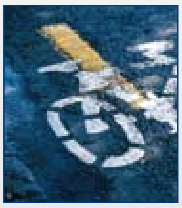

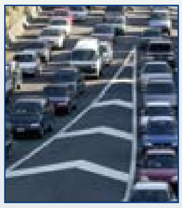

Good Practice Guide for Assessing Discharges to Air from Land Transport

June 2008

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Foreword by the Ministry

The national environmental standards for air quality were introduced in 2004 because of a strong need for action on ambient levels of particles in most parts of the country. The standards also laid the foundation for an effective management framework for other pollutants associated with land transport, such as oxides of nitrogen.

In addition to requirements to consider safe and sustainable regional land transport strategies, and national objectives to protect and promote public health, territorial authorities and/or requiring authorities must now consider the national environmental standards for air quality when granting new designations and land-use consents. The assessment of the impacts of land transport development on air quality can, however, be highly technical and complex.

In response to the need for guidance, in June 2006 the Ministry for the Environment published a *Draft Good Practice Guide for Assessing Discharges to Air from Land Transport* for consultation. A number of submissions on the draft document were gratefully received, and the guide was updated to reflect the comments and information provided.

This updated *Good Practice Guide for Assessing Discharges to Air from Land Transport* provides clear, comprehensive guidance on exactly how to consider the impacts on air quality from transport development. The guide promotes a three-tiered assessment approach and makes recommendations for which approach to adopt in a given situation. This document is aimed specifically at practitioners (consultants, council officers, scientists and reviewers) making assessments of the effects of discharges to air from land transport projects.

I am pleased to present this Good Practice Guide and encourage practitioners to adopt the recommended protocols in the interests of national consistency and technical best practice.

Howard Fancy
Acting Secretary for the Environment

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1 Introduction

1.1 Purpose of the Good Practice Guide

The purpose of this guide is to provide good practice protocols for assessing discharges to air from land transport in New Zealand. The information will enable transport and policy planners to determine whether a project is likely to have significant air quality impacts.

The guide only considers the effects of emissions to air from land transport, and principally those from petrol and diesel on-road vehicles. Shipping and aviation transport are *not* included. Projects involving maintenance works and/or minor safety upgrades are not likely to have significant air quality impacts and would not require assessment. Finally, the guide does not include guidance for assessing and controlling dust during the construction phase of relevant projects. Dust emissions are addressed by the *Good Practice Guide for Assessing and Managing the Environmental Effects of Dust Emissions* (Ministry for the Environment, 2001a).

For projects that *are* likely to have significant air quality impacts, a detailed assessment – including traffic modelling, vehicle emissions estimation and dispersion modelling – may be required. This type of assessment is complex and requires a multidisciplinary approach. The guide provides recommended protocols for these more detailed air quality impact assessments, but is not a substitute for expert input.

This guide is one of a series of good practice guides developed by the Ministry for the Environment. The series includes the:

- *Good Practice Guide for Assessing Discharges to Air from Land Transport* (the subject of this guidance document)
- *Good Practice Guide for Assessing Discharges to Air from Industry* (Ministry for the Environment, 2008)
- *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004).

There is a strong relationship between the guides. For example, if an assessment requires a quantitative estimation of pollutant concentrations from industry, this guide will refer you to the *Good Practice Guide for Atmospheric Dispersion Modelling.*

The *Good Practice Guide for Assessing Discharges to Air from Land Transport* applies the framework provided in the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations 2004 (including amendments 2005) and the *Updated Users Guide* (Ministry for the Environment, 2005), which covers the regulations themselves. The aim is that the Good Practice Guide series, taken together, will help provide for comprehensive and consistent management of air quality in New Zealand. The framework for these documents is shown in Figure 1.1.

This Good Practice Guide for land transport makes recommendations for which assessment approach to adopt, while recognising the wide range of potential users. This may include transport or planning professionals, technical experts, council staff, hearing commissioners, and others who may be affected by the air quality effects of transport projects. Although the focus is on providing consistent guidance, there is some flexibility if documented and well-justified alternative approaches are proposed.

More specifically, this guide:

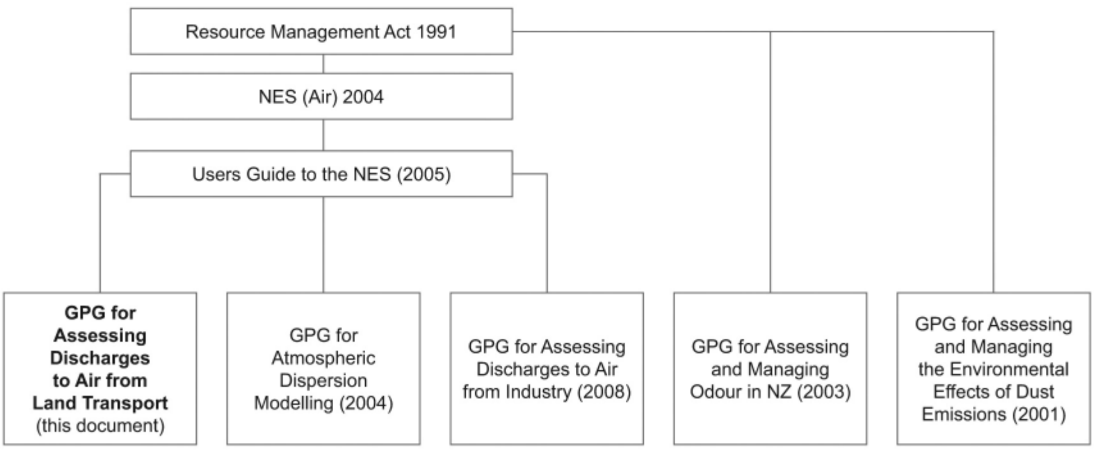
- outlines the legislative context for the assessment process, in particular the Resource Management Act (1991) (RMA) and the New Zealand Transport Strategy
- provides guidance on appropriate levels of assessment, given the variety of types of development for which assessment will be required
- provides guidance on characterising both the development and the receiving environment
- identifies the air quality criteria by which impacts should be assessed
- provides guidance on key considerations under the national environmental standards for air quality
- provides guidance on the methods available for assessing the impacts of air quality on both human health and the wider environment.

The assessment of potential dust and odour impacts arising from industrial emissions is not covered in any detail in this guide because these are the subject of existing Ministry guidance (Ministry for the Environment, 2001a and 2003b).

Although the aim of the guide is to promote national consistency in approach, it should be noted that the guidelines have no legal standing.

Figure 1.1 outlines how the guidance framework fits within the legislative framework. Figures 1.2 and 1.3 show the wide range of relevant Ministry for the Environment air quality publications, and their areas of applicability.

Figure 1.1: Legal and guidance framework for assessing discharges to air



Notes: NES = national environmental standard; GPG = Good Practice Guide.

Figure 1.2: New Zealand air quality guidance documents

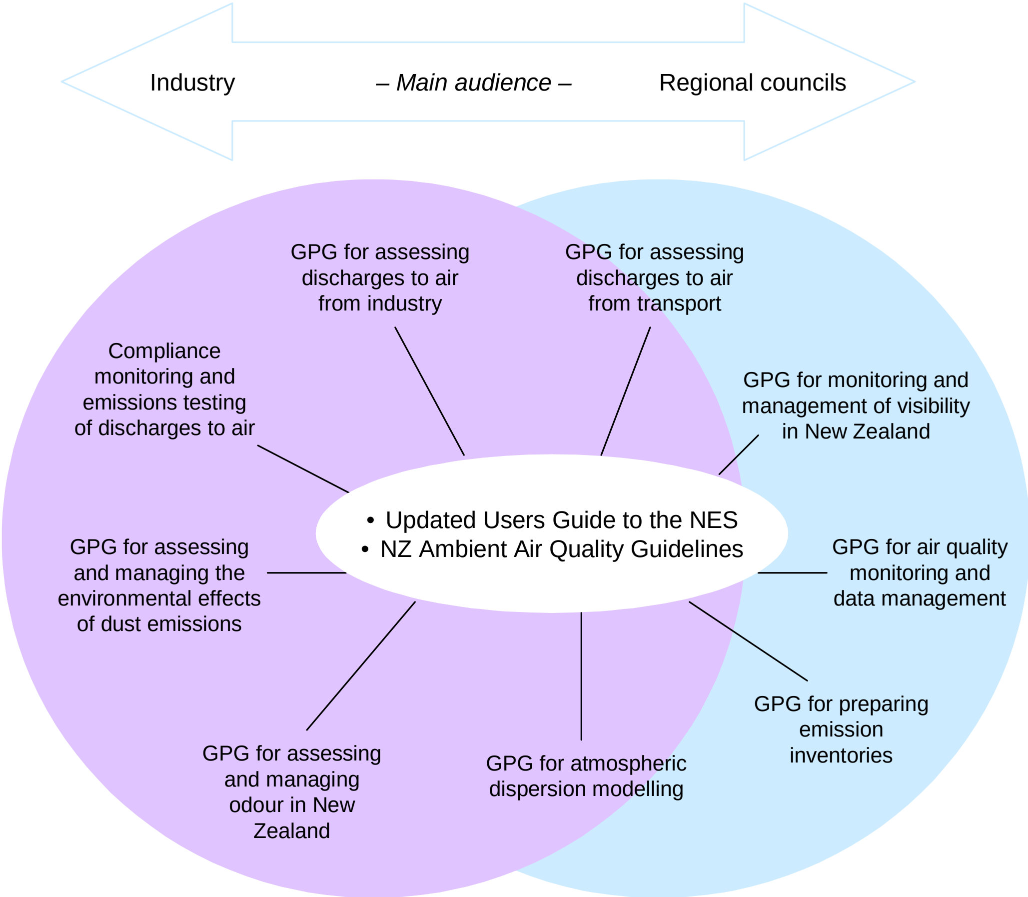
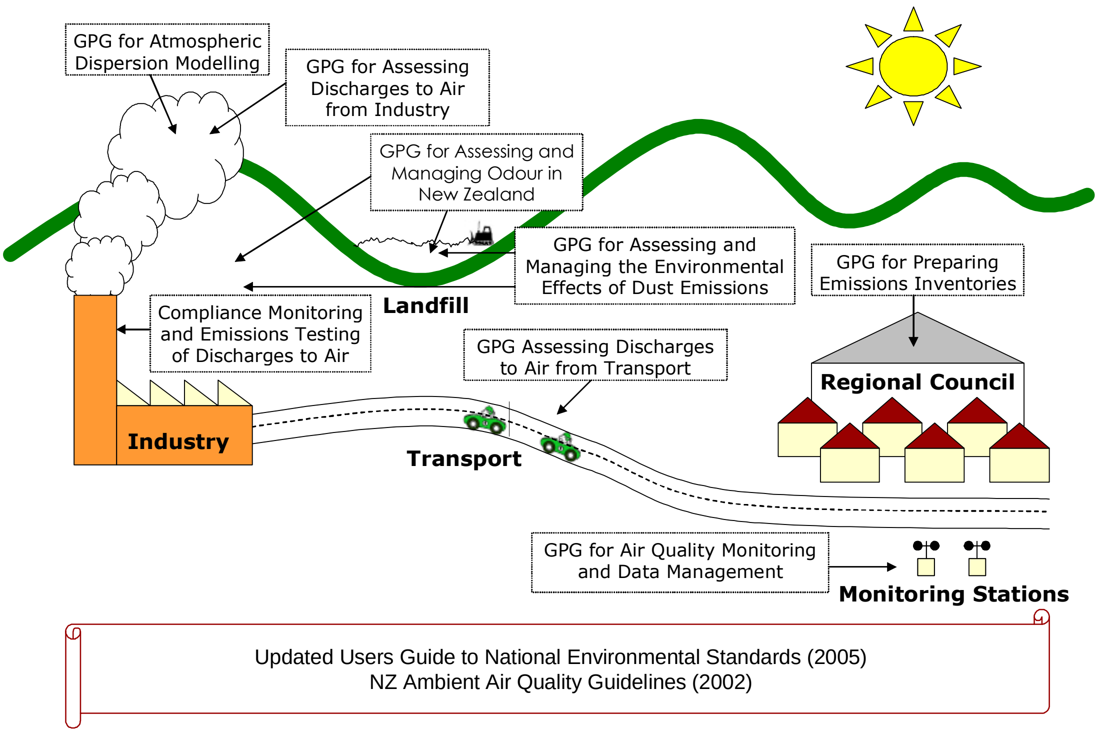


Figure 1.3: Application of air quality guidance documents



1.2 Target audience

This document is aimed at practitioners making assessments of the effects of discharges to air from land transport projects, including consultants, council officers, scientists and reviewers. It is a detailed technical document, and as such it is not aimed at non-specialists such as the general public, lawyers, planners, hearing commissioners, or specialists in areas other than air. Although some sections may be useful to this latter group, the document has not been prepared with this audience in mind.

As noted above, it is designed to provide assistance, advice and sources of information with the aim of making the assessment process more streamlined and more consistent around the country. It is not binding, and in some cases the level of detail required will go beyond what has been covered here.

2 Legislative and Policy Context

The following section outlines the legislative context for an assessment of environmental effects relating to air quality for land transport projects.

2.1 The Resource Management Act

The purpose of the Resource Management Act 1991 (RMA) is to promote the sustainable management of natural and physical resources, including air, as outlined in section 5:

> ***5. Purpose***
>
> *(1) The purpose of this Act is to promote the sustainable management of natural and physical resources.*
>
> *(2) In this Act, "sustainable" means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while –*
>
> > *(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
> >
> > *(b) Safeguarding the life-supporting capacity of air, water, soil and ecosystems; and*
> >
> > *(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment ...*

In relation to land transport developments, section 5(2)(c), is of particular relevance with its duty to avoid, remedy or mitigate adverse effects.

Within the RMA there are also policy instruments (regional policy statements, regional plans and district plans) that enable more detailed regional and local management of environmental resources, such as air. For an assessment of effects of any significant land transport project, liaison with the relevant local authorities is recommended so that any such constraints are identified at an early stage.

2.2 National environmental standards

Readers should familiarise themselves with the *Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004* as amended in 2005 (hereafter referred to as the Standards). The Standards are technical environmental regulations prepared in accordance with sections 43 and 44 of the RMA. The Standards are designed to protect public health and the environment in New Zealand by setting concentration limits for clean air and regulating or prohibiting certain activities that pollute the air.

The detailed application and interpretation of the Standards is provided in the *Updated Users Guide* (Ministry for the Environment, 2005). The ambient air quality concentration limits provided by Schedule 1 of the Standards are discussed in section 5.

2.3 Regional plans and policy statements

The RMA is the applicable overarching legislation and the Standards provide an absolute baseline for acceptable effects. Regional councils provide the next level of regulation in their regional plans and associated policy statements.

Each of the councils responsible for air quality management in New Zealand addresses air quality in its regional plan, and each has a more detailed 'air plan' of some form. These are different for each region, reflecting different local circumstances. The differences are usually not significant at the general level − for instance, all plans have the same basic objective 'to maintain and enhance air quality' – but there can be differences in detail, since the exact form of the plans is determined by local political and public consultation processes.

Some regional plans include specific *policies* requiring assessment of the air quality impacts of transport projects, and many regional policy statements, regional plans and district plans have qualitative provisions requiring the 'maintenance or enhancement' of air quality. Accordingly, significant new developments involving roadways or increases in traffic volumes now typically incorporate air quality assessments as part of the land-use consenting or notice of requirement process.

Notwithstanding the above, there are currently no specific *rules* in regional plans that require transport projects, or land-use projects that affect traffic volumes, to obtain resource consents to discharge contaminants to air. This may change, and readers are strongly recommended to consult the relevant regional plan.

Many plans do, however, contain more stringent criteria than exist in the Standards (or the national *Ambient Air Quality Guidelines*). One of the justifications for this is to allow adequate time for regional councils to respond if air quality is approaching unacceptable levels. The regional council process to develop and implement policy for emissions reduction takes several years. One of the ways that councils address this is by adopting 'target' values that are typically 66% of the relevant national ambient air quality standard or guideline value. This allows them a time buffer that helps ensure the Standards are not exceeded. For more information on air quality criteria, please refer to section 5.

One important new feature, following the RMA Amendment Act 2005, is that regional and district plans must now “give effect to” any national policy statement and to regional policy statements (under sections 67(3) and 75(3) of the RMA). The exact implications of this change are difficult to assess until some precedents are established.

Regional policy statements and district plans may also include policies and objectives that are relevant to the assessment of transport projects. Such matters are well known to territorial authorities but not to external parties (eg, consultants preparing air quality impact assessments for transport development). It is recommended that all readers review regional policy statements and district plans to ensure the assessment is consistent with any local objectives, policies or rules.

2.4 Designations and notices of requirement

The RMA gives requiring authorities the ability to have areas of land designated for specific uses (eg, as roads). These areas of land are identified in the district plan, usually in the maps. This is called a 'designation', and it means that the work can be carried out without the need to comply with district plan rules.

If a requiring authority wishes to designate land, it must submit a notice of requirement for a designation to the council, in a similar manner to a resource consent application. A notice of requirement is how a requiring authority gives notice to a city or district council that it is seeking to designate land. Until included in a district plan, a proposed designation continues to be referred to as a notice of requirement.

Transit New Zealand uses designations for its state highway network. The national rail network is also designated.

Territorial authorities need to consider the Standards when issuing or assessing a notice of requirement. A designation may include conditions relating to air quality (eg, a large supermarket granted consent with conditions relating to the use of service vehicles).

The regional council will often become involved in assessing discharges to air from major projects by making a submission on the notice of requirement. However, as discussed above, there are currently no specific rules in regional plans that require transport projects to obtain resource consents from regional councils to discharge contaminants to air.

2.5 Land-use consents

Territorial authorities need to consider the Standards when notifying or assessing land-use consents. For many transport projects (and land-use projects that affect traffic) this will be the only opportunity to formally consider air quality impacts.

2.6 New Zealand Transport Strategy and Land Transport Management Act 2003

The New Zealand Transport Strategy (NZTS) and the Land Transport Management Act 2003 set the framework for the use, development and funding of land transport in New Zealand.

The NZTS sets out the Government's vision for transport. It is a statement on the approach the Government will take to transport, both now and in the future. The NZTS guides policy decisions about transport, and it is reflected in the activities of all government agencies that have responsibilities for, or an interest in, transport.

The NZTS vision is that "by 2010 New Zealand will have an affordable, integrated, safe, responsive and sustainable transport system". The NZTS's objectives are to:

- assist economic development
- assist safety and personal security
- improve access and mobility
- protect and promote public health
- ensure environmental sustainability.

Managing the air quality impacts of transport projects is an important aspect of protecting and promoting public health and ensuring environmental sustainability.

The NZTS will be implemented through policy development, rules and legislation such as the Land Transport Management Act 2003 (LTMA). The purpose of the LTMA is to contribute to the aim of achieving an integrated, safe, responsive and sustainable land transport system. The Act includes requirements for funding land transport, and defines the objectives and functions of Land Transport New Zealand and Transit New Zealand. The Act states that:

> *The objective of the Authority [Land Transport New Zealand] is to allocate resources and to undertake its functions in a way that contributes to an integrated, safe, responsive, and sustainable land transport system.*
>
> *The objective of Transit is to operate the state highway system in a way that contributes to an integrated, safe, responsive, and sustainable land transport system.*

In meeting their objectives, these agencies are also required to "exhibit a sense of social and environmental responsibility", which includes "avoiding, to the extent reasonable in the circumstances, adverse effects on the environment".

The LTMA also requires road-controlling authorities to take into account the NZTS objectives in preparing their land transport programme.

2.7 Regional land transport strategies

Each regional council is required to prepare a land transport strategy for its region. The LTMA requires regional land transport strategies to contribute to an integrated, safe, responsive and sustainable land transport system. Regional land transport strategies are likely to include objectives and policies that are relevant to the assessment of discharges to air from transport.

For example, the Environment Canterbury Regional Land Transport Strategy 2005–2015 includes the policy:

> *Ensure adverse environmental impacts from transport are monitored and national and regional standards are met.*

One of the methods for achieving this policy is to "implement traffic management measures that reduce pollutant levels in areas where these are close to, or exceed, national and regional environmental standards/guidelines".

In another example, the Auckland Regional Land Transport Strategy 2005 includes the following policies in accordance with the purpose of the RMA:

> *Identify and evaluate reduction strategies to ensure that emissions from new and existing transport sources comply with the national environmental standards.*
>
> *Work with the Government and stakeholders to identify and evaluate measures that will limit the adverse environmental effects of transport.*
>
> *Develop and implement consistent procedures for assessing the environmental and health impact of transport policies and projects.*
>
> *Ensure that transport projects consider, at an early stage of the scheme, assessment options to avoid and/or remedy human health risks and adverse effects on the natural and physical environments.*
>
> *Ensure that appropriate environmental mitigation techniques are implemented for transport projects, where adverse effects cannot be avoided or remedied.*

It is strongly recommended that the relevant regional land transport strategy be checked before undertaking any assessment of discharges to air from transport.

2.8 Transit New Zealand Environmental Plan

Transit New Zealand is responsible for planning, constructing and maintaining New Zealand's state highway network in accordance with the Transit New Zealand Act 1989, LTMA and NZTS. The Transit New Zealand Environmental Plan sets out Transit's environmental policy, objectives, implementation plans and performance measures. The plan specifically includes the following objectives:

> *A1 Understand the contribution of vehicle traffic to air quality.*
>
> *A2 Ensure new state highway projects do not directly cause national ambient air quality standards to be exceeded.*
>
> *A3 Contribute to reducing emissions where the state highway network is a principal source of exceedances of national ambient air quality standards.*

Legislative and policy context − recommendations

An assessment of the discharges to air from transport projects, or land-use projects that affect traffic, should be undertaken to determine the impacts on air quality.

Similarly, territorial authorities need to consider the national environmental standards for air quality when notifying or assessing a land-use consent, and when issuing or assessing a notice of requirement.

There is significant relevant policy that needs to be reviewed before undertaking any assessment of air discharges from land transport to ensure the assessment is consistent with any local objectives, policies or rules. This includes the regional policy statement and regional land transport strategy, as well as regional and district plans.

3 Assessing Discharges to Air: General Considerations

This section includes background information on assessing the air quality effects of transport projects, including:

- contaminants of concern (including indicator contaminants)
- factors influencing vehicle emissions
- information sources in local government
- consultation.

3.1 Contaminants of concern

The energy to propel motor vehicles comes from burning fuel in an engine. Discharges to air from vehicles arise from by-products of the combustion process (emitted via the exhaust system), the evaporation of fuel itself, and particulate matter from brakes and tyre wear, among others. There are a large number of contaminants, many of which have some effect on health, the ecosystem or the environment. It is beyond the scope of this document to address all of these, but a more detailed summary is given in Appendix 3.

Most of the effects of transport air pollution emissions can be assessed by examining a few of the key indicator pollutants. These indicator pollutants and the background to their selection are discussed below.

3.1.1 Health effects of motor vehicle pollution

Emissions from motor vehicles known to cause adverse health effects are the gases carbon monoxide, nitrogen oxides, volatile organic compounds and sulphur dioxide, as well as solid particulate matter. Other gases (such as ozone) and secondary particulate (sulphates and nitrates) can form in the atmosphere from reactions involving some of these primary emissions.

There is extensive information available about the health effects of these pollutants. A brief summary is provided in Appendix 3, but further information is available in the *Ambient Air Quality Guidelines* (Ministry for the Environment, 2002), technical reports (Ministry for the Environment 2003a, 2003b), and New Zealand research from the Health and Air Pollution in New Zealand programme (www.hapinz.org.nz).

3.1.2 Ecosystem effects

Air pollution can also have effects on the environment and ecosystem. These are usually less of a concern than effects on public health, but in some circumstances they may warrant attention. A detailed discussion of ecosystem effects is not repeated here, but can be found in another technical publication *The Effects of Air Pollution on New Zealand Ecosystems* (Ministry of Transport, 1998b).

Some effects include damage to plants and animals due to both direct emissions to air and secondary effects through deposition and run-off. However, relatively high levels of air pollution are usually required to cause effects of concern, and these rarely occur in New Zealand at such levels. In most cases, public health effects dominate the assessment criteria.

3.1.3 Indicator contaminants

Such a large range of contaminants with synergistic effects can usefully be reduced to a series of indicator contaminants. These are the contaminants with the highest potential to cause adverse effects, and as such provide a general indication of emissions from vehicles. The Ministry of Transport has identified five indicators of emissions from vehicles. They are:[1]

- carbon monoxide (CO)
- oxides of nitrogen (NO_x, including NO_2)
- photochemical oxidants, including ozone (O_3)
- particulate matter (PM_{10} and $PM_{2.5}$)
- volatile organic compounds (VOCs), including benzene and 1,3 butadiene.

These indicators are described briefly below.

Carbon monoxide (CO)

Vehicle traffic is the single largest source of CO in most urban areas. CO disperses rapidly from the discharge source, with the highest potential exposure levels being immediately adjacent to roads. CO concentrations measured near New Zealand roads have frequently approached, or exceeded, guideline levels, and so CO is a key indicator for assessing local effects.

Oxides of nitrogen (NO_X)

As with CO, vehicle traffic is the largest source of oxides of nitrogen in urban areas. Most is emitted as nitric oxide (NO) but is subsequently oxidised in air to nitrogen dioxide (NO_2). Emission rate characteristics are different to those for CO, and local dispersion of NO_2 is often slower due to oxidation of NO to NO_2. Concentrations of NO_2 measured near busy roads in Auckland have shown levels approaching, and exceeding, guidelines.

1 *Vehicle Fleet Emissions Control Strategy for Local Air Quality Management: Final Report* (Ministry of Transport, 1998d) and supporting technical publications.

Ozone (O_3)

Ozone (O_3) and other secondary pollutants are primarily associated with regional effects because the rate of formation is such that they result from long-range dispersion. Their formation also depends on the mix of chemicals within the urban airshed. An assessment of O_3 will generally only be necessary for major projects where an assessment of regional effects is required. Most assessments will provide adequate coverage of all potential effects if based on CO, particulate matter and NO_x. However, the selection of the contaminants of concern is dependent on the scale and size of the development and the sensitivity of the receiving environment. The assessor needs to justify the selection of contaminants used in the assessment of environmental effects and provide information to support the decision.

Particulate matter (PM)

Sources of particulate matter (PM_{10} and $PM_{2.5}$) include exhaust emissions, re-suspension of road surface dust, tyre wear, and brake and road surface wear. In considering the combustion emissions of PM, essentially all PM is less than 2.5 μm (micrometres).

Diesel exhausts contain much higher particulate concentrations than petrol exhausts, and the contribution of transport to urban discharges of particulate matter (PM_{10} and $PM_{2.5}$) may be growing with increasing numbers of heavy diesel vehicles. Diesel particulate is especially concerning because it has been identified as a potential carcinogen, although at present all particulate matter is assessed in the same way regardless of its source. In many parts of New Zealand existing concentrations of particulate are high due to discharges principally from domestic sources. This means it may sometimes be difficult to identify the particulate contribution from a road as distinct from other sources. Nevertheless, particulate matter is a crucial contaminant for assessing the effects of transport sources, particularly if the fleet in question contains a large proportion of diesel vehicles.

Volatile organic compounds (VOCs)

Significant sources of VOCs include home heating and industry, as well as motor vehicles. VOCs are difficult to assess because there is very limited information on emissions and existing background levels. Also, VOCs comprise a large number of compounds and it is difficult and expensive to measure them all. For most assessments it is valid to assume that CO, PM_{10} and NO_x are good indicators of the likely effects.

In some instances individual VOCs can have specific effects that may need to be assessed. One example is benzene, which is a significant component of petrol and diesel. Long-term exposure to elevated benzene concentrations has a carcinogenic effect. Another VOC that is becoming a concern is 1,3 butadiene, also a carcinogen. Motor vehicles are the main sources of benzene and 1,3 butadiene in urban areas, and there are ambient air quality guidelines for both of these compounds. An assessment of benzene and 1,3 butadiene should be considered for major projects or in special circumstances; for example, if monitoring has shown high existing concentrations.

Others

As detailed in Appendix 3, vehicles and other transport-related sources can emit a wide range of air pollutants. In some very special cases these may need to be explicitly assessed, but such instances would be extremely rare. In general, if the above indicators pass any assessment criteria, then so will all the other types of emissions.

3.1.4 Greenhouse gases

The widest interpretation of the term 'air pollution' would include greenhouse gases such as carbon dioxide (CO_2). Greenhouse gas emissions are not a formal part of any consenting process for road development, but they are of increasing concern to the community and government. These gases are subject to national mitigation strategies, and (increasingly) to local government initiatives. However, these emissions from transport are not included in this Good Practice Guide. The focus here is on local effects on public health and the environment associated with air pollutants that are known to have some toxic effect. Greenhouses gases do not have direct toxic effects, are not covered by current standards or guidelines, and are currently outside the scope of the policies and regulations being considered here.

3.2 Factors influencing vehicle emissions

Factors influencing vehicle emissions are complex and are only discussed briefly below. Detailed information is available from technical reports associated with the Vehicle Fleet Emissions Control Strategy (Ministry of Transport, 1998d). More recently, the results of on-road remote sensing of emissions from more than 40,000 vehicles in the Auckland region has shown the real world effects of some of these factors (Auckland Regional Council, 2003). A more comprehensive review of the influences on vehicle emissions in New Zealand is included in the *Pilot Project Report for Petrol Vehicles* (Ministry of Transport, 2006b) and the *Pilot Project Report for Diesel Vehicles* (Ministry of Transport, 2006a).

3.2.1 Vehicle fleet composition

Vehicle fleet composition has a significant influence on emissions, because different types and sizes of vehicles emit very different amounts of pollution. The proportion of diesel heavy commercial vehicles is particularly important because they are the most significant source of PM_{10}. Assessments and modelling often assume an average fleet profile, but local variations can be substantial. Vehicle fleet composition is discussed further in the Tier 2 and Tier 3 assessment procedures of this guide (sections 7 and 8).

3.2.2 Vehicle technology and fuel standards

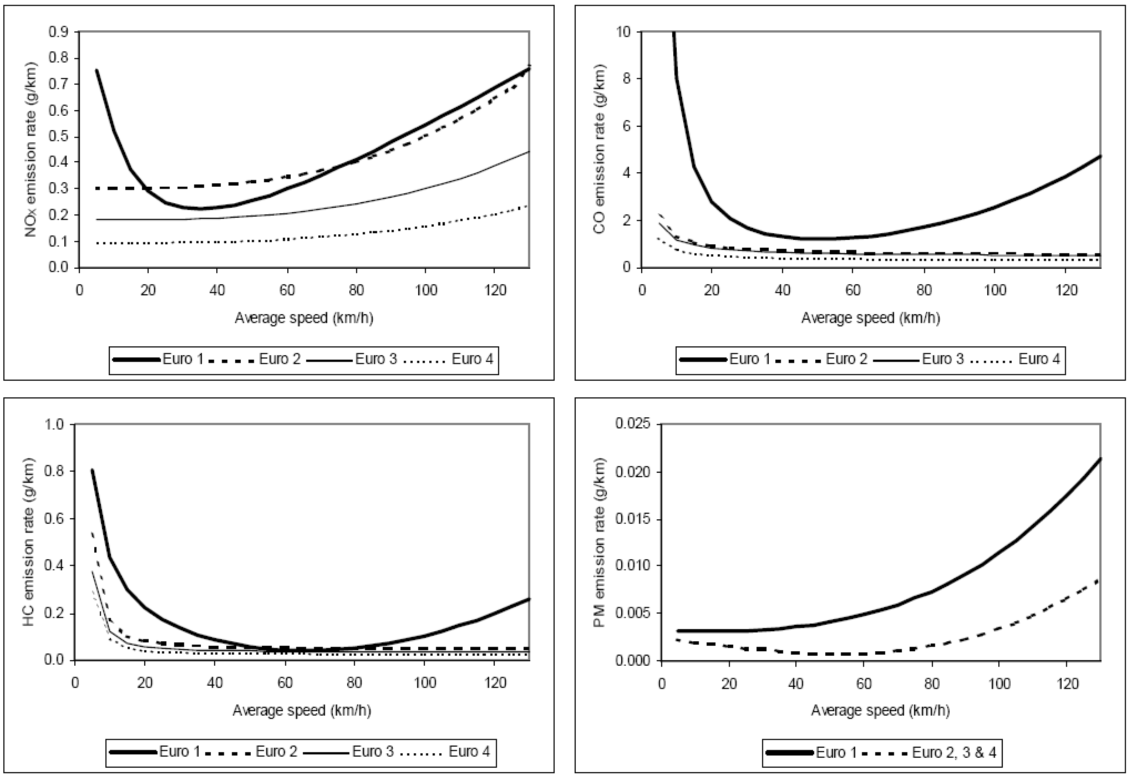
Most of the New Zealand vehicle fleet comes from countries that have well-defined emissions standards for vehicles, including Japan, the USA, Australia and Europe. These emissions standards reflect the environmental goals of the source countries and are achieved through various technologies that affect either engine performance or after-combustion treatment. In New Zealand, the Ministry of Transport recently introduced the Vehicle Exhaust Emissions Rule 2003. From the time the rule takes effect for the various vehicle types, vehicles entering the fleet will be required to be built to an international emissions standard (including Australian, Japanese, US [federal] and the European Union [EU/UN-ECE] jurisdiction standards). The emissions standards in different countries vary, and so there is no one particular standard that is applicable to New Zealand, although the largest fraction of New Zealand vehicles originate from Japan. Further information on vehicle emissions standards and their applicability in New Zealand is available from the Ministry of Transport website (www.transport.govt.nz).

To illustrate the point, some details of the European emissions standards are shown below, for the simple reason that they are well defined and easily obtainable. Figure 3.1 shows the influence of improving vehicle emissions standards. Emissions are shown as a function of speed for Euro 1 to Euro 4 vehicles; Euro 1 was the European emissions standard for vehicles manufactured between 1992 and 1995, and Euro 4 is the emissions standard from 2005.

The way the fleet changes with time has significant effects, especially when considering options more than a few years into the future. It is expected that fleet-weighted emission factors will reduce over time as more modern, lower-emissions vehicles enter the fleet and older vehicles retire.

Fuel standards are also improving over time, and fuel improvements can lead to some direct emissions reductions. More importantly, they are a prerequisite for modern low-emissions vehicles. However, the overall rate of reduction in emissions from vehicles is uncertain because of uncertainties in the likely future fleet composition, vehicle maintenance requirements, etc.

Figure 3.1: Emissions as a function of speed for several European standards



Source: National Roads Authority and DEFRA, 1992/2003.

3.2.3 Vehicle maintenance

Similarly, the state of tuning of vehicles determines their emissions. At any given time many vehicles will be out of tune to various degrees. Again, an average profile is used, but this can be different locally and can change substantially over time. Common overseas experience with vehicle emissions testing shows that in many cases the total air pollution emissions on a road can be dominated by a small percentage of vehicles – the 'gross emitters'. In New Zealand, on-road remote sensing has found that the worst 10% of vehicles may be responsible for over 50% of emissions (Auckland Regional Council, 2003). This factor may be one cause of the high variability in monitoring results, even when total vehicle counts are consistent. One poorly tuned, large diesel truck or bus can emit as much particulate air pollution as 100 well-tuned, private diesel cars.

3.2.4 Cold start

A cold engine is inefficient. This means that before the engine warms up, vehicles emit significantly higher amounts of CO and hydrocarbons and have higher fuel consumption than when they achieve their normal operating temperature. This effect is much more significant in catalyst-equipped vehicles. Catalysts do not begin to work until their temperature reaches a 'light off' value of around 300°C. This delay varies for different vehicles, but is generally within the first three minutes of the trip. This factor needs to be accounted for, and can be significant – many surveys show that a high proportion of trips in New Zealand are less than five kilometres. The cold-start performance differs between petrol and diesel vehicles and can also be influenced by the vehicle's state of tune, the level of service on the road (congestion) and driver behaviour.

3.2.5 Speed and level of service

Vehicles generally emit lower amounts of pollutants when they are travelling steadily at their optimal design speed, which is around 30 to 70 km/hour for most vehicles. Emission rates tend to increase at higher and lower average speeds.

Emission rates under stop-start driving conditions (often associated with congested traffic conditions) are much higher than those when vehicles are driven more smoothly. This means that in stop-start traffic, emissions of some pollutants (eg, CO and VOCs) can be substantially higher than in free-flow conditions. For example, studies have shown hydrocarbon emissions from a car travelling at a steady speed to be only half of those measured at the same average speed but with the car driven in a more typical way − over drive cycles containing accelerations, decelerations and periods of idling (National Roads Authority and DEFRA, 1992/2003).

Emission factors provide an estimate of emissions for a typical drive cycle. The effect of speed and level of service (LOS, or extent of stop-start) is implicitly considered in most emission factors (including the New Zealand Transport Emissions Rate database – NZTER) because the variability of speed during a trip is closely related to the average speed. Slow-speed journeys in towns involve frequent speed changes in response to the traffic conditions, while higher-speed trips are normally driven more smoothly (National Roads Authority and DEFRA, 1992/2003). Nevertheless, for two trips at the same average speed (or for the same LOS / road combination in the NZTER), emissions can vary substantially depending on speed variability.

This effect is not usually significant over the averaging times being considered. For an air quality assessment, average emissions over an hour or longer are needed, so an emission factor for an average drive cycle is generally appropriate.

Graphs illustrating typical variations in emission rates as a function of average speed are presented in Figure 3.1 for catalyst-equipped vehicles. Figure 3.1 illustrates the relationship between average vehicle speed and emissions for four key pollutants. The performance of vehicles complying with other standards (eg, Japanese and US) will not be identical, but they do show similar patterns.

3.2.6 Road design

Road design can significantly affect emissions from vehicles. For example, emissions are significantly higher on steep gradients and sharp bends, where braking and acceleration are required. Another significant influence on air pollution levels is the location of the road. Roads located in an area with reduced dispersion will result in higher levels of air pollution. This could include valleys or street canyons (where high buildings reduce dispersion).

The influence of average vehicle speed / level of service on emissions and reduced dispersion characteristics on pollution levels can be assessed. However, more detailed assessments of the impacts of road design are unusual. This is discussed further in section 8.1.3 (micro-simulation of emissions).

3.3 Information sources in local government

Air discharge assessments can be complex, and are typically very site- or case-specific. It is recommended the relevant council with responsibility for air quality management in the region be consulted before undertaking any significant air quality investigation. The regional authority can provide advice on issues such as relevant policies or rules, existing air quality, and local air quality issues and concerns.

Where a notice of requirement or resource consent is required, establishing what information is available can assist the process greatly, particularly if this is established early in the process. Councils with air quality responsibility will be interested in the proposals and may make submissions or even be formally involved in the process. In particular, councils will have:

- information on current air quality in the area
- knowledge of development plans and potential reverse sensitivity issues
- experience of community concerns
- information on the locations of potentially sensitive receptors
- experience of what is required in air quality assessments.

For projects that may have a number of options, such as alternative routes, the council will be interested in providing early input to these from the viewpoint of air quality issues (as well as other environmental issues within their jurisdiction).

3.4 Consultation

It is important to consider air quality as part of any consultation process for a land transport or land-use project that will have air quality impacts. Detailed guidance on consultation and affected persons is provided on the Ministry for the Environment website.[2]

> **Assessing discharges − recommendations**
>
> To ensure all relevant information is considered, the relevant council with responsibility for air quality management in the region should be consulted before undertaking any significant air quality investigation.
>
> Air quality should be considered as part of any consultation process for a land transport or land-use project that will have air quality impacts.

[2] http://www.mfe.govt.nz/publications/rma/everday/

4 The Assessment Process

Transport or land-use projects have the potential to affect air quality if there are changes in traffic flows, speed, congestion or traffic composition. If these changes are significant, an air quality assessment may be required. This section provides guidance on assessing the air quality effects at a level of detail appropriate to the likely effects of the project.

Note that projects involving maintenance works and/or minor safety upgrades are *not* likely to have significant air quality impacts and do not require assessment.

4.1 Key steps in the assessment process

An assessment of discharges to air from land transport will typically involve the following steps.

1. Gather information and make a qualitative preliminary assessment of air quality impacts.
2. Liaise with relevant local authorities.
3. Predict the contribution of the proposal to ground-level concentrations.
4. Characterise the existing environment.
5. Assess the cumulative air quality impacts.

In practice the process may be simpler – or more complex. For example, a proposal with minor impact would generally only require a preliminary assessment.

Each of these steps should be undertaken to a level of detail that is appropriate to the nature and scale of the proposal. This guide suggests a three-tiered approach to assessment, as discussed below. A brief description of each component of the process is provided in this section, with more detail given in the following sections of the guide.

Make a preliminary assessment

The first step in any assessment of air quality impacts is to compile information and make a qualitative assessment of the likely impacts. For some proposals this preliminary assessment may be all that is needed. However, in most cases the purpose of this stage is to identify key issues early in the process.

The preliminary assessment is referred to as a Tier 1 assessment in this guideline.

Liaise with relevant local authorities

For any significant assessment of discharges to air from land transport, the relevant council should be involved early in the process.

Predict the contribution of the proposal to ground-level concentration of air pollutants

Predicting the likely contribution of the proposal to ground-level pollutant concentrations requires an estimate of emissions and future trends. Traffic data are combined with emission factors (from an emissions model or database), and emissions are calculated accordingly.

Atmospheric dispersion modelling is often used to predict the likely contribution of the proposal to ground-level pollutant concentrations. Detailed guidance is provided in the Ministry for the Environment's (2004) *Good Practice Guide for Atmospheric Dispersion Modelling*. Transport projects requiring dispersion modelling would, in most cases, require the use of models that are designed specifically for transport emissions assessments (eg, CALINE4).

Characterise the receiving environment

The potential impacts of the proposal on air quality must be considered in light of the existing air quality, the sensitivity of the receiving environment, and the local topography and meteorology.

Assess the cumulative impacts of the proposed discharges

Transport projects can cause a range of environmental effects, including human health effects and effects on ecosystems. These effects can generally be assessed by comparing the predicted ground-level concentration of pollutants (including existing background concentrations) with appropriate assessment criteria. Air quality assessment criteria are discussed in section 5.

4.2 The level of assessment required

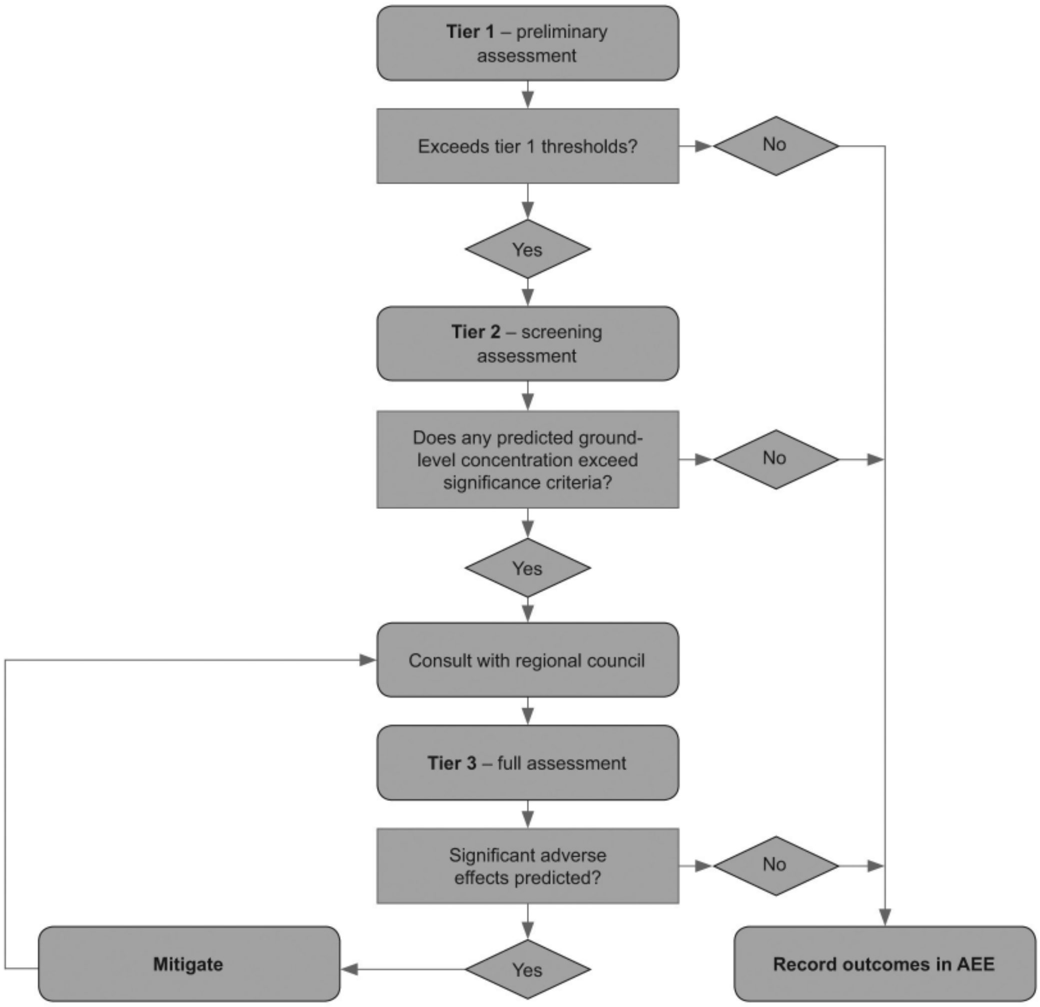
Section 88 of the RMA requires an assessment of environmental effects to be provided "in such detail as corresponds with the scale and significance of the effects that the activity may have on the environment". This section provides guidance on the level of assessment that is appropriate for land transport assessments. Figure 4.1 illustrates the overall assessment process recommended in this guideline. The three-tiered approach is intended to ensure that the level of assessment undertaken reflects the likely level of effect from a proposal.

The three tiers of assessment are:

- **Tier 1:** preliminary assessment, to identify whether there are likely to be significant air quality effects
- **Tier 2:** screening assessment, using straightforward dispersion modelling techniques
- **Tier 3:** full assessment, with increased complexity in modelling and reliance on site-specific data.

Tier 1 and Tier 2 assessment procedures apply only to the assessment of emissions from motor vehicles. Assessment of other land transport projects (eg, railways and tunnels) requires specialist input. The focus of the Tier 3 assessment is also on emissions from motor vehicles, but the same general principles are applicable to any transport project or traffic-generating development.

Figure 4.1: Components of the air quality assessment process



Note: AEE = assessment of environmental effects.

4.2.1 Tier 1 assessment

Any transport or land-use project has the potential to affect air quality and exposure risk if there are changes in traffic flows, speed, vehicle fleet composition, congestion, or the location of traffic relative to receptors. The Tier 1 preliminary assessment is a qualitative assessment to determine whether there are likely to be adverse effects. The level of detail required will vary depending on the nature of the proposal. Some projects that are unlikely to result in significant increases in emissions will not require further assessment, and the Tier 1 assessment suggests quantitative criteria to identify these projects. These criteria are intended as a guide only. The extent of the air quality assessment is a matter for judgement.

For larger projects the Tier 1 preliminary assessment provides an opportunity to identify key air quality issues early in the process.

4.2.2 Tier 2 assessment

Tier 2 is a relatively quick and easy quantitative assessment. A Tier 2 screening dispersion-modelling study provides conservative estimates of likely air quality impacts. This means the assessment can provide confidence that a project will not result in significant air quality impacts, despite the relative uncertainty of the predictions. If this screening assessment indicates there is a potential for adverse impacts or non-compliance with air quality criteria, then the modelling and assessment approach may need to move up to the Tier 3 assessment level, with the modelling further refined to increase the accuracy of the estimates, enabling some of the conservativeness of the assessment to be removed.

A Tier 2 assessment should be undertaken for any project (or part of a project) that is identified from the Tier 1 assessment as needing further assessment, to determine whether significant adverse effects on air quality are likely. For major projects it may be immediately obvious that a Tier 3 assessment will be required. However, Tier 2 may still be useful for doing a quantitative ranking of options and for identifying parts of the project that require detailed assessment.

4.2.3 Tier 3 assessment

A more detailed Tier 3 assessment is required if the screening assessment indicates potential significant adverse effects, or if the project is sufficiently complex that a screening assessment is not appropriate. As stated earlier, for some projects the need for a Tier 3 assessment may be obvious during the preliminary assessment.

It is recommended that the relevant council with responsibility for air quality management be consulted before undertaking a Tier 3 assessment.

A Tier 3 assessment may require site-specific emission calculations, including ambient air monitoring data (to confirm background concentrations), and atmospheric dispersion modelling. In many cases the tools or models are the same as those used for a Tier 2 screening assessment but require more detailed input data. For example, an atmospheric dispersion model may accommodate real-time meteorological data, or at least a representative meteorological frequency distribution, rather than simple worst-case assessments.

Detailed assessments may also be required to handle special localised features, which may affect the dispersion of contaminants that are not adequately examined by the screening models. This could include areas of complex terrain, severe street canyons, complex intersections and discharges from road- or rail-tunnel vents.

4.2.4 Deciding which tier

The concept of splitting the assessment methodology into three tiers is somewhat arbitrary. The aim is to provide some guidance – particularly to people new to the field – on the different levels of work and detail needed. For instance, looking crudely at the resources required:

- Tier 1 probably requires just *several hours* of work, using existing documentation and information.
- Tier 2 probably requires *several days* of work, including the generation of some new results, and probably a report.
- Tier 3 probably requires *several weeks* (or months) of work, including advanced modelling, possibly new monitoring, the use of a number of experts, and probably several reports, with peer review (such as for a new large road, near sensitive receptors, in a poor quality airshed). These types of activities are those most likely to be appealed to the Environment Court.

The delineation between the tiers is not absolute. Basically, a Tier 2 or 3 assessment should be undertaken to a level of detail sufficient to determine the air quality effects in a robust and defensible manner.

4.3 Factors affecting the level of assessment

The factors affecting the level of assessment required include the:

- scale of the development
- extent of any increase in emissions
- scale of effect
- whether the project is within an airshed that is likely to exceed the national environmental standards for air quality (the Standards)
- existing air quality
- physical geography of the receiving environment
- land use of the receiving environment
- any legislative or consent requirements.

The Tier 1 preliminary assessment process includes a qualitative assessment of these factors. In some cases it will be obvious from the preliminary assessment and discussions with the regional council that a Tier 3 assessment will be required. However, a Tier 2 screening assessment may still be undertaken to identify the pollutants or sources of most concern before undertaking a Tier 3 assessment.

In reality, it is likely that the methodologies described in the Tier 2 and Tier 3 procedures would be combined for any significant assessment. For example, a scarcity of information on existing air quality may result in the need for air quality monitoring, whereas the required dispersion modelling technique may be very straightforward due to simple topography.

One of the advantages of early liaison with the relevant local authority is the opportunity to get advice on what level of quantitative assessment is likely to be required based on their experience with similar proposals. In this way, the assessment process can be targeted at the appropriate level rather than wasting time by following an iterative approach of increasing detail and complexity.

For major projects, the level of assessment required will also depend on the stage or status of the project. A major project will have several assessment stages before consideration of the notice of requirement, including feasibility studies, scheme assessments and detailed design. For these types of project it is important that a preliminary Tier 1 assessment be undertaken early in the process so that air quality issues can be identified and considered in the project design. For example, if there are three choices of route at the scheme assessment phase, but one option takes the route near a rest home or school, then from an air quality perspective the other two route choices may be preferable.

4.3.1 Legislative and policy requirements

Legislative and policy requirements are outlined in section 2. It is important to consider any requirements of relevant legislation or policies in determining the appropriate level of assessment.

4.3.2 National environmental standards for air quality

At the time of publication, 69 areas throughout New Zealand have been gazetted as 'airsheds' under the provisions of the Standards. Of these, around 30 are likely to exceed the national ambient air quality standard for PM_{10} and are therefore subject to controls on the granting of resource consents. It is likely that any development within these airsheds that shows any significant increase in PM_{10} emissions will require a Tier 3 assessment.

The additional requirements imposed by the Standards (as well as those already in council plans) cover many other pollutants aside from PM_{10}. For instance, some regions have an issue with NO_2 (mainly in Auckland, due to its high level of traffic emissions) and some with SO_2 (mainly due to industries using coal).

4.4 Comparing project options

Air quality is one of many issues that need to be considered in comparing project options. Transport projects are evaluated against the five objectives of the New Zealand Transport Strategy, which are:

- assisting economic development
- assisting safety and personal security
- improving access and mobility
- protecting and promoting public health
- ensuring environmental sustainability.

Projects can also be evaluated against other central, regional or local government objectives and policies. The legislative and policy framework is discussed in section 2.

For major projects, there are often compromises between objectives. For example, an option that improves safety by providing pedestrian facilities may increase vehicle emissions and degrade air quality. In these cases, it can be difficult to assess the relative importance of air quality compared with other objectives. However, there are two key questions that can help in comparing project options:

1. Is the option likely to result in any significant localised adverse effects? In particular, is the option expected to result in an exceedance of the national ambient air quality standards, and can this be mitigated?
2. What is the estimated overall health cost (value) from air pollution for each option?

A quantitative method for estimating overall health impacts and associated costs is recommended in Appendix 4.

An assessment of the impacts of a transport project cannot be carried out in isolation, but it is vital to take account of the wider aspects. For instance, a mitigation measure on one particular road segment, designed to improve air quality around that road, may have consequences for increased emissions elsewhere. This can occur through increasing congestion, re-routing traffic through a more sensitive area, increasing total volumes in the area, or altering the vehicle mix.

There are numerous examples throughout the world of this, such as in the Swedish city of Stockholm. Expensive measures to heavily control the CBD traffic did not decrease the total amount of excessive air pollution – it simply moved it out of the CBD and into a wide band around the city, where the new ring roads had been constructed.[3]

[3] For a discussion of the Stockholm displacement problems and similar issues in other cities, see Sustainable Mobility Assessment & Renewal Technology for Capital Improvements of Transportation Infrastructure (SMARTCITI), *Proceedings of the 9th Intercontinental Conference*, Seattle, Washington, 29 June–1 July 2005.

In major developments it is important to consider environmental impacts early in the process. For example, route choices should not be considered and eliminated before considering air quality impacts. At the early stages of project evaluation, quantitative comparison may not be possible. At this stage it is recommended that comparison of projects be based on a qualitative assessment, as described in the Tier 1 assessment section. This should consider the likely air quality issues for each project option, such as:

- the background air quality
- any areas where dispersion is likely to be poor (valleys or building canyons)
- the location of any traffic 'hotspots' (intersections, congested areas, busy areas) in relation to any areas with poor dispersion or sensitive receptors
- the location of any sensitive receptors (residential areas, hospitals, schools, etc) in relation to the development, and in relation to any likely hotspots or areas with poor dispersion
- the existence of any location-specific plans, policies or community requirements.

Mitigation will need to be considered for any option that results in exceedances of the national ambient air quality standards, so it is advisable to undertake a quantitative assessment (Tier 2 or Tier 3) of local air quality impacts as soon as practicable in the project evaluation process.

4.5 Reporting

It is a good idea to develop a standard reporting methodology and format. Although specific projects will have specific requirements, any report should contain the following features.

1. **Executive summary:** a one-page statement of the key features and results. This may be the only part of the report that some users read, so it should be succinct and clear.
2. **Scope:** who has commissioned the project, and why, including the intended outcomes.
3. **Introduction:** the background to the issues and the relevance of any previous work.
4. **Methodology:** a description of the process used, any models employed, assumptions made, and any statistics or analysis used.
5. **Site description:** the area being assessed, including maps with all relevant features (and photos if available). Show any facilities where there are likely to be sensitive members of the public (eg, young, old, sick), such as hospitals and schools, in relation to the proposal.
6. **Description of proposal:** a description of the project and any changes to existing activities. This section should include enough information to characterise the discharges and the receiving environment, as detailed in later sections of this guidance. This section should also include a clear description of the options being considered.
7. **Description of the receiving environment:** a description of the receiving environment as detailed in later sections of this guide.
8. **Data used:** the sources and validity of all input data, including traffic flow data, fleet profiles, emission factors, meteorology, existing concentrations and all assumptions made.
9. **Assessment of effects:** the outcomes of the study, and all options assessed, as much as possible in summary tabular and graphic form. The emphasis should be on key results that can inform decision-making. Where possible, errors should be estimated and stated. Detailed results should be given in an appendix.

10. **Discussion:** any implications, uncertainties and reliance on assumptions. Include discussion of possible mitigation options and associated emissions reduction.
11. **Conclusion:** a summary of the scope, method, result and implications.
12. **References:** all material used should be referenced explicitly, and should include web-based links where appropriate.
13. **Appendices:** any detailed calculations or results that are used. This should include model control files.

The size and nature of each of these sections will depend on the project, but it is anticipated that for any Tier 3 assessments each section will be included and the report will typically run to 30 to 60 pages. Specific requirements for Tier 1, 2 and 3 assessments are discussed in sections 6, 7 and 8 of this guide.

4.6 Reasonableness

Assessing air quality effects is a complex task. Although a number of quantitative tools are applied, many of these have uncertainties that at times can be difficult to quantify. Many steps in the process require assumptions to be made, and this is where the concept of 'reasonableness' comes in.

For instance, although in theory it would be possible to describe and model all possible options (all types of traffic, all types of drivers, all weather conditions, etc), this would result in hundreds or even thousands of sets of results, for an unreasonable cost. It is also remarkably difficult to gain accurate information on future emissions characteristics, particularly with evolving engine technologies and the sometimes unrealistic performance of transport models out beyond a few years.

Even if very accurate emissions and dispersion modelling for the project under consideration are possible, the situation is further compounded by the fact that the state of knowledge about other sources and their effects is imperfect, particularly in areas that are geographically complex and have many other sources and no ambient monitoring (ie, some New Zealand cities).

Calls are often made – particularly by the various engineering professions responsible for the design, implementation and operation of the transport networks – to provide quantified uncertainty estimates. However, the current state of knowledge about emissions and dispersion is such that this is simply impossible to do with the same rigour as most engineering calculations. Simple uncertainty estimates at each stage can compound to create enormous uncertainties in the final results. This is not so much looseness in the computations as a feature of not having developed the right statistical methods (for instance, many processes are far from being normally distributed and/or are often not independent, so common statistical measures of uncertainty are inappropriate).

This lack of rigorously quantified uncertainty does not detract from the value of the methodology used. Indeed, this is precisely why so much emphasis is placed on monitoring, validations and experience from similar projects.

As a result, any assessment of the air quality effects of transport needs to apply a factor of *reasonableness*. This is difficult to define, but should include consideration of the following factors.

- **Fleet composition:** Is it accurate enough? Does it represent the conditions of interest?
- **Transport corridor being assessed:** How far does it go? Are the right number of feeder routes included?
- **Project options:** Are there a manageable number (not just one or two, but also not 50 or 60)?
- **Time horizon:** How far into the future is reasonable? One year is not enough, but 30 is probably too much.
- **Contaminants:** Are the right ones on the list? Are there not too many, but not too few?
- **Existing air quality and effects:** Are the time and spatial variability captured?
- **Cumulative effects:** Is the procedure for examining the additive effects of the project emissions to existing effects robust?
- **Receiving environment:** How far to go − right on the road, or 10 m, or 200 m?
- **Reporting:** Just enough to tell the story? Or should there be hundreds of pages of background and justification?
- **Mitigation options to assess:** Just what might be sensible and practical versus unrealistic or cost prohibitive?

The rest of this good practice guide should help with deciding these questions, but the answers to them will never be absolute.

The assessment process − recommendations

An assessment should be undertaken in such detail as corresponds with the scale and likely significance of the effects. A three-tiered approach is outlined as a guide to the different types of information required and the different levels of resources required to complete the application.

It is important that air quality is considered early in a transport project. A Tier 1 preliminary assessment should be undertaken early enough so that air quality issues can be identified and considered in the project design.

Air quality should be considered when comparing project options (including alternative routes). This comparison should include a qualitative (Tier 1 preliminary assessment) and, where possible, a quantitative (Tier 2 or 3) assessment of the air quality impacts of different options. A quantitative method for estimating overall health impacts and associated costs is further recommended in Appendix 4.

A level of 'reasonableness' needs to be applied in any assessment of the air quality effects of transport (based on the judgement of experienced practitioners).

A reporting format is suggested for any assessment of environmental effects reports to ensure consistency and avoid omissions of important relevant material.

5 Air Quality Criteria

The extent to which the impacts on air quality caused by a transport development are considered acceptable is judged by the use of air quality criteria. The New Zealand regulatory framework contains the following air quality criteria:

- national environmental standards for air quality
- national ambient air quality guidelines
- objectives and policies in regional plans.

It is important to note that regional plans are statutory instruments under the RMA. **If the air quality objectives in a regional plan are more stringent than the national environmental standards for air quality, then the regional plan takes precedence.** For this reason it is very important to check the requirements of the relevant regional plan before undertaking any assessment of the discharges to air from land transport.

New Zealand and other international air quality criteria are discussed in more detail below.

A thorough air quality assessment (some Tier 2 and all Tier 3) should address both short-term and long-term impacts. This means you will need to use air quality criteria with both short- and long-term time averages. Air quality criteria published by different agencies may overlap, complement or sometimes outright contradict each other for some pollutants and some time averages. It is very important, therefore, when selecting air quality criteria for an air quality assessment, that the fundamental purpose of the standard or guideline is understood. Similarly, the application of the criteria should be considered.

It should also be noted that air quality criteria may become outdated. Check the Ministry for the Environment website (www.mfe.govt.nz) for any updates to the national ambient air quality standards or guidelines discussed in this section.

In all cases, the assessment should explain which criteria have been selected and why. For those pollutants not covered by the criteria discussed below, or in cases where the criteria are exceeded, health risk assessment techniques should be applied.

5.1 National environmental standards for air quality

Schedule 1 of the Standards provides ambient concentration limits for the following pollutants:

- carbon monoxide (CO)
- nitrogen dioxide (NO_2)
- ozone (O_3)
- fine particulate matter that is less than 10 micrometres in diameter (PM_{10})
- sulphur dioxide (SO_2).

The primary purpose of the national ambient air quality standards is to provide a guaranteed level of protection for the health of all New Zealanders.

The national ambient air quality standards, therefore, comprise acceptable concentrations for a particular time average, with a specified number of permissible exceedances each year, as summarised in Table 5.1.

Guidance on applying the national ambient air quality standards is provided in the *Updated Users' Guide* (Ministry for the Environment, 2005). A number of key issues relevant to the assessment of discharges from transport are discussed here.

The national ambient air quality standards apply in the open air *everywhere people may be exposed*. This includes roadside verges, residential areas, central business districts, parks and beaches. Areas that are *not* in the open air and where the Standards do *not* apply include:

- inside a house
- inside tunnels
- inside vehicles.

Table 5.1: National ambient air quality standards 2004

Pollutant	Standard	Time average	Allowable exceedances per year
PM_{10} (particulate)	50 µg/m^3	24-hour	1
Nitrogen dioxide (NO_2)	200 µg/m^3	1-hour	9
Carbon monoxide (CO)	10 mg/m$_3$	8-hour	1
Sulphur dioxide (SO_2)	350 µg/m^3 570 µg/m^3	1-hour 1-hour	9 0
Ozone (O_3)	150 µg/m^3	1-hour	0

When assessing the potential impacts of discharges to air from land transport, careful judgement is required to determine whether people may be exposed. General guidance on determining exposure for assessment purposes is provided in Table 5.2.

Table 5.2: Location and applicability of the Standards for assessment purposes

Averaging period	Locations where assessment against the Standards *should* apply	Locations where assessment against the Standards *should not* apply
1 hour	This includes any outdoor areas where the public might reasonably be expected to spend one hour or longer, including pavements in shopping streets, as well as facades of any building where the public might reasonably be expected to spend one hour or longer.	Any industrial premises that have resource consents (for that pollutant).
24 hours and 8 hours	This includes all outdoor locations where members of the public might be regularly exposed (eg, residential gardens) as well as facades of residential properties, schools, hospitals, libraries, etc.	Any industrial premises that have resource consents (for that pollutant).
All		In any enclosed space (ie, not in the open air) including: • indoors • inside tunnels • inside vehicles.

The regulations place constraints on resource consents depending on the pollutant, the existing air quality of an airshed relative to the national ambient air quality standards, and the date of the application. Although transport projects generally do not require a discharge consent, the national ambient air quality standards are relevant to assessing whether a project meets the purposes of the RMA (eg, safeguarding the life-supporting capacity of air).

In particular, for new designations and land-use consents after September 2005, territorial authorities and/or requiring authorities should consider the national ambient air quality standards. The authority will need to consider the potential impacts of a new designation or land-use consent on air quality, and the subsequent impact this may have on future resource consent applications.

A full discussion of the Standards, and their applicability, can be found in the *Updated Users Guide* (Ministry for the Environment, 2005).

5.2 New Zealand air quality guidelines

The national ambient air quality standards are based on the existing *Ambient Air Quality Guidelines* (Ministry for the Environment, 2002). These guidelines were developed following a comprehensive review of international and national research, and are widely accepted among New Zealand practitioners. The *Ambient Air Quality Guidelines* were published by the Ministry for the Environment as guidance under the RMA. They provide the minimum requirements that outdoor air quality should meet in order to protect human health and the environment.

The primary purpose of the national *Ambient Air Quality Guidelines* is to promote sustainable management of the air resource in New Zealand.

Guideline levels for pollutants (and averaging periods) not covered by the Standards still apply. The Standards replace any previous guideline levels for that particular pollutant and averaging period. In addition to the human health-based guidelines presented in Table 5.3, guidelines for ecosystem protection are provided for sulphur dioxide, sulphate particulate, nitrogen dioxide, ammonia, ozone and fluoride in Table 5.4.

Table 5.3 National Ambient Air Quality Guidelines, 2002

Indicator	Level	Averaging time
Carbon monoxide	30 mg/m^3	1 hour
Fine particulates (PM_{10})	20 µg/m^3	Annual
Fine particulates ($PM_{2.5}$)	25 µg/m^3	24 hours – monitoring value only
Nitrogen dioxide	100 µg/m^3	24 hours
Sulphur dioxide	120 µg/m^3	24 hours
Ozone	100 µg/m^3	8 hours
Hydrogen sulphide	7 µg/m^3	1 hour
Lead	0.2 µg/m^3	3-month moving average, calculated monthly
Benzene (2002) Benzene (2010)	10 µg/m^3 3.6 µg/m^3	Annual Annual
1,3 butadiene	2.4µg/m^3	Annual
Formaldehyde	100 µg/m^3	30 mins
Acetaldehyde	30 µg/m^3	Annual
Benzo(a)pyrene	0.0003 µg/m^3	Annual
Mercury (inorganic) Mercury (organic)	0.33 µg/m^3 0.13 µg/m^3	Annual Annual
Chromium V1 Chromium metal and Chromium III	0.0011 µg/m^3 0.11 µg/m^3	Annual Annual
Arsenic (inorganic) Arsine	0.0055 µg/m^3 0.055 µg/m^3	Annual Annual

Table 5.4: Critical levels for protecting ecosystems

Contaminant and land use	Critical level	Averaging period	Additional requirements
Sulphur dioxide: • agricultural crops • forest and natural vegetation • lichen	 30 µg/m³ 20 µg/m³ 10 µg/m³	 Annual and winter average Annual and winter average Annual	
Sulphate particulate: • forests	 1.0 µg/m³	 Annual	 Where ground-level cloud present > 10% of time
Nitrogen dioxide	30 µg/m³	Annual	
Ammonia	8 µg/m³	Annual	
Ozone: • forests • semi-natural vegetation • crops (yield) • crops (visible injury)	 21,400 µg/m³/h 6,420 µg/m³/h 6,420 µg/m³/h 428 µg/m³/h 1,070 µg/m³/h	 6 months 3 months 3 months 5 days 5 days	 Daytime vpd below 1.5 kPa Daytime vpd above 1.5 kPa
Fluoride: • special land use • general land use • conservation areas	 1.8 µg/m³ 1.5 µg/m³ 0.8 µg/m³ 0.4 µg/m³ 0.25 µg/m³ 3.7 µg/m³ 2.9 µg/m³ 1.7 µg/m³ 0.84 µg/m³ 0.5 µg/m³ 0.1 µg/m³	 12 hours 24 hours 7 days 30 days 90 days 12 hours 24 hours 7 days 30 days 90 days 90 days	

Notes: Critical levels for NO_2 assume that either O_3 or SO_2 are also present at near guideline levels. Critical levels for O_3 are expressed as a cumulative exposure over a concentration threshold referred to as AOT40 values (accumulative exposure over a threshold of 85.6 µg/m³, at 0°C), calculated as the sum of the difference between hourly ambient O_3 concentrations and 85.6 µg/m³, when O_3 concentrations exceed 85.6µg/m³). O_3 is only measured during daylight hours, with a clear global radiation of 50 Wm^{-2} or greater.

vpd = vapour pressure deficit.

5.3 Regional plans

In 2007 all regional councils had regional air quality plans either operational or in the final stages of becoming operational. The plans reflect particular regional circumstances and may range from being very straightforward, dealing primarily with issues of open burning, to the more complex, with specific rules and plans for meeting the Standards.

It is important to understand the purpose of each regional plan when considering the application of air quality objectives (sometimes referred to as targets or goals).

From a regulatory viewpoint, regional air quality plans are statutory instruments under the RMA and have equal status with the Standards. Where concentration thresholds double up, the more stringent level applies. Thus, a regional air quality objective, that is more stringent than a national ambient air quality standard, supersedes the national standard. The regional air quality objectives cannot, however, be more lenient than the national ambient air quality standards.

5.4 WHO guidelines

Given the increasing evidence of the health impact of air pollution, the World Health Organisation (WHO) revised its existing air quality guidelines for Europe in October 2006 and expanded them to produce the first global air quality guidelines. These guidelines are based on the latest scientific evidence and set targets for air quality to protect the large majority of individuals from the effects of air pollution on health.

The primary aim of the WHO guidelines is to provide a uniform basis for protecting public health from the effects of air pollution. They are intended for worldwide use.

Table 5.5 summarises the updated WHO air quality guideline levels. These include guidelines for $PM_{2.5}$ and for nitrogen dioxide annual average, which are not currently covered by New Zealand standards or guidelines. The WHO 24-hour average $PM_{2.5}$ guideline is consistent with the New Zealand monitoring guideline (Ministry for the Environment, 2002). The WHO 24-hour guideline for sulphur dioxide is considerably more stringent than the New Zealand ambient air quality guideline.

Table 5.5: Updated WHO air quality guideline values

Pollutant	AQG value	Averaging time
Particulate matter $PM_{2.5}$ PM_{10}	 **10 μg/m³** 25 μg/m³ 20 μg/m³ 50 μg/m³	 **1 year** 24 hours (99th percentile) 1 year 24 hours (99th percentile)
Ozone (O_3)	100 μg/m³	8 hours, daily maximum
Nitrogen dioxide (NO_2)	**40 μg/m³** 200 μg/m³	**1 year** 1 hour
Sulphur dioxide (SO_2)	**20 μg/m³** **500 μg/m³**	**24 hours** **10 minutes**

Notes: Items in bold are not covered by New Zealand standards or guidelines; AQG value = air quality guideline.

5.5 Other air quality criteria

It is unlikely that an assessment of discharges to air from land transport would need to consider any pollutant that is not covered by the New Zealand and WHO standards and guidelines. However, if there are special circumstances that require consideration of another pollutant, there are a number of other air quality criteria that can be used. The *Good Practice Guide for Assessing Discharges to Air from Industry* (Ministry for the Environment, 2008) includes discussion and recommendations for the use of international air quality criteria and workplace exposure standards.

Air quality criteria − recommendations

A number of criteria are available for assessing the effects of air quality. Some take precedence in terms of stringency (eg, regional objectives over the national environmental standards for air quality). Others take precedence in terms of time average and application (eg, the WHO guideline for sulphur dioxide should be applied to new proposals).

In general terms, the following criteria should be selected in the following order of priority:

- national environmental standards for air quality
- national ambient air quality guidelines
- regional objectives (*unless more stringent than above criteria*)
- WHO air quality guidelines.

6 Tier 1 Preliminary Assessment

The Tier 1 assessment is a qualitative assessment. The objectives are to compile background information, identify key issues and determine the appropriate level of assessment. It is recommended that a Tier 1 preliminary assessment be undertaken at the beginning of a project, before the design phase, and before consultation with the regional council or other interested parties.

The Tier 1 assessment should consider the receiving environment and the nature and scale of the proposal, focusing on the:

- scale of the development
- alternatives
- airshed designation under the Standards
- existing air quality
- physical geography of the receiving environment
- sensitivity of the receiving environment
- any relevant objectives, policies or rules in the regional or district plan.

These factors are discussed further below. The level of detail required will vary depending on the proposal. Some projects that are unlikely to result in significant increases in emissions will not require a Tier 2 or 3 assessment. Section 6.1 suggests thresholds to identify these projects, as well as basic reporting recommendations.

For projects that require further assessment, the main purpose of the Tier 1 assessment is to identify key issues early in the process. For significant projects a preliminary assessment may allow options to be ranked. The important point is that air quality issues be identified and addressed as early as possible in the project, and a preliminary or qualitative assessment provides the opportunity to do this.

6.1 Proposals that do not require further assessment

A Tier 1 assessment will be all that is required for any project that does not result in significantly increased emissions. Table 6.1 suggests quantitative assessment thresholds to help determine whether further assessment of a project is required.

Note: an air quality assessment is not necessary for any project that will not result in a significant increase in emissions at any location.

For projects that do not require further assessment, a formal Tier 1 assessment report may not be required. Where a report is necessary (eg, to meet funding requirements), an assessment for this type of activity should include:

- a description of the project
- a summary of any traffic data used to determine whether further assessment is required
- a description of the receiving environment, including air quality, topography and meteorology
- an assessment of the sensitivity of the receiving environment, including the location of any sensitive receptors in relation to the project.

6.1.1 Suggested thresholds to determine whether further assessment is required

Table 6.1 suggests thresholds to determine whether a Tier 2 or 3 assessment is required. These thresholds are intended as a guide only: the extent of the air quality assessment is a matter for judgement. For example, even if a project is well below the suggested thresholds, it may be appropriate to undertake more detailed air quality assessment in areas where there is a high level of community concern about air quality or new roads. The basis for the suggested assessment thresholds is discussed in Appendix 1. The thresholds are conservative, and are based on limited information. There is currently no other policy or guidance available to help agencies identify projects that do not require assessment, so these thresholds have been suggested as a first step. It is likely that thresholds will change over time as practitioners become more experienced in transport assessments and the availability of project monitoring improves.

Assessment against thresholds should be undertaken for all new roading projects. For changes to existing roads or road networks, this assessment should be undertaken for all roads or links where the project is likely to result in a significant increase in emissions. The assessment will need to demonstrate that the assessment area includes all roads or links that are *directly or indirectly affected by the project*.

The suggested thresholds rely on estimated traffic as a proxy for air quality effects. In cases where the estimated traffic is close to the thresholds described in Table 6.1, a Tier 2 assessment should be considered, particularly if there are sensitive receptors such as residential houses, childcare or health-care facilities close to the proposal.

To assess a project against the suggested thresholds, traffic information will be required for all links and intersections affected by the project, including:

- annual average daily traffic (AADT)
- level of service (or average speed)
- traffic composition (for current and future conditions, where available)
- traffic forecasts.

In relation to the last point, the future assessment years may depend on the availability of traffic demand models, but should include a long-term forecast (at least 10 to 20 years). Where local traffic forecasts are not available, the default traffic growth rates provided by the *Project Evaluation Manual* (Transfund, 2004) should be used. If it is likely that the Tier 1 traffic thresholds will be exceeded in future, then a Tier 2 assessment should be considered.

Table 6.1: Suggested thresholds to identify projects that do not require further assessment

Location to be assessed	Steps to complete assessment	Notes
STEP 1: Determine whether the project requires assessment		
New roads	Go to Step 2	
Changes to traffic on existing roads due to land-use changes, or permanent changes to the road network or infrastructure	Are there any parts of the project being assessed where there will be: • any significant increase in traffic, or • any significant decrease in level of service, or • any significant increase in the proportion of heavy duty vehicles (> 3.5 tonnes)?	Determining whether the change is significant is a matter for judgement. If there is doubt, a Tier 2 assessment will quickly determine whether changes are significant.
Action: Proceed to STEP 2 for these projects. Projects that do not require assessment include temporary diversions, maintenance works, and any project that is not likely to increase emissions.		
STEP 2: Evaluate traffic information to identify possible 'hot spots'		
Busy roads	Identify links where traffic is likely to be greater than 7,000 vehicles per day.	
Congested roads	Identify any links that may be congested, where traffic is likely to be greater than 3,000 vehicles per day.	Concentrations are often higher where traffic is slow-moving with stop/start driving. Use local knowledge and/or results of traffic modelling to identify likely areas of congestion.
Busy intersections	Identify any busy intersections with more than 7,000 vehicles per day, regardless of level of congestion.	Where two or more roads intersect, the traffic flows should be added to give a combined total.
Roads with a high flow of buses and/or heavy-duty vehicles	Identify any links where the flow of heavy duty vehicles (> 3.5 tonnes) is likely to be more than 500 vehicles per day.	
Action: For any links or intersections identified in STEP 2, proceed to a Tier 2 assessment. If there are no links or intersections identified in STEP 2, no further assessment is required.		

6.2 Information required for a Tier 1 assessment

This section describes the information requirements for a Tier 1 preliminary assessment of projects that will require further assessment.

The scale of the development

The assessment should include a description of the project, including traffic data. Relevant information to assess the scale of the development will include the amount of traffic, the level of service and the proportion of diesel vehicles. Key questions to ask include:

- Will the project cause an increase in traffic volumes at any location?
- Will the project change the composition of traffic or flow dynamics at any location? For example, will existing roads linked to the new project experience an increase in the proportion of heavy traffic, or an increase in the level of congested flow?
- Is the project of sufficient scale to affect air quality across the airshed?

Alternatives

The Tier 1 assessment should consider alternatives including:

- alternative locations that may be less sensitive
- alternative locations for any likely hotspots (eg, intersections) that may be less sensitive
- alternative transport schemes (eg, a different mix of road / public transport / traffic demand management).

Airshed designation under the national environmental standards for air quality

At the time of publication, 69 areas throughout New Zealand have been gazetted as airsheds under the provisions of the Standards. Of these, around 30 are likely to exceed the national ambient air quality standard for PM_{10} and are therefore subject to controls on the granting of resource consents. It is likely that any development within these airshed areas that shows any significant increase in PM_{10} emissions will require a Tier 3 assessment. For up-to-date information on airshed designations, contact the appropriate regional council.

The existing air quality

Existing air quality is an important consideration in any air quality assessment. The Tier 1 preliminary assessment should determine what information is available (if any) on existing air quality, and how this compares to relevant air quality criteria.

The physical geography of the receiving environment

The physical geography of an area can affect the dispersion of pollutants, and is a particularly important consideration in dispersion modelling. The preliminary assessment should identify whether there are any significant topographical features that may affect dispersion.

Features such as coasts and mountainous terrain require more complex predictive modelling techniques than, for example, flat inland sites. These considerations are well covered in the *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004), which is a companion guidance to this document.

Plan and transport strategy requirements

The Tier 1 assessment should include a review of the relevant regional and district plans, and regional transport strategy to identify any relevant objectives, policies or rules.

The sensitivity of the receiving environment

Adverse effects on air quality can be exacerbated by the sensitivity of the receiving environment. An assessment of the sensitivity of the receiving environment requires an assessment of land use and the likely sensitivity of the local population to air emissions. Table 6.2 provides a general classification of the sensitivity of various land uses to discharges of contaminants into air. Because land uses are the key criteria for classifying the sensitivity of the receiving environment, district plan zonings can have a large influence on an area's sensitivity. Higher sensitivity land uses will require a higher level of assessment. Key questions to ask include:

- Are there any facilities (schools, hospitals, etc) or sensitive receiving environments located within close proximity to the project (200 m)?
- What is the distance to these sensitive locations (or receptors)?
- Are any of these sensitive locations (or receptors) close to potential hotspots?

Table 6.2: Types of land use/location and the sensitivity of the receiving environment

Land use	Reasons for sensitivity	Rating
Hospitals, schools, childcare facilities, rest homes	People of high sensitivity (including children, the sick and the elderly) are exposed. People are likely to be exposed continuously (up to 24 hours, seven days a week).	High
Residential	People of high sensitivity (including children and the elderly) are exposed. People cherish a stress-free environment at home and have the view that "my house is my castle". People may be present at all times of the day and night, both indoors and outdoors. Visitors to the area are unfamiliar with any discharges and are more likely to be adversely affected (which can cause embarrassment to residents and raise awareness of the problem).	High
Open space recreational	These areas are used for outdoor activities and exercise, in circumstances where people tend to be more aware of the air quality. People of all ages, physical conditions and sensitivity can be present.	High
Tourist, cultural, conservation	These areas can have high environmental values, so adverse effects are unlikely to be tolerated.	High
Commercial, retail, business	These areas have a similar population density to residential areas as people of all ages and sensitivity can use them. Commercial activities can also be sensitive to other uses (eg, food preparation affected by volatile organic compounds emissions from paint manufacture). There can be embarrassment factors for businesses with clients on their premises.	Medium to high
Rural residential / countryside living	Population density is lower than in residential areas, so the opportunity to be adversely affected is lower. However, people of high sensitivity can still be exposed at all times of the day and night. Often people move into these areas for a healthier lifestyle and can be particularly sensitive to perceived health risks.	Medium to high
Rural	A low population density means there is a decreased risk of people being adversely affected. People living in and visiting rural areas generally have a high tolerance for rural activities and their associated effects. Although these people can be desensitised to rural activities, they are still sensitive to other types of activities (eg, industrial activities).	Low
Heavy industrial	Adverse amenity effects tend to be tolerated as long as the effects are not severe. Many sources discharge into air, so there is often a mix of effects. People who occupy these areas tend to be adult and in good physical condition, so are more likely to tolerate adverse effects, particularly if the source is associated with their employment.	Low
Light industrial	These areas tend to be a mix of small industrial premises and commercial/retail/ food activities. Some activities are incompatible with air quality impacts (such as paint sprayers requiring a dust-free environment), while others will discharge to air.	Low

Tier 1 preliminary assessment − recommendations

An air quality assessment is not necessary for any project that will not result in a significant increase in emissions at any location.

A Tier 1 preliminary assessment should be undertaken at the beginning of a project.

A Tier 1 assessment will be all that is required for any project that does not result in significantly increased emissions at any location. Table 6.1 provides suggested thresholds to identify these projects. Note, however, that these may be superseded as more information becomes available.

If there is any doubt, the assessment should proceed to Tier 2, or be discussed with the regional council.

7 Tier 2 Screening Assessment

The Tier 2 assessment is a relatively simple screening exercise to determine whether a proposal is likely to result in exceedances of ambient air quality criteria, in particular the national ambient air quality standards.

The aim of a screening assessment is to provide conservative estimates of air quality effects. These may not be completely accurate, but they can provide confidence that a project will not result in significant air quality effects. The recommended screening assessment process is based on the methods most commonly used in New Zealand.

The Tier 2 and Tier 3 assessments use essentially the same tools and techniques. However, this section suggests conservative default values for traffic data, emission factors and dispersion modelling, so that a Tier 2 assessment can be undertaken relatively quickly and easily. Users who are not familiar with the assessment process should read this section in conjunction with section 8 (Tier 3 assessments).

In general, the Tier 2 assessment should be undertaken for any transport links and intersections identified in the Tier 1 assessment. For projects that affect multiple links or intersections, the worst cases can be assessed to determine whether problems are likely at other locations. The worst case will be the location with the closest receptors and highest emissions.

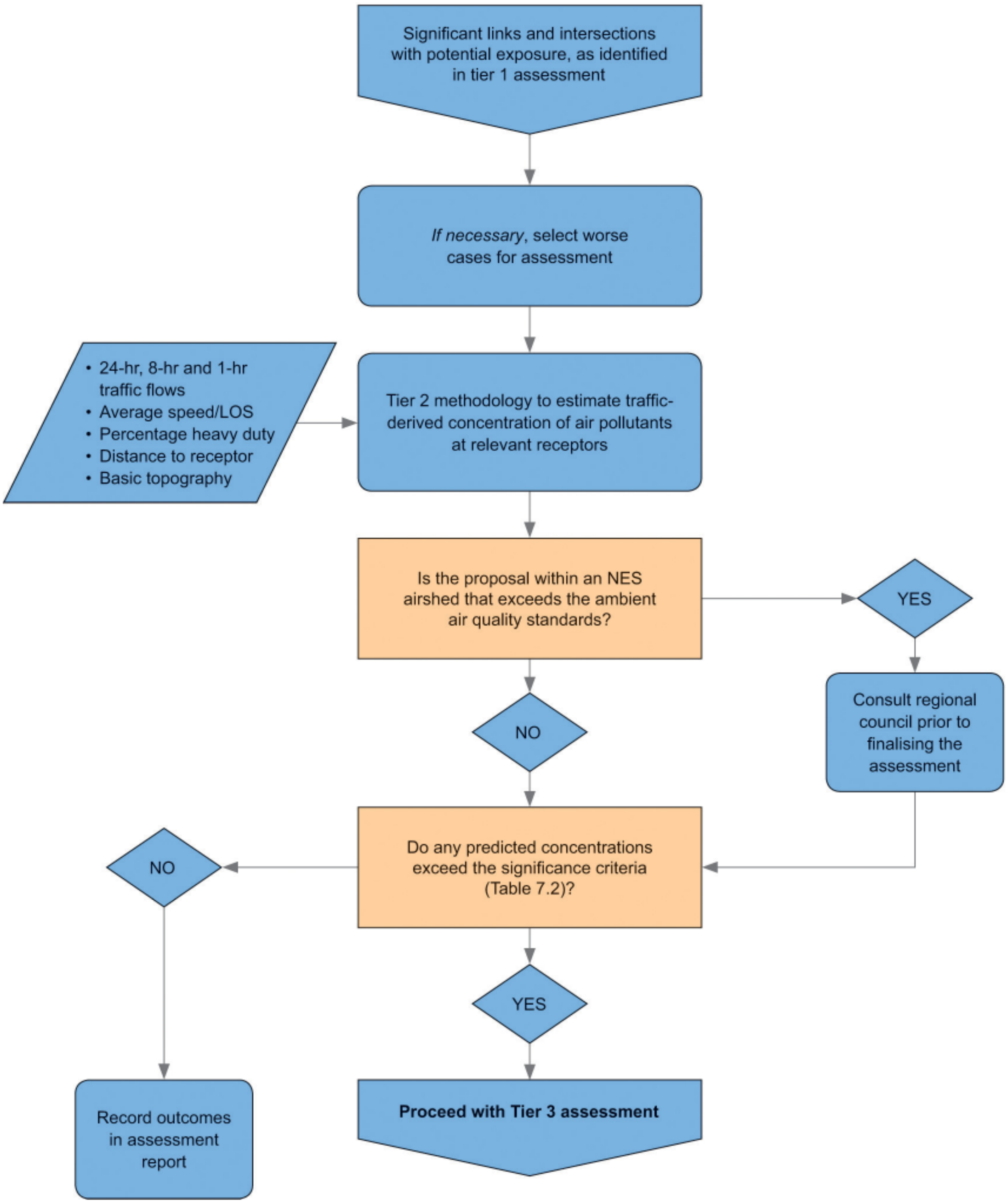
For changes to existing roads or networks, the assessment must be undertaken both with and without the proposal so that the impacts of the proposal can be clearly established.

7.1 National environmental standards for air quality

Special care may be needed for any assessment in an airshed that exceeds the national ambient air quality standards. Consultation with the regional council is recommended before finalising any detailed Tier 2 assessment within an airshed that already exceeds the national ambient air quality standards.[4]

[4] Exceedances of the standard are required to be published by the council in local newspapers.

Figure 7.1: Tier 2 assessment of local impacts



7.2 Characterising the discharges to air

Characterising the discharges to air for a Tier 2 assessment includes:

- estimating the effect of the proposal on traffic
- using emission factors to estimate the change in emissions as a result of the proposal.

The following sections provide guidance on estimating traffic effects and emissions for a Tier 2 air quality assessment.

7.2.1 Traffic data requirements

Traffic flow

The assessment ideally requires an estimate of 24-hour, eight-hour and one-hour traffic flows for a high-traffic day. Currently, annual average daily traffic (AADT) counts are often the only available traffic data. AADT is an estimate of the average traffic count over a year, and on any given day traffic may be considerably higher or lower than the AADT. Newer traffic models being employed are capable of giving more detailed and accurate information, down to an hourly or finer resolution, for each link at various times of the day, week or year. Whenever possible, the best data should be used, preferably at least at hourly resolution.

In some cases, peak and inter-peak hourly data are available, but these are generally the peak and inter-peak hourly traffic for the *annual average* day. The aim of a screening assessment is to predict worst-case air quality. Therefore, the traffic analyst should provide an estimate of daily one-hour and hour-hour traffic flows on a high-traffic day based on local traffic count information, or on traffic count information from a similar location. Traffic count data are generally available from territorial local authorities (or Transit for state highways).

It is essential that the air quality assessor understands the basis, meaning and limitations of any traffic data.

Example

For an assessment where only daily traffic flow data are available, the one-hour peak and worst eight hours should be estimated from traffic count data.

Auckland traffic count data, which were compiled for the Auckland Regional Council emissions inventory, showed that the highest proportion of vehicle kilometres travelled (VKT) over one hour was approximately 7–8% of the 24-hour traffic count, occurring from 5 pm to 6 pm. The highest proportion of VKT in eight hours was approximately 54% of the 24-hour traffic count, occurring between 11 am and 7 pm. Therefore, for the purposes of assessment, one-hour and eight-hour traffic could be estimated as 10% and 60% of the 24-hour traffic flow, respectively.

Average speed

Vehicle emission factors are sensitive to speed and level of service (congestion level). In most cases, a Tier 2 screening assessment can be based on worst-case emission factors, so speed data are not required. Where speed data are readily available (eg, the local council may have SCATs data at intersections), they can be used to help select the most appropriate emission factors. However, the assessor should justify that the emission factors are conservative. Selection of emission factors is discussed in section 7.2.2 below.

Vehicle fleet composition

Vehicle fleet composition is an important parameter in air quality assessments because of the relative health importance of different pollutants. The health effects of air pollution are dominated by particulates, and emissions of particulates from transport are dominated by heavy commercial vehicles (HCVs).

For a Tier 2 screening assessment, vehicle fleet composition data are typically not required unless a high proportion of HCVs is expected compared to the default of 7.6% HCVs over 3.5 tonnes (Auckland Regional Council, 2005a). This might occur, for example, on busways, port access roads and quarry access roads. Default emission factors are provided in Table 7.1 for the national average fleet composition (as provided in Table 8.1). For assessments where there is a higher proportion of HCVs (compared to the default), emission factors will need to be derived from the New Zealand Traffic Emissions Rate database (NZTER), as described in section 8.1.3.

Table 7.1 Fleet-weighted exhaust emissions factors for 2004 (NZTER)

Road type	Congestion level	Fleet-weighted exhaust emission factors (g/km)					
		CO	CO_2	NOx	SO_2	Particulate*	VOC
Central urban	Free	7.15	329	2.07	0.11	0.17	1.10
	Interrupted	11.77	499	2.69	0.15	0.24	1.52
	Congested	22.34	695	3.25	0.20	0.36	3.79
	Cold start	40.00	698	2.81	0.19	0.37	4.65
Motorway	Free	3.52	262	2.47	0.09	0.20	0.50
	Interrupted	4.67	239	1.72	0.08	0.13	0.54
	Congested	7.21	288	1.77	0.09	0.17	0.93
	Cold start	20.82	331	1.80	0.10	0.19	3.65
Suburban	Free	6.13	312	2.00	0.10	0.15	1.00
	Interrupted	9.38	357	2.15	0.11	0.18	1.17
	Congested	13.62	433	2.28	0.13	0.26	1.85
	Cold start	30.48	499	2.43	0.14	0.29	5.06
Fleet-weighted average		10.8	346	2.12	0.11	0.19	1.55

* NZTER provides total suspended particulate (TSP) exhaust emission factors. It can be assumed that 100% of exhaust TSP is less than $PM_{2.5}$.

7.2.2 Emission factors

The Ministry of Transport's Vehicle Fleet Emissions Model and associated NZTER are currently the preferred sources of emissions information for the New Zealand fleet. The limitations and applicability of NZTER are discussed in section 8.1.3. Updated emission factors are being developed, but until these become available NZTER is considered appropriate for Tier 2 screening assessments.

For a Tier 2 screening assessment, the most conservative approach for calculating one-hour emissions from a transport corridor would be to assume the worst-case level of service (LOS) for the type of road being assessed. LOS is a representation of the level of congestion on a road. The appropriate (highest) emission factors are for congested conditions, except for NO_x and PM_{10} emission factors for motorways. Higher speed limits on motorways mean that NO_x and PM_{10} emissions are higher under free-flow conditions.

A conservative prediction of eight-hour and 24-hour emissions in an urban area therefore assumes congested emission factors for peak hours (eg, four hours of the eight-hour and 24-hour averaging periods) and interrupted emission factors for the remainder of the eight-hour or 24-hour period. Ultimately, the assessor will need to use his or her judgement, and justify that the emission factors selected are appropriately conservative for a screening assessment, recognising that the assessment should consider worst-case locations. So, for example, if the air quality near an intersection is being assessed, the emission factor should be selected for the expected LOS in that location, as opposed to the average speed or LOS for the link. In all cases, the assumptions used and their justification should be clearly reported.

Cold-start emission factors represent emissions from vehicles that have not warmed up. This effect is most significant in catalyst-equipped petrol vehicles. The emission factors are high because emissions control equipment does not function well until the vehicle is warm, and until then the combustion process is not as efficient as it can be. Cold-start emission factors should generally apply for the first three minutes of vehicle travel (or at least 2.5 km). For the purposes of a screening assessment it should be assumed that 20% of all vehicles are operating under cold start conditions in urban areas (Auckland Regional Council, 2005a). In practice, cold-start rates may be lower depending on the route and the feeder roads; for instance, the Auckland-wide average rate, from the regional traffic model, is 17%. In a study comparing modelled emission rates with those measured using an on-road remote sensing device, better agreement was obtained when assuming cold-start rates of 10% or greater (Bluett and Fisher, 2005). In the absence of specific data on this factor from a reliable traffic model, the 20% figure is an appropriately conservative choice.

Use of speed-dependent emission factors

It is likely that NZTER emission factors will be updated or replaced with speed-dependent emission factors for the New Zealand fleet in the near future. For a screening assessment using speed-dependent emission factors, it will be necessary to select an appropriate speed. As we have seen, vehicles generally emit lower amounts of pollutants when they are travelling at their optimal speed (30 to 70 km/hour for most vehicles). Emission rates tend to increase at higher and lower speeds.

Speed data may be available from the results of traffic modelling or monitoring. However, the assessor needs to demonstrate that the average speed selected is conservative for the location and averaging period being considered. Where speed data are not available, a worst-case assumption can be made based on the typical speed ranges given in Table 7.2. When there is doubt about the likely speed, the lowest speed within the range should be used.

Table 7.2: Typical speed ranges for use with speed-dependent emission factors

Traffic condition/location	Speed
Around intersections	10 km/hr
Urban or suburban areas that experience congested conditions during rush hour	10–25 km/hr for a 1-hour average
Urban or suburban roads with interrupted flow (some traffic lights, etc)	25–45 km/hr
Free-flowing urban or suburban roads	45 km/hr
Free-flowing motorway	80 km/hr

7.2.3 Traffic data and emission factors for additional future years

Predicting the likely future impacts of transport projects is difficult. Any prediction requires an estimate of likely future traffic, as well as the fleet composition and emission factors. It is expected that fleet-weighted emission factors will reduce over time as more modern, lower-emission vehicles enter the fleet and older vehicles retire. NZTER includes emissions factors for future years, based on predicted changes in the fleet and emissions technology. However, there is a great deal of uncertainty about these predicted emissions.

In general, it is typically assumed that the rate of reduction in fleet-weighted emission factors will be higher than the overall rate of growth in traffic (except for CO_2). A Tier 2 assessment for additional future years should only be necessary if it is expected that the rate of traffic growth (after the assessment year) on the road or link under consideration will be significantly greater than expected overall traffic growth rates (say 2–3% per annum), or if it is expected that the LOS will significantly decrease, or if the proportion of heavy-duty vehicles will significantly increase for some reason.

For future years, a Tier 2 assessment using the latest 2004 emission factors will provide a conservative assessment of likely impacts. If this assessment indicates that significant impacts are likely, then emission factors from NZTER for the year being assessed could be adopted. However, this should be done with caution.

The analyst should document predicted traffic for future years (with and without the project, where appropriate) and justify whether to assess likely future impacts. The future assessment years may depend on the availability of traffic demand models, but should include a long-term forecast (at least 10 to 20 years).

Where future emission factors are adopted, the limitations of these need to be recognised and discussed. This also applies to any projects currently being considered which will not be constructed immediately.

7.3 Exposure estimates

Appendix 1 shows a screening method for estimating the traffic-derived, ground-level concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2) and fine particulate (PM_{10}). This method uses simple techniques and relatively crude assumptions, with the aim of ensuring conservative estimates. Alternatively, a near-road dispersion model, such as CALINE4, may be used with worst-case meteorology to estimate the traffic-derived, ground-level concentrations of air pollutants. The use of CALINE4, as well as other corridor dispersion models, is discussed in the *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004).

7.4 Assessing the effects

7.4.1 Tier 2 assessment of effects

To assess whether significant air quality impacts are likely, the maximum ground-level concentration predicted by the screening methodology should be compared to the significance criteria in Table 7.3. This comparison should be made for locations where people may be exposed for the relevant averaging period. A Tier 3 assessment should be undertaken if the predicted concentration of PM_{10}, NO_2 or CO due to the proposal exceeds any of the assessment criteria. A Tier 3 assessment should also be undertaken if the Tier 2 assessment is inconclusive for any reason.

The Tier 2 assessment is intended to provide a conservative estimate of the likely air quality impacts of a project. If these criteria are exceeded, this does not necessarily mean the air quality impacts will be significant; it simply means a more accurate assessment should be undertaken. Mitigation options, or alternative options that do not exceed the criteria, could be considered at this stage, but it should be noted that further assessment may show these are not required.

Table 7.3: Significance criteria for incremental analysis only

Pollutant	Standard/guideline	Significance criterion	Time average
PM_{10}	50 µg/m³	2.5 µg/m³	24 hours
$PM_{2.5}$	25 µg/m³	1.3 µg/m³	24 hours
Nitrogen dioxide (NO_2)	200 µg/m³ 100 µg/m³	20 µg/m³ 5 µg/m³	1 hour 24 hours
Carbon monoxide (CO)	10 mg/m³	1 mg/m³	8 hours

In general, the Tier 2 assessment should be undertaken for all links and intersections identified in the Tier 1 assessment. For projects that affect multiple traffic links or intersections, the worst cases can be assessed to determine whether problems are likely at other locations. The worst case will be the location with the closest receptors and highest emissions.

Other pollutants do not need to be assessed for a Tier 2 screening assessment. CO, NO_2 and PM_{10} provide a good indicator of transport effects and are the pollutants of most concern. If the assessment shows that levels of these contaminants are within acceptable criteria, then the analyst can be reasonably confident that levels of other traffic-related pollutants will be acceptable.

The primary reference criteria are the national ambient air quality standards provided by the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004. However, for Tier 2 assessments, compliance with the Standards is not explicitly required. This is because of the difficulty of assessing the existing (or background) concentrations. These are either (a) usually not known at the location of interest, (b) highly variable and may not have peaks at the same time as traffic-related peaks, or (c) may already include contributions from the transport project being assessed, resulting in double counting. A full assessment of air quality effects against the Standards, or other criteria, is left to Tier 3 assessments.

7.4.2 Derivation of significance criteria

The recommended approach for Tier 2 is to determine whether the quantitatively derived adverse effects are likely to be 'significant'. This is an absolute criterion that is not related to the existing air quality.

The concept of significance allows for a level of increase in the air pollution due to a transport emission source, as long as the maximum increase is below some specified significance criterion for each pollutant being assessed. (See also the discussion on 'reasonableness' in section 4.6.) Table 7.3 recommends criteria for determining whether effects are likely to be significant based on such an incremental analysis. These criteria are suggested as a guide only. The criteria are necessarily stringent because they are intended to be applied in any location, regardless of existing air quality.

The selection of appropriate criteria for significance is based to some extent on the relative effects of the increase, and to some extent on the inherent variability in the measurements due to space and time variability in the concentration of the pollutant. These assessment criteria are somewhat subjective, but are based on practical considerations. The recommended criteria are tighter for longer time averages because of the serious health effects associated with long-term exposures to PM_{10} and NO_2.

NO_2 one-hour: This is set at 20 µg/m^3, or 10% of the national ambient air quality standard. This is around the same order as the background value found in many houses (those with electric heating – it can be over 100 µg/m^3 for those with gas, wood or coal heating) and is lower than that found inside most vehicles. The health effects of short-term increases of this order will be very small.

CO eight-hour: This is set at 1 mg/m^3, or 10% of the national ambient air quality standard. Short-term exposures to CO tend to be reversible. Exposure to elevated values over periods longer than eight hours may have some long-term effects, as may exposure to very high levels (greater than 10 mg/m^3). The general background through any large city tends be around 1−2 mg/m^3.

PM_{10} and $PM_{2.5}$ 24-hour and NO_2 24-hour: The thresholds are set at 5% of the national ambient air quality standard and/or guidelines (where standards do not apply). Longer-term exposure to these pollutants has a more serious health effect, and is consequently set at a relatively low percentage.

These thresholds are not intended to define an acceptable or insignificant increase in actual ambient air quality. Instead, they are intended to provide an indication of the likely significance of *predicted* ground-level concentrations. These thresholds are suggested in the context of a Tier 2 assessment, which is conservative and based on worst-case scenarios.

7.5 Reporting a Tier 2 assessment

The results of a Tier 2 assessment should be documented for inclusion in any assessment of environmental effects, and to provide the basis for a Tier 3 assessment, where necessary. The report should summarise the findings of the Tier 2 assessment, including the basis of the traffic information, air quality information, any assumptions and their justification. Recommended reporting requirements are given in section 4.5.

Tier 2 screening assessment − recommendations

A Tier 2 assessment is a relatively quick and easy screening exercise. Any users who are not familiar with the assessment process should read this section in conjunction with section 8.

A Tier 2 assessment should be undertaken for all locations identified in the Tier 1 assessment, or for the worst-case locations. The assessment should be undertaken both with and without the proposal. The air quality assessor must understand the basis, meaning and limitations of any traffic data.

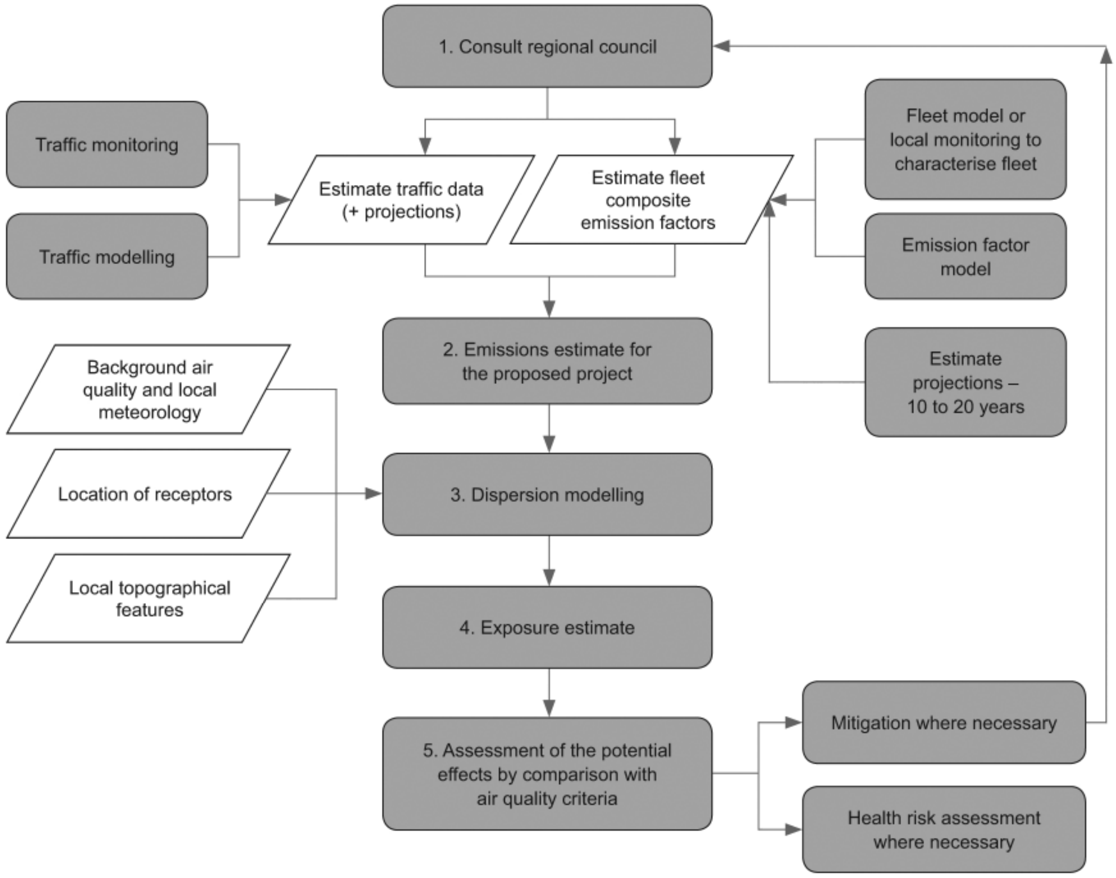
Consultation with the regional council is recommended before finalising any detailed Tier 2 assessment within an airshed that already exceeds the national ambient air quality standards.

8 Tier 3 Full Assessment

This section of the guide provides an outline of the issues to be considered, and recommends good practice protocols for undertaking a Tier 3 assessment. An overview of the Tier 3 assessment process is provided in Figure 8.1.

The aim of a Tier 3 assessment is to provide reasonably accurate estimates and a detailed assessment of the likely air quality impacts associated with a project. This is usually done through the use of detailed traffic information, emission factors, ambient air quality data and dispersion modelling. For any aspect of the assessment where detailed information is not available, or is not necessary, it is appropriate to adopt the conservative assumptions discussed for Tier 2 assessments.

Figure 8.1: Tier 3 assessment process



A Tier 3 assessment should be carried out by experienced practitioners. This may necessitate input from a multidisciplinary team, including experts in traffic, vehicle emissions and air quality. A Tier 3 assessment should be undertaken for the current year and for future years, both with and without the proposal so that the effect of the proposal can be assessed. The future assessment years may depend on the availability of traffic demand models but should include a long-term forecast (at least 10 to 20 years).

8.1 Characterising the discharges to air

Characterising the discharges to air from a transport project typically includes:

- a detailed description of the proposal
- estimating the effect of the proposal on traffic
- estimating fleet composition.

The following sections provide guidance on estimating and reporting traffic effects and emission factors for the purposes of an air quality assessment.

8.1.1 Description of the proposal

The description should be sufficient to enable a full understanding of the proposal from an air discharge viewpoint, and should also provide sufficient information to ascertain whether any consents are required. The depth of information required will vary depending on the type of activity, but the following should generally be provided:

- a detailed site plan, including maps with all relevant features and the location of sensitive receptors
- a written summary of the project proposal focusing on aspects that give rise to emissions to air
- details of the alternatives considered and the reasons for their rejection
- details of any relevant historical information, including past changes to the activity
- details of any proposed changes to an existing activity
- any relevant timeframes or constraints for undertaking the activity
- any mitigation and/or preventive measures undertaken to manage discharges to air
- details of traffic data and emission factors, as discussed in the following sections.

8.1.2 Traffic data requirements

A key component of transport project assessment is the calculation of changes to traffic as a result of the project. Traffic and transport models provide traffic flows and speeds, which are used to estimate shifts and changes in pollutant loadings. Traffic and transport models are described in Appendix 2.

Traffic measurements or models used to determine traffic volumes and composition for air quality impact assessments should generally comply with the requirements of the *Transfund Project Evaluation Manual* (Transfund, 2004, available at www.ltsa.govt.nz/funding/manuals.html).

Traffic modelling results should be reported concisely in an air quality assessment report. The results need to be communicated in a way that can be understood by people who may not be experienced in interpreting traffic modelling, and the results need to be relevant to the air quality impacts being assessed.

Documentation for the air quality assessment should include:

- a summary of the basis of the model, including its validation, performance and forecasting
- a summary of how the area of influence was determined, to demonstrate that all roads affected by the proposal are being assessed
- sensitivity analysis for traffic speeds and traffic volumes, particularly model results, growth rates, and the assessment of diverted and induced traffic.

Traffic analysts need to be particularly aware of the need for conservatism in air quality assessments. In particular, traffic projections developed in accordance with the *Project Evaluation Manual* generally assume that projects do not induce new trips − which may not always be the case. This is a common criticism of traffic projections produced for environmental assessments, and should be addressed in a Tier 3 assessment. If appropriate, an allowance for induced traffic should be included in projections.

The assessment should be undertaken for the opening year and for future years, both with and without the proposal. The future assessment years may depend on the availability of traffic demand models but should include a long-term forecast (for at least 10 to 20 years). Assumptions made in deriving projections should be clearly stated, including the basis for the assumed traffic growth rate and any induced traffic.

The error associated with current and predicted traffic volume and composition estimates should also be estimated and stated in the report.

The traffic data requirements will depend on the type of emission factor model being used. (The types of emission factor models are discussed further below.) However, most assessments will be based on NZTER. The following traffic information is generally required for a Tier 3 assessment using NZTER:

- one-hour, eight-hour and 24-hour traffic flows on the links being evaluated (including confidence limits, where possible)
- LOS / average speed on each link
- vehicle class composition (if it is likely to be different to the default).

If detailed traffic data are not readily available, a Tier 3 screening assessment could be based on adjusted annual average daily traffic (AADT) and worst-case congestion levels, as discussed for the Tier 2 assessment.

It is critical that the assessor be absolutely clear about the basis and meaning of any traffic data within the confines of the assessment. Many traffic studies provide estimates of daily and peak-hour traffic for an average day, whereas air quality studies must estimate worst-case air quality. The main aim of an air quality assessment is to determine the effects of a roading proposal on air quality. The national ambient air quality standards only allow between one and 24 hours of exceedance per year, depending on the pollutant. To assess whether these criteria are likely to be exceeded, traffic data for a 'high traffic emissions day' are needed. High traffic emissions will occur on days with high traffic flow and associated low speed / LOS. Where there are adequate data, confidence limits associated with the traffic estimates should be reported.

Analysts must use their judgement to define a high traffic emissions day. For instance, in some cases the most appropriate 'day' will be an average one; in others it might be a particular weekday, and in yet others it may be the day of a special event (say peak traffic near a local stadium when a major event is occurring).

Average speed / level of service

Most emission factors (including NZTER) provide estimated average emissions in grams per kilometre (g/km) for a typical drive cycle. This means the emission factor represents average emissions from an average vehicle over a typical length of road. For example, at low speeds (or congested LOS), the drive cycle includes some allowance for stopping and starting, queuing at intersections, etc. Vehicle emissions are highly speed dependent, and most emission factor models require an estimate of average speed on each link.

NZTER emission factors are provided for three different LOS. LOS is a representation of traffic congestion, and includes:

- **free** – little or no vehicle impedance, with warm running (LOS A or B)
- **interrupted** – moderate vehicle interaction, with warm running (LOS C or D)
- **congested** – severe vehicle interactions such as traffic jams, with warm running (LOS E or F).

These LOS are described in terms of road type and average speed in section 8.1.3. NZTER emission factors provide estimated average emissions for a typical New Zealand drive cycle, including intersection delays. This means average speeds for each link should be determined from the total link travel time and intersection delay at the downstream end of the link. So if the traffic model explicitly represents intersection delay at the end of the link rather than as part of the link travel time, the downstream intersection delay needs to be added to the link travel time before calculating the level of service on the link.

For assessing air quality at a specific location (eg, a receptor close to an intersection), the emission factor should be selected based on the expected speed or LOS at that location, as opposed to the average for the link.

For some projects, much more detailed traffic information is available. Micro-simulation traffic models represent the travel behaviour of individual vehicles, and with an appropriate emissions model can provide much more accurate estimates of emissions from a transport corridor. This is discussed further in section 8.1.3 (micro-simulation of emissions).

Vehicle fleet composition

Vehicle fleet composition is an important parameter in air quality assessments because of the high degree of variation in emissions from different sizes and types of vehicles, especially for particulates. The health effects of air pollution are dominated by particulates, and particulate emissions from transport are dominated by heavy commercial vehicles (HCVs).

Traffic composition can be estimated from traffic surveys, traffic models, or from vehicle size classification information associated with automated traffic counts. Wherever possible, site-specific data, or information from nearby locations, should be used to estimate the proportion of HCVs. Vehicle size classification information may be available from territorial local authorities (for local roads), Transit NZ (for state highways), or the Ministry of Transport (for national/ regional estimates).

There are a number of vehicle classification systems in use in New Zealand, and unfortunately there is limited consistency across these. The vehicle classification systems commonly used in New Zealand are summarised in Appendix 2.

Site-specific data should be estimated for any projects where the proportion of HCVs is expected to be significantly higher than the default values provided in Table 8.1 (eg, in busways, port access roads and quarry access roads).

Table 8.1: Percentage of VKT, by vehicle class[5] (VFM) for New Zealand

	Cars		LCVs		HCVs				Buses	
					3.5−7.5 t	7.5−15 t	15−30 t	> 30 t	3.5−12 t	> 12 t
Fleet year	Petrol	Diesel	Petrol	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
2004	70.8%	7.9%	4.8%	8.9%	1.8%	1.2%	3.2%	0.9%	0.3%	0.3%
2011	70.0%	8.5%	3.3%	10.9%	1.6%	1.1%	2.9%	1.2%	0.2%	0.3%
2021	68.5%	9.1%	2.5%	12.0%	1.5%	1.1%	3.2%	1.5%	0.2%	0.3%

Notes: VKT = vehicle kilometres travelled; VFM = vehicle fleet model; LCV = light commercial vehicle; HCV = heavy commercial vehicle; t = tonnes (1,000 kg).

Where relevant size classification or other composition data are available, these should be used to adjust the national average default values provided in Table 8.1. The most conservative approach assumes the highest proportion of HCVs based on either local information or the default data. Where the estimated proportion of HCVs (or buses) is higher than the default, the most conservative way to adjust the data would be to simply reduce the proportion of light-duty vehicles by the corresponding amount.

For urban areas, the regional council will generally have information on the amount of bus travel associated with public transport. However, these figures generally will not include private coaches, so some care is needed in estimating the proportion of buses from these figures.

5 Percentages are based on vehicle kilometres travelled by vehicle class in the Ministry of Transport Vehicle Fleet Emissions Model (VFEM). Model outputs were provided by Stuart Badger in August 2007. VKT for all petrol HCVs and buses have been added to petrol LCVs (because these classes are not included in the NZTER).

The Ministry of Transport Vehicle Fleet Emissions Model (VFEM) is a computer model that estimates vehicle kilometres travelled, by vehicle class. Table 8.1 shows the estimated proportion of VKT by vehicle class from the VFEM for 2004, 2011 and 2021. Where site-specific or local data are not available, VFEM data should be used to provide default fleet composition data. The Transfund *Project Evaluation Manual* data may then be used to adjust the VFM data for different road types, and time periods, if appropriate. The *Project Evaluation Manual* provides traffic composition data for different road types but does not include projections and does not differentiate between petrol and diesel vehicles.

The Research Unit of Land Transport New Zealand (formerly Land Transport Safety Authority) plans to report national estimates of vehicle kilometres travelled by vehicle type on a regular basis. Any updated national estimates should be used to provide default data as they become available.

The Motor Vehicle Register is another source of data that can provide regional vehicle classification information. However, care must be taken when using vehicle classification data to ensure the proportions are adjusted to reflect utilisation. Commercial vehicles tend to travel greater distances than cars, so it is generally not valid to assume that the proportion of vehicle kilometres travelled by a vehicle class is the same as the proportion of vehicles in each class.

8.1.3 Emission factors

Emission factors provide an estimate of emissions from individual vehicles. When combined with traffic information, they are used to estimate discharges of contaminants from roads, as follows:

$$\text{Emission rate} = \Sigma_v \Sigma_r \Sigma_d \Sigma_p (VKT_{v,r,d,p} \times \text{emission factor}_{v,r,d,p})$$

where: v = vehicle type, including fuel type
r = road type
d = driving conditions
p = emission process (exhaust, evaporation or tyre wear).

Emission rates should be calculated using emission factors determined for the New Zealand fleet. The Vehicle Fleet Model and associated NZTER are currently the most readily available emissions information sources for the New Zealand fleet.

Using NZTER exhaust emission factors

The NZTER database includes emission factors dependent on road type, LOS and vehicle class. The emission factors provide average emissions in g/km for a typical drive cycle for the type of road and LOS selected. Descriptions of the road types are as follows.

- **Central urban:** routes with a combination of one-block links, essentially all with signalised intersections, an approximate minimum of six per kilometre; maximum speed limit 50 km/h.
- **Motorway:** a multi-lane divided freeway without intersections but with the frequency of on/off ramps reflecting routing through an urban zone; maximum speed limit 100 km/h.

- **Suburban:** a mixed route representing daily commuter / local trip traffic (outside of the CBD) with a high frequency of intersections, mainly uncontrolled and relying on queuing and gap acceptance to change or join traffic flows; maximum speed limit 50 km/h.
- **Rural highway:** routes in rural areas[6] with uncontrolled intersections, with overtaking dependent on oncoming traffic; maximum speed limit 100 km/h.

LOS are described as follows.

- **Free flow:** little or no vehicle impedance with warm running; LOS level A/B, defined as having speed ≥ 80 km/h on motorways and ≥ 45 km/h on central urban and suburban roads.
- **Interrupted:** moderate vehicle interaction with warm running; LOS level C/D, defined as 67 km/h ≤ speed < 80 km/h on motorways and 25 km/h ≤ speed < 45 km/h on central urban and suburban roads.
- **Congested:** severe vehicle interactions such as traffic jams, with warm running; LOS level E/F, defined as speed < 67 km/h on motorways and < 25 km/h on central urban and suburban roads.
- **Cold start:** this is not a congestion level. Cold start describes the emissions from vehicles that have not warmed up. This can be assumed to be the first three minutes of any trip. In urban areas it is conservative to assume that 20% of vehicles are operating under cold-start conditions on average. This proportion could be significantly higher or lower at any specific location; for example, on motorways there are very few vehicles operating under cold start.

Fleet-weighted NZTER emission factors for the default vehicle class composition defined above are provided for the Tier 2 assessment procedure. These emission factors are appropriate for a Tier 3 assessment unless better information is available, or the vehicle class composition is expected to be different to the default.

Issues relating to the use of NZTER in effects assessment

Users have raised a number of concerns regarding the use of NZTER for assessing air quality impacts. These are documented in section 3.2.1 of the *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004). Updated emission factors are being developed, but until these become available NZTER is the recommended tool. Alternative emission factors are discussed below.

Emissions calculated using NZTER have been compared to emissions calculated using Australian emission factors (Auckland Regional Council, 2005a). This analysis shows that Australian emission factors result in significantly lower emissions estimates, particularly for future years. However, this analysis does give some confidence that NZTER emission factors are conservative.

6 The distinction between urban and rural roads is that made in the annual Roading Statistics, published by Transit NZ, which distinguishes state highways from roads controlled by territorial local authorities.

Non-exhaust emission factors

The NZTER database does not include non-exhaust emission factors. However, tyre wear, brake wear and evaporative VOC emission factors have been developed for the Auckland Regional Council emissions inventory (Auckland Regional Council, 2005b). A summary of these emissions factors follows.

VOC evaporative emission factors

Volatile organic compound (VOC) emission factors may be required for assessments of airshed air quality impacts (see section 8.4.3), or for an assessment of local impacts that includes consideration of one or more VOCs (eg, benzene).

Evaporative emissions are highly variable. The emission factors provided take into account some of the main variables involved, and provide an indication of relative emissions from petrol vehicles. Diesel vehicles are often not considered because their evaporative emissions are small compared with petrol vehicles (in the order of 0.2 g/km). The emission factors are summarised in Table 8.2.

The evaporative VOC emission factors for petrol vehicles are expected to decrease over time due to reduced petrol vapour pressure and improved vehicle technology. Key assumptions are:

- the evaporative emissions from vehicles with no control technology are in the range of 3 to 6 g/km
- the evaporative emissions from vehicles with control technology are less than 0.08 g/km
- the maximum vapour pressure for summer grade petrol was 85 kPa, reducing to 65 kPa in 2006
- the proportion of vehicles in the fleet with evaporative emissions control is predicted to be:
  - none in 1993
  - 5% by 1998
  - 55% by 2011
  - 100% by 2021.

Table 8.2: Evaporative VOC emissions

Vehicle type	LOS / congestion level	Evaporative VOC (g/km)			
		1993	1998	2011	2021
Petrol car	Free	0.50	0.50	0.13	0.08
	Interrupted	2.80	2.60	0.30	0.10
	Congested	5.00	5.00	0.40	0.15
	Cold start	0.30	0.20	0.10	0.04
Petrol LCV*	Free	0.80	0.80	0.20	0.10
	Interrupted	4.00	4.00	0.40	0.12
	Congested	6.00	6.00	0.50	0.20
	Cold start	0.50	0.50	0.14	0.04

* HCVs and buses were assumed to have the same evaporative VOC emissions as LCVs. HCV = heavy commercial vehicle; LCV = light commercial vehicle.

Source: Auckland Regional Council, 2005a

Tyre-wear and brake-wear emission factors

Tyre-wear and brake-wear emission factors have been derived from Ministry of Transport studies on potential water contamination from road transport. These emission factors for PM_{10} assume that 15% of tyre-wear particulate emissions are PM_{10} and 40% of brake-wear particulate emissions are PM_{10}. It can be assumed that 80% of brake and tyre wear PM_{10} is $PM_{2.5}$. These emission factors are similar to those used internationally. However, there is a great deal of uncertainty about tyre and brake wear emissions, and the factors are based on very few measurements. Tables 8.3 and 8.4 show the emission factors.

Table 8.3: Tyre wear PM_{10} emission factors

Vehicle type	Tyre wear PM_{10} (g/km)		
	Free	Interrupted	Congested
Car	0.009	0.018	0.036
LCV	0.0113	0.0225	0.045
HCV (small)	0.0188	0.0375	0.075
HCV (medium)	0.0282	0.0563	0.113
HCV (large)	0.126	0.252	0.504
Bus (medium)	0.027	0.054	0.108
Bus (large)	0.105	0.210	0.420
Motorcycle	0.0045	0.009	0.018

Notes (Tables 8.3 and 8.4): LCV = light commercial vehicle; HCV = heavy commercial vehicle.

Source: Auckland Regional Council, 2005a

Table 8.4: Brake wear PM_{10} emission factors

Vehicle type	Brake wear PM_{10} (g/km)		
	Free	Interrupted	Congested
Car	0.004	0.0128	0.0168
LCV	0.006	0.018	0.024
HCV (small)	0.0084	0.0256	0.034
HCV (medium)	0.010	0.030	0.040
HCV (large)	0.016	0.048	0.064
Bus (medium)	0.0096	0.0284	0.038
Bus (large)	0.0136	0.04	0.054
Motorcycle	0.002	0.004	0.008

Source: Auckland Regional Council, 2005a

Previously, brake- and tyre-wear emissions have not generally been included in assessing transport effects, mainly due to the lack of data on these factors. For future Tier 3 assessments it is recommended they be considered, because for busy roads these can be a significant source of PM_{10}. However, due to the high level of uncertainty associated with these emission factors it is recommended that sensitivity analysis be undertaken.

A recent review by the UK Department for Environment, Food and Rural Affairs (Air Quality Expert Group, 2004) suggested that actual tyre-wear emission factors could be anywhere between 10% and 1,000% of published results. In New Zealand, analysis has been undertaken to attempt to quantify non-tailpipe PM_{10} (Kuschel and Bluett, 2002). This analysis found that dispersion modelling results, based on NZTER exhaust PM_{10} emission factors, correlated reasonably well with measured PM_{10}. Although further work is required, this analysis suggests that non-exhaust PM_{10} emission factors are not significant compared to exhaust emissions. For the purposes of sensitivity analysis it should be assumed that non-tailpipe emission factors are between 10% and 200% of the values quoted above.

Benzene and 1,3-butadiene emission factors

Benzene emission factors for petrol and diesel vehicles have been estimated based on fuel properties (see Appendix 1). It is assumed evaporative emissions from diesel vehicles are negligible. Recommended benzene emission factors are provided in Table 8.5. 1,3-butadiene emission factors recommended by the Australian National Pollutant Inventory (Environment Australia, 2000a) are also provided in Table 8.5.

Table 8.5: Benzene and 1,3-butadiene emission factors

	Petrol vehicles		Diesel vehicles
	% of exhaust VOC	% of evaporative VOC	% of exhaust VOC
1,3-butadiene	0.649	0.18	0.115
Benzene:			1.01
1998–2001	8.71	1.488	
2002/03	8.51	1.385	
2004/05	7.84	1.038	
2006–	5.90	0.346	

Rail emission factors

The Ministry of Transport has developed a spreadsheet for calculating emission rates from the New Zealand rail fleet based on the locomotives used and the tracks that travel throughout the country. The publication, *Impacts of Rail Transport on Local Air Quality* (Ministry of Transport, 1999) and accompanying database provide data and information on the calculations and emission factors.

The emission factors are based on US Environmental Protection Agency (US EPA) data for rail-sector emissions inventories. The Ministry of Transport spreadsheet should be used for determining emissions from rail, but the user needs to be aware that any new or upgraded fleet may differ from that defined in the spreadsheet.

Bus emission factors

The Auckland Regional Council has developed a Bus Emissions Prediction Model (BEPM) (Auckland Regional Council, 2005b). This model is based on overseas emissions databases, and allows the user to define:

- average speed
- fleet profile (percentage of each vehicle type by country of origin, technology and year of manufacture)
- fuel (sulphur content, biodiesel, water-blend fuel)
- percentage retrofit of diesel-oxidising catalysts or particle traps.

The BEPM provides fleet average-emission factors for the defined fleet and average speed, and allows the user to compare scenarios.

Alternatives to NZTER emission factors

Auckland Regional Council is developing a Vehicle Emissions Prediction Model (VEPM), which is similar to the BEPM but will be applied to other vehicle classes. This will enable updated emission factors to be developed for the New Zealand fleet. In the meantime it is possible to estimate emission factors based on reported overseas databases and New Zealand fleet information. This will mean the assumptions and errors associated with the emission factors are well understood.

However, it is important that *fleet composite* emission factors from overseas are not used. The New Zealand fleet has much higher fleet average emissions than most comparable countries (like Australia) because of the delayed introduction of vehicle emissions standards in New Zealand. This means any emission factors must be based on detailed New Zealand (or local) fleet information, including the proportion of vehicles by class, and emissions build standard (or year of manufacture and country of origin). This information is available from the Ministry of Transport Vehicle Fleet Emissions Model.

Estimation of emission factors should be undertaken by professionals with specific vehicle emissions expertise. The BEPM is an example of how overseas emissions databases can be used to predict emissions from the New Zealand (in this case, bus) fleet.

Intersections and idle emissions

As discussed above, most emission factors (including NZTER) provide an estimate of emissions for a typical drive cycle. For example, for the congested level of service, the drive cycle includes some allowance for stopping and starting, idling at intersections, etc. This effect is also implicitly considered in most speed-related emission factors (like BEPM), since the variability of speed during a trip is closely related to the average speed. Slow-speed journeys in towns involve frequent speed changes in response to the traffic conditions, while higher-speed trips are normally driven more smoothly (National Roads Authority and DEFRA, 1992/2003). Nevertheless, for two trips at the same average speed (or for the same LOS/road combination in NZTER), emissions can vary substantially depending on speed variability.

This effect is not usually significant over the averaging times being considered. For an air quality assessment, average emissions over an hour or longer are needed, so an emission factor for an average drive cycle is generally appropriate.

However, emissions at locations such as intersections may give cause for concern because of the high proportion of vehicles idling and accelerating. To address this, the congested/central urban emission factors from NZTER should be used. This will provide a reasonably good representation of emissions around intersections, because it includes a high proportion of idling and acceleration/deceleration. Similarly, a speed-dependent emission factor for low average speed (say 10 km/h) should be reasonably representative of average emissions around intersections.

Micro-simulation of emissions

In circumstances where more detail about the variability of emission factors is required, micro-simulation of emissions can be undertaken. The use of micro-simulation traffic models, which represent the travel behaviour of individual vehicles, is becoming more common in New Zealand. Many of these models provide for the micro-simulation of emissions, but at the time of writing these have not been calibrated for the New Zealand fleet.

The accuracy of any assessment based on micro-simulation of emissions is likely to be limited by the availability and accuracy of local fleet information, and background air quality and meteorological data. Micro-simulation of emissions should therefore only be used in special circumstances, and then only with detailed justification. For an air quality assessment, average emissions over an hour or longer are needed, so an emission factor for an average drive cycle is generally appropriate.

As for any development of emission factors, this should only be undertaken by professionals with specific vehicle emissions expertise.

8.2 Characterising the receiving environment

8.2.1 Existing air quality

To assess the cumulative effect of any proposal on air quality, the predicted traffic-derived concentration of air pollutants must be added to existing air quality, including the concentrations discharged by other sources.

Existing air quality data are of critical importance in any assessment. Ambient air quality monitoring to establish existing air quality is strongly advised for any major projects where there is no nearby or relevant monitoring data. This should be considered at the planning stages of any major project because of the time involved in obtaining data (a full year of data is recommended).

When existing air quality data are required

Existing air quality should be considered in all assessments of discharges to air. The level of detail and accuracy required are influenced by the:

- **anticipated air quality** – areas that are anticipated to have poor air quality due to a combination of existing emission sources and/or adverse terrain or meteorology would be expected to require a more robust definition of the existing air quality
- **sensitivity of the receiving environment –** where discharges have the potential to affect highly sensitive receiving environments (see Table 6.2), existing air quality would be expected to be well defined.

It is the combination of these considerations that determines the extent to which existing air quality should be addressed. A small increase in emissions within a commercial/light industrial area, for example, might only require a qualitative statement on existing air quality, which identifies the reasons existing air quality is anticipated to be good. Conversely, a large-scale transport development with the potential to affect residential suburbs might be expected to provide good-quality, representative and quantitative air quality data.

Identifying existing data

Pre-existing air quality data can be obtained from a range of sources. Usually the regional council will have the best knowledge of the full range of data available within its region. The council will also be able to provide an opinion on whether the pre-existing data are sufficient for the assessment proposed.

The range of air quality data sources is identified in section 6.4.1 of the Ministry for the Environment's *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004).

Reviewing existing data

Guidance on assessing the quality of currently available ambient air quality data as well as quality assurance and control procedures for the collection of new air quality data is provided in the Ministry for the Environment's (2000) *Guide to Air Quality Monitoring and Data Management*. The assessment criteria often include requirements for the air quality monitoring technique to be used. For example, the Standards contain specific requirements for the monitoring of pollutants within gazetted airsheds. The Ministry for the Environment's *Ambient Air Quality Guidelines* also contain recommended monitoring methods.

The use of such methods reduces uncertainty and minimises inaccuracy. Before using existing air quality data in an assessment, it is important that the monitoring technique and protocols be audited against the requirements of the Standards and the *Guide to Air Quality Monitoring and Data Management* to demonstrate that the existing air quality data are of appropriate quality.

The location of a monitoring site and the time of monitoring also affect how representative existing air quality data might be. The site should be representative in terms of location (ideally, within the affected airshed), but also representative in terms of land use and physical setting. The specific location of the monitoring site (eg, its proximity to major sources such as roads) will also be important.

The time of the monitoring is also relevant, in that data collected at the site in previous years may not be representative if the character of the area has changed markedly since monitoring was last undertaken. For example, historical data from a roadside monitoring site in an area that has experienced significant traffic growth would no longer be representative of current levels.

Trends in air quality should be considered, and it is preferable for several years of data to be analysed so that any improvement or deterioration of the air quality of an area can be ascertained. As a minimum, one year of data could be used if there are other longer-term monitoring sites in similar locations which can be used to provide an indication of long-term trends. Ideally, 10 years of data should be used to determine trends.

As noted above, monitoring data should be reviewed with reference to the monitoring method identified in Schedule 2 of the Standards and other Ministry for the Environment guidance (Ministry for the Environment, 2000a, 2002 and 2004).

When local existing air quality data are not available

Section 6.4 of the *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004) includes options for estimating existing air quality (without the project) when local data are not available. These options include:

- comparing the location with somewhere similar
- making a worst-case assumption
- modelling other sources in the area
- starting a new monitoring programme.

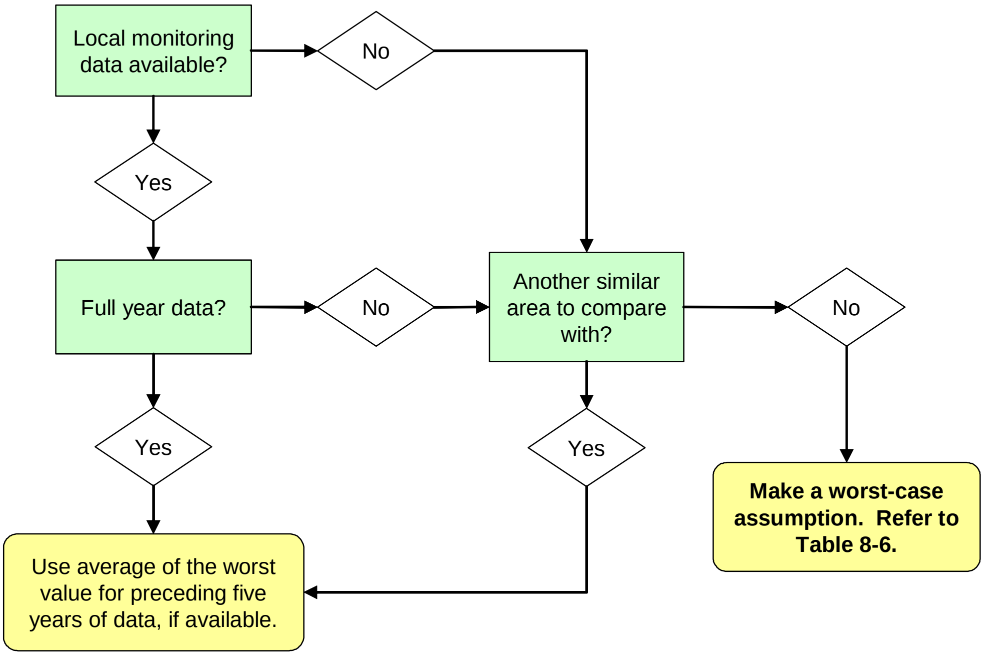
The most straightforward options are to compare the location with somewhere similar or make a worst-case assumption. If the area does not have significant large sources and does not have any complex geographical or meteorological features, then it can be assumed that the air quality will be similar to another area of similar population density, emission sources and meteorology. This method requires that such an area can be identified and that monitoring data are available.

Making worst-case assumptions

In the absence of air quality data from local or similar areas, it might be necessary to simply estimate the existing air quality. The safest approach is to assume a concentration at the upper end of what might be feasible.

The most conservative (and straightforward) approach to estimating existing air quality without the project is to make worst-case assumptions, as outlined in Figure 8.2 below. This approach is very conservative, and a more accurate assessment of existing air quality, or a health risk assessment, may be required if this results in a prediction of unacceptable air quality effects.

Figure 8.2: Determining existing air quality with conservative assumptions



Some examples of worst-case assumptions are outlined in Table 8.6. Once again, it needs to be stressed that this approach is very conservative, and in areas where air quality is likely to be poor, ambient air quality monitoring may be required. It is important to ensure the 'existing air quality without project' concentration selected is appropriate and relevant to the location of the proposed project. For example, to avoid double counting it is important to select existing air quality data from an area that is not influenced by traffic, if the assessment includes dispersion modelling to predict the impact of any existing traffic as well as traffic associated with the proposal.

Table 8.6: Examples of existing NO_2, PM_{10} and CO concentrations 'without project'

Area where estimate of background air quality is required	Pollutant	Value to assume	Justification for worst-case assumption, based on review of data to 2004 (extracted from various council monitoring reports and website data in mid-2005)
An urban area with a significant wood- or coal- burning problem	NO_2 1 hr	150 (μg/m^3)	10-year average of maxima, Packe St Christchurch = 124. 3-year average of maxima, Coles Pl, Christchurch = 110. 1-year maximum, Fire Station, Nelson = 148. *Christchurch and Nelson represent the worst case for areas with significant domestic heating pollution.*
	PM_{10} 24 hr	100 (μg/m^3)	Christchurch, Nelson, Timaru, Masterton, Mosgiel, Arrowtown, Richmond and Kaiapoi have all recorded peaks of over 100 (the highest is 252 in Christchurch in 2002).
	CO 8 hr	8 (mg/m^3)	The highest values recorded in Christchurch have been slightly above 8.
Area with poor dispersion (eg, urban canyon) within 5 m of a busy intersection or congested area (with over 10,000 vehicles per day and/or wood or coal burning).	NO_2 1 hr	340 (μg/m^3)	4-year average of maxima Khyber Pass = 343. *Khyber Pass is a peak traffic monitoring site for NO_2 (traffic approx. 30,000 vehicles/day, air quality monitoring < 5 m from roadside).*
	PM_{10} 24 hr	80 (μg/m^3)	Even smaller centres that have poor dispersion can record high values (Reefton 55, Nelson 165, Wainuiomata 57, Upper Hutt 60).
	CO 8 hr	10 (mg/m^3)	The highest values recorded in Auckland have been slightly above 10.
Area within 20 m of vehicle routes of over 10,000 per day, or within 100 m of a motorway.	NO_2 1 hr	140 (μg/m^3)	10-year average of maxima, Auckland Penrose = 139. 2-year average of maxima, Peachgrove Rd, Hamilton = 133. *Penrose and Peachgrove Road have the highest maximum NO_2 levels of all data reviewed, except for Khyber Pass.*
	PM_{10} 24 hr	70 (μg/m^3)	There are not many sites in this category with monitoring results, but Auckland's Khyber Pass has recorded 81, almost certainly largely due to traffic.
	CO 8 hr	5 (mg/m^3)	4-year average of maxima, Peachgrove Rd, Hamilton = 4.75. Maxima at peak traffic sites in Rotorua and Tauranga are also less than 5.
Urban area that doesn't have significant wood-burning problem and no vehicle routes of over 10,000 vehicles per day within 20 m, or motorways within 100 m.	NO_2 1 hr	50 (μg/m^3)	Hastings, less than 1 year of data, maximum = 36. Napier, less than 1 year of data, maximum = 66. Wellington, all sites, all years, maximum = 53. *These sites have some traffic influence, so represent a worst-case assumption for urban areas without significant traffic.*
	PM_{10} 24 hr	40 (μg/m^3)	Residential neighbourhood monitoring sites in Hawke's Bay and Bay of Plenty have recorded occasional exceedances of the PM_{10} standard, although averages of maxima taken over several years tend to be lower than 40.
	CO 8 hr	2 (mg/m^3)	Maximum concentrations measured at residential neighbourhood sites in Upper Hutt, Lower Hutt and Masterton are typically 2 or less.
Rural area, or urban area that is very open with low population density.	NO_2 1 hr	15 (μg/m^3)	Masterton 2-year average of maxima = 13.5. *There are no results available from rural monitoring sites. Masterton is the lowest result for a 'residential neighbourhood' site, so this is a worst-case assumption for a rural area.*
	PM_{10} 24 hr	15 (μg/m^3)	This is a typical maximum concentration when no obvious sources occur upwind.
	CO 8 hr	0 (mg/m^3)	With no local sources, CO concentrations are generally very low, and can be taken as effectively zero.

Model other sources in the area

Atmospheric dispersion modelling may be the preferred approach for estimating existing air quality where:

- there are a small number of existing emission sources in the area for which reliable emission data are available
- any contribution to ambient levels from other hard-to-characterise sources (such as vehicle emissions, domestic fires or dust from wind erosion) is negligible.

This situation would be unlikely to occur in urban areas of New Zealand. Again, the *Good Practice Guide for Atmospheric Dispersion Modelling* provides advice on the appropriate application of dispersion models.

Commission a monitoring programme

For significant projects, where the issue is likely to be of importance and when local data are not available, it is recommended that an air quality monitoring programme be undertaken. **Monitoring should determine concentrations of the critical indicator contaminants (generally CO, NO_x and PM_{10}, and possibly benzene) as well as meteorology, and traffic counts.**

Comprehensive guidance on setting up ambient air quality monitoring stations is provided in the *Guide to Air Quality Monitoring and Data Management* (Ministry for the Environment, 2000). It is recommended that the regional council be consulted before undertaking any new ambient air quality monitoring.

There are two general categories of monitoring site that can be used for background monitoring of ambient air quality concentrations for transport developments.

- **Receptor monitoring sites:** a monitoring station can be established in the grounds of a receptor located within the potential zone of influence of the proposed project. The aim of this monitoring is to measure the existing or *baseline* concentrations of selected contaminants so that the impact of the project on that specific receptor can be determined by ongoing monitoring at the same site after the project has been established. It may be suitable to select a particularly sensitive receptor for this type of site, such as a school, residential dwelling or area where concerns have been raised during a submission process.
- **Representative monitoring sites*:*** these sites are usually located in the area a proposed development will go through, where the aim is to obtain a representative measure of the existing ambient air concentrations over most of the area of concern.

Site-specific monitoring should be undertaken over a sufficient period to obtain representative existing air quality data. The assessor should justify any monitoring period that is less than 12 months.

8.2.2 The built environment

Sensitivity to air quality impacts will vary with land-use type. For example, residential land use (including schools) will typically have greater sensitivity than an industrial setting.

The land use surrounding a proposed development should be reviewed and described in any assessment of air quality impacts. Any facilities where there are likely to be sensitive groups of people (young, old, unwell), such as hospitals and schools, should be identified. The review will provide both an indication to any developer of the likely acceptability of, or objections to, a proposal and a guide to the depth of consultation required. The sensitivity will also be one factor that influences the level of assessment of environmental effects required for a proposed development. Table 6.2 (Tier 1) provides a general classification of the sensitivity of various land uses to discharges of contaminants into air.

Conversely, when considering changes to land use in areas surrounding transport corridors, 'reverse sensitivity' should be considered. The separation distance between transport corridors and sensitive receiving environments should be maintained for the duration of the corridor. Maintaining the existing separation distance should be a consideration in any notice of requirement for new corridors.

8.3 Exposure estimates

8.3.1 Dispersion modelling

Atmospheric dispersion models are used to estimate contaminant concentrations downwind of a discharge source. The information generated by dispersion models can be used in a number of ways, including to:

- assess the potential adverse effects of proposed activities or changes to existing activities – dispersion modelling is usually the only way to assess the potential effects of an activity that has not yet been constructed
- predict the effects of changes in emission rates or parameters over time (eg, a change in traffic flows)
- estimate the influence of factors such as terrain, buildings and meteorology on an activity and their effect on the dispersion of the contaminants discharged by the activity
- estimate the effect of any mitigation options.

Local and community effects will need to be assessed near the roads by atmospheric dispersion modelling (using a 'near-road' model). In New Zealand, the most common dispersion model used for this type of assessment is CALINE4.

The *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004) gives extensive guidance on dispersion models, including those used for transport assessments. They include Gaussian line source models such as CALINE4, and those that can model line sources or account for regional airshed dispersion and secondary reactions, such as CALPUFF/CALGRID and TAPM. All dispersion modelling should be carried out in accordance with the recommendations of the *Good Practice Guide for Atmospheric Dispersion Modelling*.

8.4 Assessing the effects

8.4.1 Incorporating background data

Background air quality data and predicted pollutant concentrations must be considered together against the selected assessment criteria. Adding the background data and predicted results to provide an estimate of the cumulative impact for comparison with the selected assessment criteria is reasonable for annual average concentrations. For short-term concentrations this simplistic approach is appropriate where the criteria are not exceeded, although it is a very conservative approach and a more accurate assessment may be necessary where compliance is an issue.

The above approach can lead to an overly conservative assessment due to issues relating to the spatial and temporal co-incidence of background and predicted concentrations, as follows.

- **Spatial co-incidence problems** – it is often difficult to know whether the background data are representative of the point at which the modelled peak occurs. In general, they will not be located in the same place, so adding the two will overestimate actual future concentrations.
- **Time co-incidence problems** – both modelled and background concentrations vary with the time of day due to factors such as meteorological patterns and changes in background emission sources (eg, domestic heating or industrial peaks). In some cases, the peak caused by the transport emissions in question may not occur at the same time as the background peak, so adding the two together may again overestimate the future concentration.

For the highest percentiles (ie, concentration values close to the peak short-term concentration of a year's worth of such concentration predictions), simple addition can overestimate the source contribution, and in general the overestimate is more severe for the higher percentiles. The best predictive assessment technique is to use hourly, sequential ambient air quality monitoring data that are recorded in the airshed of interest, and then add the hour-by-hour predicted concentrations. These predicted concentrations should be made using meteorological data recorded at the same time as the recorded air quality data. Where data are available, such an approach is recommended.

Careful examination of the locations and conditions under which measured and modelled peaks occur may help determine whether the peaks are likely to occur at the same time and place. Any alternative to adding hour-by-hour data, or adding peak background and peak predicted concentrations, should be fully explained and justified.

8.4.2 Comparing model results with air quality criteria

It is generally sufficient to assess health effects by comparing modelled predictions (including background air quality) with appropriate health assessment criteria.

As noted in section 5, it is important to ascertain both the short-term and the long-term impacts of discharges to air. For most assessments this will necessitate the use of both the national ambient air quality standards (one-hour and 24-hour standards) and the national ambient air quality guidelines (annual guidelines). In all cases, as noted in section 5, the selection of air quality criteria should be justified. In doing so the purpose of the standard or guideline should be clearly stated. *None* of the criteria provided in section 5 are levels that may be 'polluted up to'. It is also important to recognise the limitations of dispersion modelling when predicting impacts.

For relevant averaging times, the model results for maximum, 99.9th percentile and 99.5th percentile concentrations should be given. As a rule of thumb, modelling using less than a 24-hour average (eg, one hour) should present maximum and percentile concentrations, whereas averaging times of 24 hours or more should only show the maximum concentration levels.

The recommended procedure in the *Good Practice Guide for Atmospheric Dispersion Modelling* requires consideration of meteorology when assessing worst-case impacts. (This is reproduced in full below.)

Recommendation 53

For the purpose of comparing modelling results to an evaluation criterion:

a) run the model for the minimum period of one full year of meteorological data where possible (ie, 8,760 hours)

b) identify the receptor(s) that are most highly impacted and those that are most sensitive

c) for the receptor(s), report the 99.9 percentile value of the predicted ground-level concentration as the maximum ground-level concentration likely to occur.

Provide an indication of the representativeness of the 99.9 percentile value ground-level concentration by also presenting a number of other percentile values (eg, maximum, 99.5th and 99th percentile values).

Use the frequency of exceedances to indicate the frequency of “pollution events” that exceed the evaluation criterion being used.

Source: Ministry for the Environment, 2004.

The above recommendation applies to one-hour time averages only. Following are a few examples.

- For sulphur dioxide, nitrogen dioxide and ozone, compare the highest 99.9 percentile predicted concentrations for all receptors with the one-hour national ambient air quality standards. A number of other percentile values (eg, 99.5th and 99th percentiles) should also be reviewed. The maximum predicted concentrations for all receptors should then be compared with the relevant eight-hour, 24-hour or annual average guidelines.
- For carbon monoxide, compare the maximum predicted concentrations for all receptors with the national ambient air quality standard of 10 mg/m^3 as an eight-hour average.
- For PM_{10}, compare the maximum predicted concentrations for all receptors with the national ambient air quality standard of 50 µg/m^3 as a 24-hour average. Similarly, compare the maximum predicted annual concentration for all receptors (if more than one year of meteorological data used) with the national ambient air quality guideline of 20 µg/m^3 as an annual average.

The review of other percentile values is very important because it furthers understanding of how meteorology (and other factors) affect the maximum downwind concentrations.

As discussed in section 3.1, transport activities have the potential to discharge a large number of different contaminants. However, unless there are special circumstances (such as elevated background concentrations of another compound), most assessments will provide adequate coverage of all potential effects if based on CO, PM_{10} and NO_2. As we have seen, these three do not explicitly cover a range of other toxics, in particular carcinogenic compounds such as benzene and 1,3 butadiene. The concentrations and effects of these other compounds are still being researched, but results from the New Zealand research under the Health and Air Pollution in New Zealand programme (further details can be found at www.hapinz.org.nz) suggest the overall health effects are substantially less than those due to CO, PM_{10} and NO_2. In other words, unless there are very specific local circumstances, transport proposals that result in acceptable effects for CO, PM_{10} and NO_2 will also most likely have acceptable effects for other toxics.

It is therefore recommended that an assessment of the effects of benzene and 1,3 butadiene only be considered for major projects or in locations where elevated levels are known or considered likely. Consultation with the regional council should clarify the level of assessment required.

8.4.3 Assessment of overall network effects

The Tier 3 assessment procedure has so far focused on the assessment of local effects. Most transport projects are designed to improve safety and traffic flows, and will therefore have an overall air quality benefit for the community. For significant projects that increase emissions in some locations and decrease emissions in others, it is recommended the assessment include an estimate of the likely air quality costs and benefits. Methods for quantifying community health impacts are recommended in Appendix 4. The method selected will depend on the level of detail required.

This guide recommends methods for assessing community impacts, but it is not possible to provide guidance on the relative importance of community versus local impacts. For example, construction of a new link may ease congestion and reduce overall vehicle kilometres over a wide area, but air quality immediately adjacent to the new link may be degraded. Although the net effect of the project would be to maintain or improve overall air quality, an assessment of local impacts is still required to determine whether any localised negative impacts are within acceptable limits, and whether mitigation can or should be applied. In cases where air quality is significantly degraded across the community, the project might require mitigation (depending on the state of air quality in the airshed).

It is recommended that the regional council be consulted to determine assessment requirements for any proposal that will result in a significant net increase in emissions.

8.4.4 Assessment of photochemical smog or other regional-scale impacts

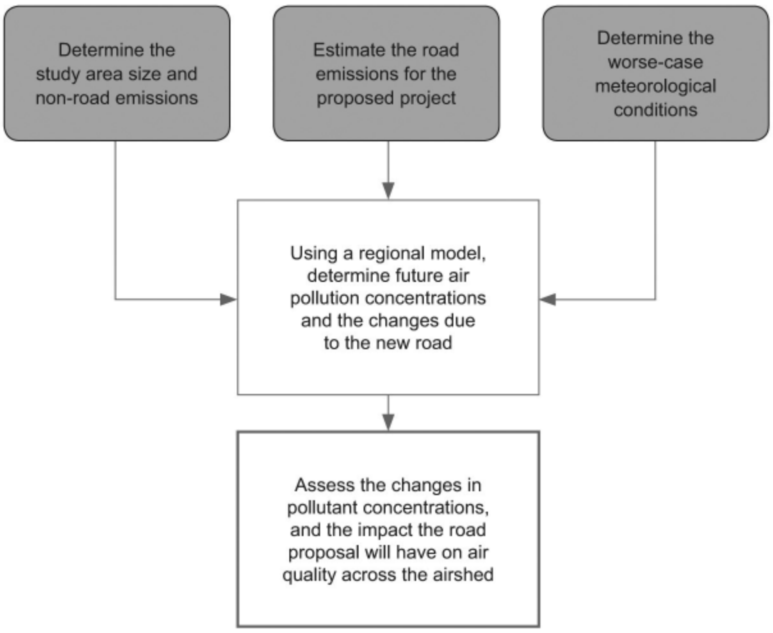
In some circumstances, urban airshed modelling may be necessary to assess photochemical smog or other regional-scale impacts, such as the formation of secondary particulates. Figure 8.3 illustrates the process for modelling regional-scale air quality impacts.

Regional-scale assessments will be more commonly used for policy development. However, a very large scheme or transport strategy may require an assessment of regional effects if there is likely to be a significant increase in emissions. This could involve working with regional council air quality staff to revise the regional emissions inventory.

In cases where a significant net increase in emissions is expected, early consultation with the regional council is recommended to determine whether an assessment of regional-scale impacts is required.

Some general guidance on assessing the regional effects of transport projects is provided in the *Guidelines for Conducting Air Quality Studies* (Austroads, 2000). Further guidance on emission inventories is provided in the *Good Practice Guide for Preparing Emissions Inventories* (Ministry for the Environment, 2001), and the *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004) provides some guidance on urban airshed modelling.

Figure 8.3: Modelling of regional-scale air quality impacts[7]



[7] Based on *Guidelines for Conducting Air Quality Studies*, Austroads, 2000, Chart 4.

8.4.5 Non-human health considerations

Air pollution effects on ecosystems

Section 4 of the *Ambient Air Quality Guidelines* (Ministry for the Environment, 2002) provides critical levels for protecting ecosystems from sulphur dioxide, sulphate particulate, nitrogen dioxide, ammonia, ozone and fluoride. *The Effects of Air Contaminants on Ecosystems and Recommended Critical Levels and Critical Loads* (Ministry for the Environment, 2000b), provides some guidance on methods for calculating pollutant deposition rates from predicted or ambient monitoring results, and guidance for assessing whether a discharge is likely to cause adverse effects on ecosystems.

In Europe and North America the effects on sensitive ecosystems of acid deposition and elevated pollutant concentrations from industrial and other anthropogenic sources have been subject to legislative controls for some decades. Similar effects in New Zealand are not so evident, although they have been reviewed in a number of technical reports (eg, Ministry for the Environment, 2000b).

Much of the work has drawn on knowledge of the effects on non-New Zealand (North American and northern European) plant species. The recommended critical levels and loads and the provisional guidance on assessing deposition and its effects given in *The Effects of Air Contaminants on Ecosystems* is based on this knowledge. There is scant information on either the effects of air pollutants on native New Zealand species or the current level of pollutant deposition or concentration in New Zealand's natural environments. The robustness of any assessment of air pollution effects on ecosystems in New Zealand is therefore very vulnerable to these knowledge gaps. Despite these limitations, it is good practice to assess potential effects on ecosystems for any significant source that may have an impact on sensitive ecosystems.

8.5 When a health risk assessment is required

In some situations it may be necessary to undertake a more comprehensive air pollution health risk assessment as part of a detailed study. For example, this may be required when the predicted effects exceed ambient air quality criteria, and decision-makers require more specific information about the likely health effects of this.

An air pollution health risk assessment would include determining exposure and dose via a number of different pathways (inhalation, dermal, ingestion, etc), assessment of dose-response data, and characterisation of health risks from the exposure/dose assessments.

The national ambient air quality standards are health-based standards, which are intended to provide a guaranteed level of protection for the health of all New Zealanders. In most circumstances it is appropriate to assess the potential health effects of discharges to air from transport by comparing model predictions with the national ambient air quality standards, any regional council assessment criteria, and (where appropriate) the national ambient air quality guidelines.

Typically it is only when national ambient air quality standards or guidelines are exceeded that an *air pollution* health risk assessment is required.

Health risk assessments are very specialised tasks, and are often designed to account for very specific local concerns. It is recommended that expert assistance be sought for any full health risk assessment.

8.6 Accuracy

The *Good Practice Guide for Atmospheric Dispersion Modelling* (Ministry for the Environment, 2004) includes guidance on accounting for, and reporting of, model error and uncertainty. This includes consideration of source characteristics, meteorological data, terrain, model performance and the misapplication of models.

Careful consideration of accuracy is especially important in transport assessments, which usually rely on models to estimate traffic and vehicle emission factors as well as dispersion. With three or more levels of modelling there is plenty of room for error and – perhaps more importantly – mistrust of the results. It is important errors and uncertainty be considered throughout the assessment, and that the report clearly demonstrates this.

Standard quality control techniques, such as the use of calculation checking and aspects as basic as checking that model data are correctly input, are extremely important and should be used. It is also recommended that within an assessment report each aspect of an assessment be auditable and repeatable so that the approach, assumptions and calculations can be independently reviewed.

Ideally, the uncertainty associated with each aspect of the assessment should be estimated and stated. Where this is not possible, sensitivity analysis should be carried out. The results of the sensitivity analysis could be used to present a 'worst-case' estimate and a 'most likely' estimate of the effects. For example, a worst-case estimate might be based on unusually high traffic levels, high emission factors, a high proportion of heavy commercial vehicles, high background concentrations and poor meteorological conditions. In reality, it is unlikely that all of these variables will be 'worst-case' at the same time, so a more realistic “'most likely' scenario is also recommended.

8.7 Reporting a Tier 3 assessment

The results of a Tier 3 assessment should be documented for inclusion into any assessment of environmental effects. The report should summarise the findings of the assessment, including the basis of the traffic information, air quality information, any assumptions, and their justification. Section 4.5 describes the recommended content of an assessment report. The size and nature of the report will depend on the project, but it is anticipated that for any Tier 3 assessment each of the sections described will be included.

Tier 3 detailed assessment − recommendations

A full Tier 3 assessment would generally only be required for large or significant projects, or very sensitive receiving environments. However, some aspects of the Tier 3 assessment may be required for other projects. For example, a project that exceeds the Tier 2 significance criteria might only require consideration of existing air quality to determine whether the effect on air quality is actually significant in the location under consideration.

For any aspect of the assessment where detailed information is not available, or is not necessary, it is appropriate to adopt the conservative assumptions discussed for Tier 2 assessments.

9 Mitigation Options

Depending on the proposal, mitigation measures may need to be considered in any assessment of the effects of land transport on air quality. Some general discussion of potential mitigation measures is therefore provided below.

9.1 Measures to mitigate local impacts

There are a number of measures to mitigate localised air quality impacts from transport projects (or projects that affect traffic), which can be implemented by those responsible for the projects or affected by the design of the project. Some examples are:

- increasing the distance between the road and receptors, particularly at intersections
- changing land use adjacent to transport corridors
- alternative transport schemes (eg, a different mix of road and rail)
- carefully siting and sizing of tunnel exhaust vents or chimneys
- traffic management systems
- flow restrictions
- orientation of the road in relation to prevailing winds
- measures to offset any increase in emissions or reduce vehicle emissions (see below)
- indirect measures that may influence travel demand, fleet composition, vehicle types and fuel quality.

If the assessment shows there will be locations where people will be exposed to air pollution levels that exceed the national ambient air quality standards, then mitigation will very likely be required. Because contaminants generally disperse quickly with distance from their source, separation is likely to be one of the most effective mitigation measures. Options to achieve adequate separation could include:

- moving the road alignment away from receptors
- placing part of the road in a ventilated tunnel
- relocating properties
- placing operational restrictions on sections of roads (similar to on-ramp signals).

Another mitigation option is to introduce measures that will reduce overall emissions from the project. Here are some examples.

- Bus priority lanes or freight priority lanes could improve average speeds, which may reduce emissions from buses or trucks. The majority of PM_{10} emissions are from heavy-duty diesel vehicles, so this could have a significant impact on overall emissions.
- Similarly, targeted measures to reduce emissions from buses or trucks could have significant impacts. Auckland Regional Council analysis has shown that a catalyst retrofit scheme for older buses could reduce emissions by more than 30% at a cost of $39,000/tonne of PM_{10} emitted (Auckland Regional Council, 2005b).
- A public transport project could achieve a significant modal shift by, for instance, having more people travel to work by bus rather than using their own vehicles, potentially resulting in an overall reduction in emissions.

- Other travel demand measures could affect the link under study; for instance, the opening or closing of a facility that attracts people using vehicles, such as a supermarket.
- Minimum emissions standards could be set through local bylaws (as is commonly used for vehicle tonnage restrictions).

It is important to consider potential air quality effects when a transport development is in the planning stages, particularly if traffic passes near sensitive receptors such as schools, childcare facilities or hospitals. It is also important to note that mitigation measures to reduce effects from air discharges at a local level may in turn influence other aspects of the proposal (eg, noise, road safety, discharges to water). In developing mitigation measures for a land transport development, all these aspects must be considered in combination rather than pursuing any air quality solution in isolation.

9.2 Offsets

Measures to offset any overall increase in emissions may sometimes be the only realistic mitigation option, particularly when existing air quality is relatively poor. For projects that result in a net increase in emissions, it is recommended that *at least* the equivalent of the emissions from other sources be offset before proceeding with the transport project. Some offsets may also be necessary if emissions from the project are sufficient to cause unacceptable localised impacts when added to (relatively high) background levels.

10 Monitoring Project Effects

The amount of monitoring required must be assessed on a case-by-case basis. For major projects it is recommended that monitoring be undertaken both before and after the project to ensure the assessment was correct and to quantify the impacts of the proposal on air quality.

The purpose of pre-project monitoring is to establish existing air quality. This is discussed in section 8. The primary purpose of ongoing post-project monitoring is to ensure effects remain within acceptable limits. A secondary purpose may be to ensure the model predictions were correct. In the case of traffic counts, the monitoring would determine the reliability of the original traffic modelling and perhaps form part of a traffic management system or serve as the basis for enforcing a limit on vehicle flows.

Ambient air quality monitoring should determine the concentrations of the critical indicator contaminants (generally CO, NO_x and $PM_{10,}$ and possibly benzene). **It is recommended that traffic counting, ambient air quality monitoring and meteorological monitoring be undertaken simultaneously to provide adequate data for trend analysis.** Comprehensive guidance on setting up ambient air quality monitoring stations is provided in the *Guide to Air Quality Monitoring and Data Management* (Ministry for the Environment, 2000a).

It is impossible to prescribe exactly when ongoing monitoring may be necessary because many factors are involved, but some likely factors are:

- sensitive receptors are in close proximity
- the predicted effects are close to the margin
- the predictions had a high level of uncertainty, and/or
- monitoring forms part of a mitigation measure (eg, flow restrictions)
- the scale of the project is such that regional impacts are likely, entailing the need for a review of the regional monitoring network.

Although monitoring needs must be assessed on a case-by-case basis, it is likely that a major project will require at least some monitoring to account for both local and regional effects.

Site selection for pre- or post-project monitoring will also need to be assessed on a case-by-case basis. The purpose of the monitoring should be clearly defined and carefully considered when selecting any monitoring site. Monitoring sites should comply with the *Guide to Air Quality Monitoring and Data Management*.

Post-project monitoring offers an assurance to the community, the transport developer and the regulatory authorities that the project turned out as predicted and that there have not been any adverse health impacts. Alternatively, monitoring data showing abrupt changes in ambient levels of indicator compounds provide a solid basis for remedial actions.

Appendix 1: Calculations and Data

A1.1 Method for estimating concentrations

Atmospheric dispersion modelling has previously been used to determine dispersion curves for New Zealand conditions (Scoggins et al, 2004; Bluett and Fisher, 2005). As part of this project the curves have been normalised for emissions factors and number of vehicles to provide an estimate of concentration per g/km of emissions as a function of distance from the roadside. To determine concentration, the road emissions are estimated based on the number of vehicles (for the relevant averaging period) and the fleet-weighted emissions factor. There are a number of assumptions and simplifications that need to be made, all described here.

None of these calculations account for existing or background concentrations. These must be added if a cumulative assessment is required. The method only applies the effects due to the transport corridor under consideration. This is relatively straightforward for CO, but can become more complex for NO_2 and PM_{10} because of atmospheric chemistry processes which depend on background concentrations that may not be known.

The dispersion curves for all other gaseous pollutants (here mainly NO_2 and PM_{10}, but also any others that may be needed) are held to be equivalent to the CO dispersion curves. This is a simplified approach because the dispersion curves for each pollutant are not identical, due not only to chemical processes but also to subtle differences in dispersion and deposition. However, it is argued that the differences are not great, and that the CO dispersion is a reasonable representation for the other pollutants over the distances and times scales of interest. This is also the methodology followed by Austroads in Australia (see, for example, Austroads, 2004) and DEFRA in the UK (National Roads Authority and DEFRA, 1992/2003).

All measurements in this document are taken from the edge of the driving lane (some methods take the measurements from the road centre line).

A1.2 Dispersion curve basics

The basic dispersion curve is derived from the modelling and experimental measurement of CO. The one-hour dispersion curve for CO was developed based on measured roadside concentrations at an Auckland monitoring site. To determine how the CO concentration varied with distance from the carriageway, CALINE4 was used (eg, Scoggins et al, 2004). NZTER emissions factors were used to estimate emissions. Using a best-fit algorithm, the estimated variation of maximum predicted one-hour concentration with distance from the carriageway can be modelled as:

$$\text{Maximum 1-hour CO concentration } (\mu g/m^3 \text{ per vehicle}) = 4 \exp(-0.3\, d^{0.5}).$$

This equation is based on an assumed NZTER fleet-weighted CO emission factor of 12.302 g/km. Therefore, an alternative normalised equation is:

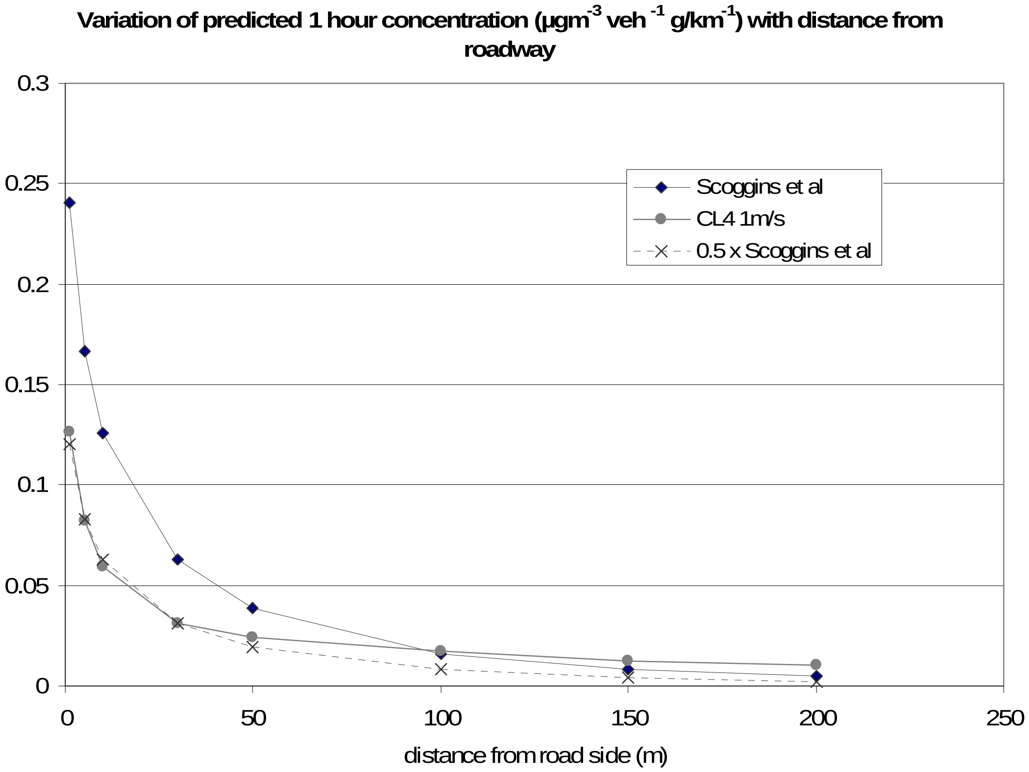
$$\text{Maximum 1-hour CO concentration } (\mu g/m^3 \text{ per g/vkt}) = 0.325 \exp(-0.3\, d^{0.5}).$$

Notes: VKT = vehicle kilometres travelled.

To evaluate the conservatism of this dispersion curve, a similar normalised curve has been developed using meteorological parameters recommended for screening assessments by Austroads (2004). For screening assessments, the Austroads review recommends the use of CALINE4, assuming a 1 m/s wind speed, stable atmospheric conditions, sigma-theta of 10 and worst-case wind angle. The Austroads review compared maximum concentrations predicted using these assumptions with maximum measured concentrations for a freeway and arterial road. The analysis showed that this approach is adequately conservative for screening assessments. The most significant sources of uncertainty were background concentration and the atmospheric chemistry rates, where these are relevant (eg, in applying the relationship to NO_2, see below).

Figure A1.1 shows a comparison of the normalised dispersion curve based on the parameters recommended by Austroads and the methods assumed here. The Austroads curve predicts significantly lower concentrations (approximately half) than the Scoggins et al curve within 50 m of the roadside. This suggests that the Scoggins et al. curve may be most appropriate in situations where worst-case wind speeds of less than 1 m/s are likely. The emphasis of the method developed here is on worst-case circumstances, and these can occur just about anywhere in New Zealand – even in very exposed places, albeit for shorter times. If this assessment is critical, then specific modelling (say, using CALINE4 and on-site meteorological data) should be used.

Figure A1.1: Concentrations of CO at various distances from a carriageway edge



The curve chosen, being the more conservative and applicable to very light wind speeds, is the upper one (Scoggins et al, 2004). This tends to be conservative relative to the Austroads recommendation within 100 m or so of the road, but allows concentrations to fall off more quickly at distances further than 100 m.

A1.3 Averaging periods

The use of these one-hour dispersion curves (with a similar methodology used in Australia and the UK) gives a theoretical worst case for one-hour concentrations. They are based on worst-case meteorology, which may not occur in some locations. Furthermore, the methodology becomes overly conservative when used for averaging times of great than one hour. It is rare for the worst-case meteorological conditions to occur for periods of eight hours or 24 hours.

For instance, in Auckland the calm conditions required for the dispersion curves to apply never occur for more than three consecutive hours. Inland and sheltered places may experience longer periods of calm, but only very rarely for more than 12 hours. Using this methodology to assess 24-hour PM_{10} or NO_2 is thus unrealistic, since it assumes that worst-case hourly conditions persist for the whole 24 hours.

On this basis, the 24-hour calculations have been divided by a factor of 2 to account for those circumstances when the required calm conditions do not occur for 24 hours. In the general case, the magnitude of effects will be lower still; for instance, only 0.125 (3/24) of the calculated effect in cases where the calm period only extends for three hours. Figure A1.1 shows that the Scoggins et al dispersion curve, multiplied by 0.5, still predicts a one-hour concentration that is consistent with the Austroads screening methodology, which is conservative.

The eight-hour averages are based on the one-hour dispersion curve. This is a conservative approach because it assumes that worst-case meteorology applies for the entire eight-hour averaging period.

Worked example of dispersion calculation: 1-hour CO

Assumptions

Emissions factors: as provided in Table 7-1 (NZTER 2004 fleet-weighted average)
Road type: central urban
Congestion level: congested
Cold start: 20%

Central urban road with estimated peak traffic = 1,653 vehicles per hour:

Traffic	= 1653 vehicles/hour
Emissions for default fleet profile	= (24.3 x 0.8) + (43.7 x 0.2) = 28 g/km per vehicle of CO
Corridor emissions	= 1,653 x 28 = 46,581 g/km

Maximum one-hour concentration at 20 m from the road = 0.325 exp (-0.3 x $20^{0.5}$) x 46,581
= 3959 $\mu g/m^3$
= 3.96 mg/m^3

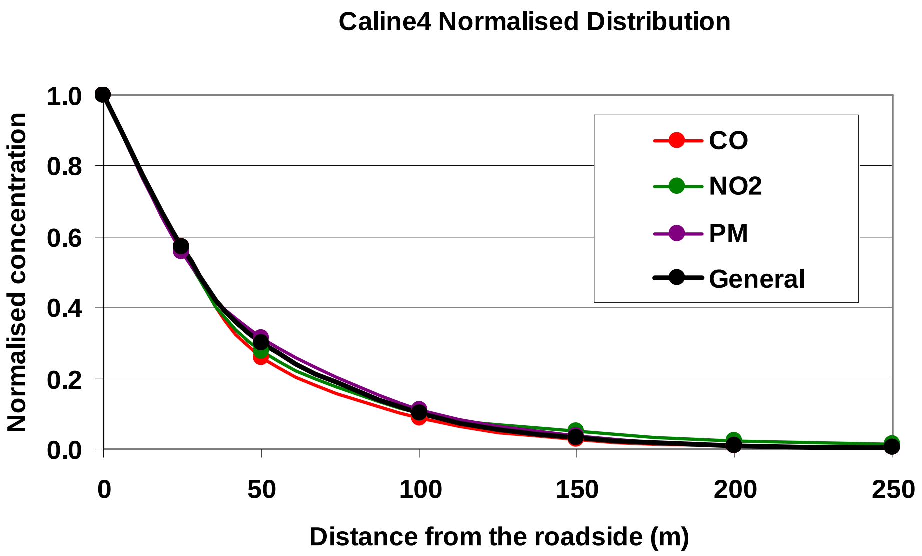
A1.4 Generalised dispersion curves

The sections above describe how the dispersion relationship is derived for CO, for one-hour, eight-hour and 24-hour periods. This is now assumed to extend to NO_2 and PM_{10}. A detailed validation of this assumption is beyond the scope of this document, and requires a fairly intensive field programme of measurements that cover the light wind-speed conditions of interest. This was partially undertaken as part of the derivations (Bluett and Fisher, 2005) but needs to be further investigated. However, as part of a checking process, the dispersion rates used in one of the more commonly applied models were examined. Using the latest (2006) version of CALINE4, through its GUI processor CalRoads View, a series of model runs were made using the New Zealand fleet-weighted average emission rates and a meteorological field with light wind speeds (1 m/s) in Auckland.

Figure A1.2 shows the results, all normalised for a concentration of 1 at the edge of the carriageway. This figure shows the CALINE4 dispersion curves for CO, NO_2, and PM_{10}. Also shown is the generalised dispersion curve based on CO, described earlier.

The data show that the choice of the generalised curve is a reasonable representation of what CALINE4 uses (although some caution needs to be applied when modelling NO_2 and PM_{10}). The atmospheric transformation of NO_2 is accounted for in CALINE4 by making assumptions about ozone. Secondary production of PM_{10} is not accounted for, but this is not significant on the short-time scales involved here.

Figure A1.2: Normalised concentrations of CO, NO_2, and PM_{10} at various distances from a carriageway edge



Notes: Figure A1.2 is produced using CALINE 4 with one-hour rates, 1 m/s and Auckland meteorology. Also shown is the general dispersion curve used in this guidance.

Therefore, to the first order and as a very good approximation, the calculation for any gaseous pollutant is made using the following relationship:

Maximum concentration over period T ($\mu g/m^3$) = $0.325 \exp(-0.3\ d^{0.5}) \times (N/T) \times EF$

Equation A:1.4.1

where: d = distance from roadside in metres
N = number of vehicles in the period T
T = time period assessed (1 to 8 hours)
EF = emission factor in g/km.

And for 24-hour averages:

Maximum concentration over 24 hours ($\mu g/m^3$) = $0.325 \exp(-0.3\ d^{0.5}) \times (N/24) \times EF \times 0.5$

Equation A:1.4.2

where: d = distance from roadside in metres
N = number of vehicles in 24 hours
EF = emission factor in g/km.

Note that this relationship is reliable within 250 m of the road, but needs to be used with caution for PM_{10} and NO_2 at greater distances. In practice this is not a serious restriction because compliance would usually be required within 250 m, and cases where non-compliance at 250 m or further would be acceptable will be uncommon.

A1.5 CO 8-hour

Thus the eight-hour CO concentration is calculated based on the one-hour dispersion curve (equation A:1.4.2) using average one-hour traffic for the eight-hour period.

Maximum 8-hour CO concentration ($\mu g/m^3$) = $0.325 \exp(-0.3\ d^{0.5}) \times (N/8) \times EF$

where: d = distance from roadside in metres
N = number of vehicles in 8 hours (worst 8 hours)
EF = emission factor in g/km.

A1.6 PM_{10} 24-hour

The 24-hour PM_{10} concentration is calculated based on the one-hour CO curve adjusted by a factor of 0.5 (equation A:1.4.2).

Maximum 24-hour PM_{10} concentration ($\mu g/m^3$) = $0.325 \exp(-0.3\ d^{0.5}) \times (N/24) \times EF$

where: d = distance from roadside in metres
N = number of vehicles in 24 hours (high traffic day)
EF = PM_{10} emission factor in g/km.

A1.7 PM_{10} annual

Annual average PM_{10} concentrations at the roadside (20 m from the edge of the road) are derived from the annual average CO curve using a scaling argument based on Auckland conditions (Scoggins et al, 2004). This is a difficult factor to generalise because it is strongly dependent on climate factors (eg, the frequency of calm conditions) at the particular site of interest. The method described here is a first-order approach, used in the absence of any more detailed data, and it must be recognised that it is based on Auckland conditions and only applicable at an indicator location 20 m from the roadside edge. This is probably adequate for a comparison of project options, but site-specific modelling should be considered for any more detailed assessment of PM_{10} effects.

Annual average 20 m from roadside PM_{10} (µg/m^3) = 0.007 x N x EF

where: N = number of vehicles in 1 hour
EF = PM_{10} emission factor in g/km.

A1.8 NO_2 1-hour

In a similar fashion, the one-hour NO_2 concentration is calculated based on the one-hour CO curve. However, since most emissions factors are given for NO_x, it is necessary to convert the concentration to NO_2.

Maximum 1-hour NO_x concentration (µg/m^3) = 0.325 exp (-0.3 d $^{0.5}$) x N x EF

where: d = distance from roadside in metres
N = number of vehicles in 1 hour (peak)
EF = NO_x emission factor in g/km.

Maximum 1-hour NO_2 concentration (µg/m^3) = NO_x x C

where: C = conversion factor from NO_x to NO_2, here assumed to be 0.2 (see detailed discussion later in this appendix).

This estimation is similar to that used by Austroads and is discussed in detail below. There are more complex and detailed models that can be used to improve accuracy, based on roadside measurements made in Auckland (eg, Scoggins et al, 2004; Bluett and Fisher, 2005). However, these are not applied here, with the emphasis instead being on establishing a conservative case envelope, which is covered by the 20% conversion factor used. This is maximised at 20–50 m from the roadside, and is lower at closer or further distances.

A1.9 NO_2 24-hour

In an identical fashion, the 24-hour NO_2 concentration is calculated based on equation A:1.4.2.

24-hour NO_2 concentration (µg/m^3) = 0.325 exp (-0.3 d $^{0.5}$) x (N/24) x EF x C x 0.5

where: d = distance from roadside in metres
N = number of vehicles in 24 hours (high traffic day)
EF = NO_x emission factor in g/km
C = NO_x to NO_2 conversion factor, 0.2.

A1.10 NO_x to NO_2 conversion

Emissions of oxides of nitrogen are generally quantified in terms of NO_x, which is mainly composed of NO and NO_2. For most combustion sources, the emission is mainly NO, which then oxidises to NO_2 in the atmosphere. The contaminant of interest, from the point of view of health effects, standards and guideline compliance, and degradation of visibility, is NO_2.

Given NO_x emissions, models can fairly easily simulate the dispersion of NO_x as if it were an inert gas. But the determination of the fraction of NO_2 requires a model that simulates chemical transformations, or some empirically determined formula for the NO_2:NO_x ratio. Even when a sophisticated model is used to simulate the oxidation of NO to NO_2, knowledge of the oxidants taking part in such reactions (eg, ozone, volatile hydrocarbon products) may still not be well quantified. Thus the NO_2 concentrations depend not only on the NO_x emissions and the distance from the source, but also on the absolute quantity of these emissions and the amount of oxidant in the air, which is not usually known.

In the United Kingdom the problem of modelling NO_2 has been addressed by air quality expert groups on behalf of the Department for Environment Food and Rural Affairs (National Roads Authority and DEFRA, 1992/2003). Using air quality data, they developed relationships between the annual mean NO_2 and NO_x.

When deriving a relationship specific to New Zealand conditions, there are several considerations.

1. The temporal and spatial variation in the NO_2–NO_x relationship needs to be assessed. NO_x may be emitted as NO, but is transformed to NO_2 further downstream, affected by both the distance the emissions travel and the time they have to react with ambient air.
2. The maximum possible NO_2:NO_x ratio is 1, but the oxidants may be depleted before all NO is transformed to NO_2. In such situations, more NO_x may be emitted as NO but little more NO_2 will result.
3. The NO_2–NO_x relationship must be applicable to the whole region rather than to individual emission sources, because NO_x from all sources becomes mixed in the atmosphere.

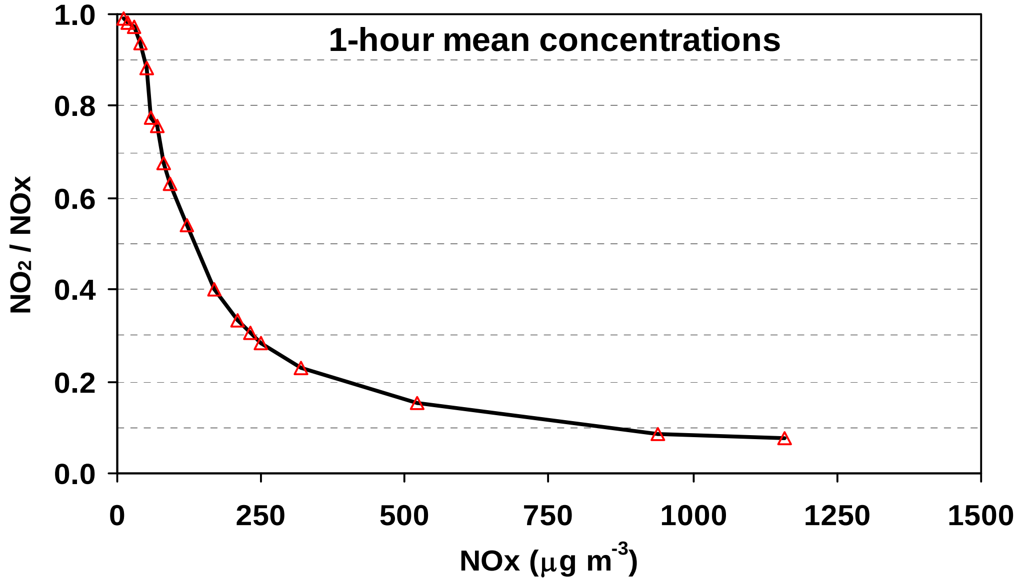
A simple universal ratio of NO_2 to NO_x was proposed 15 years ago (Janssen et al, 1988) to change linearly with distance from the source:

$$[NO_2] / [NO_x] = 0.2\, x$$

where x is the distance from the source in km, and the concentrations are in units of either parts per billion by volume (ppbv) or $\mu g/m^3$ as NO_2. However, this does not account for the NO_2 fraction near the source ($x = 0$), nor the limiting value at larger distances (ie, the ratio should always be ≤ 1).

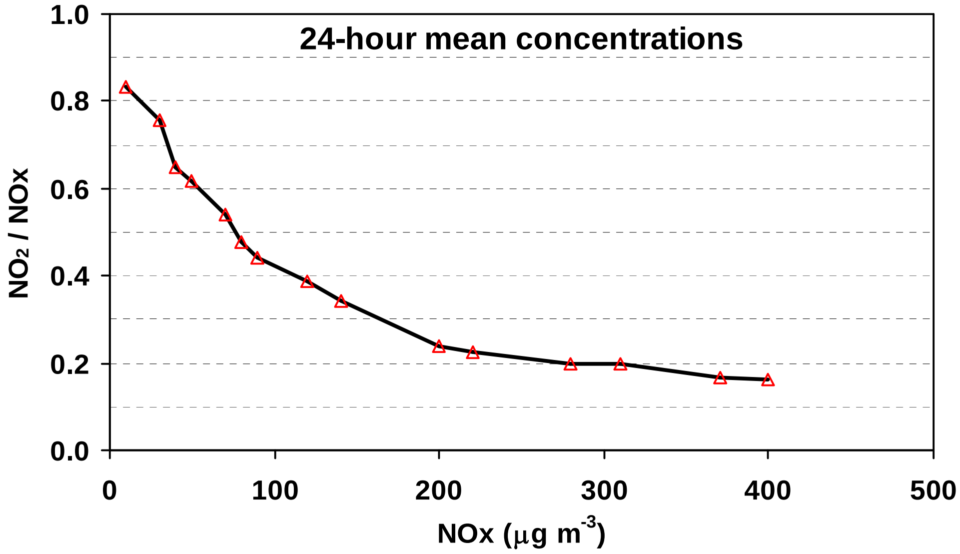
Considering air quality observations in Auckland at Khyber Pass, the $[NO_2]/[NO_x]$ ratio varies from close to 1.0 to quite low values (down to 0.1 during winter), with day-to-day variations of the order of 0.1. At Musick Point, 10 km away, there is a range from around 1.0 to 0.2, with a median value of 0.86. Detail of these ratios from data from the Penrose site is shown in Figures A1.3a and b.

Figure A1.3a: Relationship between NO_x and NO_2/NO_x at the Penrose, Auckland site



Source: Graph courtesy of NIWA, data source ARC monitoring data 2002–2004.

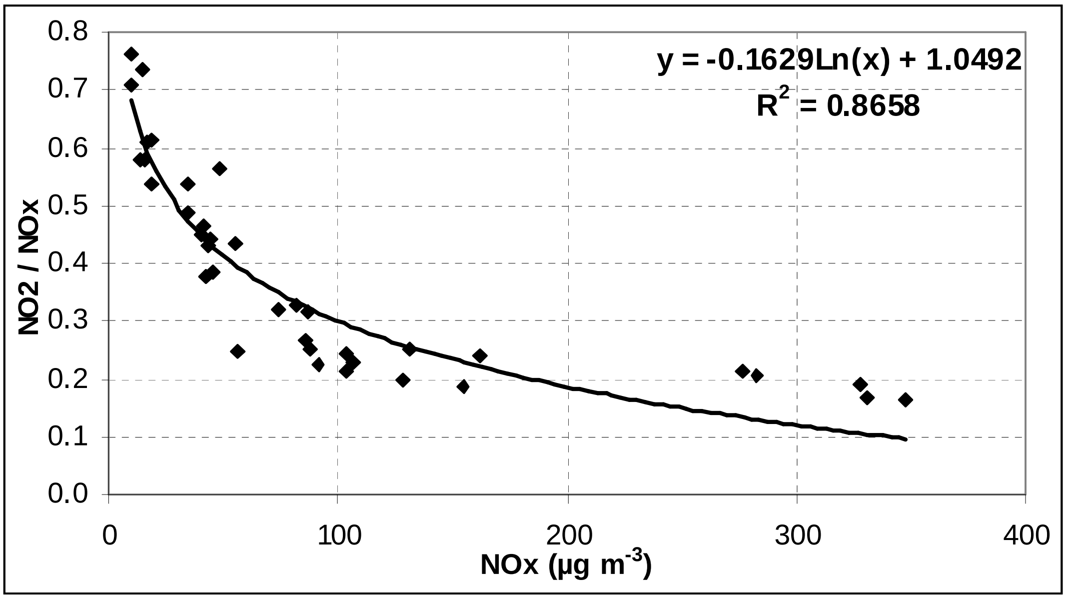
Figure A1.3b: Relationship between NO_x and NO_2/NO_x at the Penrose, Auckland site



Source: Graph courtesy of NIWA, data source ARC monitoring data 2002–2004.

A further analysis conducted on annual ratios from a number of stations throughout Auckland shows a similar pattern (see Figure A1.4).

Figure A1.4: Annual average NO_2–NO_x relationship in the Auckland region for the period 1995–2002



Source: Scoggins, et al, 2004.

It can be seen from these figures that the NOx:NO_2 ratio is strongly dependent on the concentration, with more complete conversion (a ratio close to 1.0) occurring at lower concentrations. At the higher end (the concentrations of most interest for standards and health effects) the ratio tends to be lower, levelling out at around 0.2 for the longer-term 24-hour and annual values.

These values are for the 'urban plume' as a whole, but are still applicable to emissions from transport as these are part of the urban air.

To make use of such information in assessing transport emissions, however, the distance-based approach has to be considered. From the observations, a formula can be derived empirically:

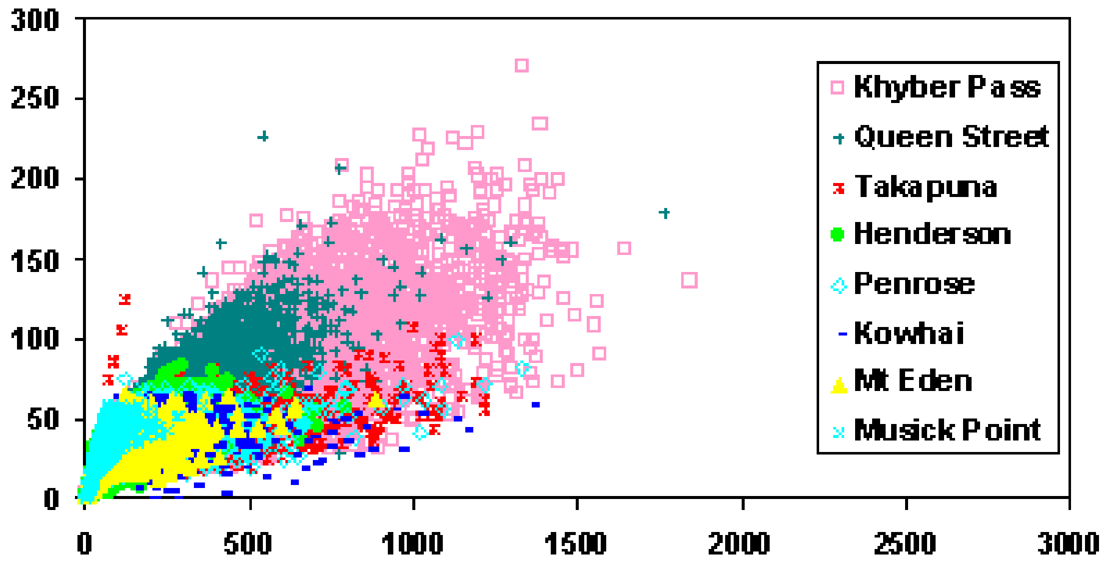
$$[NO_2] / [NO_x] = 0.1 + 0.2\,(x / (1 + x/5)).$$

The ratio starts at 0.1 when $x = 0$, increases at a rate of 0.2 per km (as given by Janssen et al, 1988), but then levels off. The factor of 5 in the formula leads to a ratio of 0.20 at $x = 0.5$ km, 0.60 at $x = 5$ km, and 1.0 in the far field at $x > 40$ km. This relationship holds well for longer-range transport, but is not strictly applicable on the roadside scales of a few tens of metres. As shown in Figure A1.4, the conversion rate can vary from 0.1 to close to 1.0 depending on the concentration.

The Austroads (2004) review recommended a maximum conversion of NO to NO_2 of 15% at 30 m from the curb (ie, a ratio of 0.15).

The data in Figures A1.3 and A1.4 can be then used to derive an appropriate rate for use in Auckland (and, by implication, other New Zealand areas affected by traffic emissions). At low concentrations, although the conversion ratio is high, the NO_x value is low and the resulting NO_2 concentration is low. At high concentrations the conversion rate is low but the NO_x value is high, resulting in higher NO_2 concentrations. The point at which the concentration tends to achieve its conservative maximum is when the NO_x is around 1,000 $\mu g/m^3$ or greater, which gives rise to a maximum one-hour NO_2 concentration of 200 $\mu g/m^3$ – the one-hour national ambient air quality standard. This is illustrated in Figure A1-5.

Figure A1.5: Hourly NO_x vs. NO_2 for all Auckland stations, 2004



Source: Graph courtesy of NIWA, data source ARC.

This maximum conversion occurs when the conversion rate is 0.2 (or 20%). This pattern also occurs in data from Christchurch, and in the 24-hour data (not shown here). Thus the appropriate NO to NO_2 conversion rate to use within the 20–50 m zone away from a roadside is 20%, or a ratio of 0.2.

A similar best-fit relationship between measured NO_2 and NO_x was developed by Scoggins et al using annual average NO_2 and NOx data from a number of Auckland monitoring sites for the period 1995 to 2002. This showed that for high values of NOx the amount of conversion to NO_2 is small. This is due to the other components (such as ozone) being used up. For lower amounts of NOx the conversion to NO_2 can be almost complete, because enough ozone is present to complete all the reactions.

As for previous discussions and recommended methodologies, the figures given here are conservative default values, which should be revised in cases where more accurate, site-specific data are available.

A further discussion of NOx conversion schemes is contained in the companion *Good Practice Guide for Discharges from Industry* (Ministry for the Environment, 2008). These are more relevant to industrial discharges and contain advice and examples on using a slightly different NO to NO_2 conversion methodology. However, the industry case is guided by the fact that most industrial NOx discharges arise from combustion sources that have emissions ratios of NO:NO_2 of the order of 5:95. Vehicle sources can have higher emissions ratios of up to 20:80, which is where the initial conversion factor of 0.2 arises. The use of this factor is justified on the basis of (a) data presented here on measurements in New Zealand, (b) the approach used by Austroads and DEFRA, and (c) consistency with the recommendation in the *Good Practice Guide for Discharges from Industry*.

In summary an appropriate NO to NO_2 conversion rate to use within the 20−50 m zone away from a roadside is 20%, or a ratio of 0.2.

A1.11 Thresholds for Tier 1 assessment

The Tier 1 assessment thresholds are intended to identify proposals that should be assessed using either the Tier 2 or Tier 3 assessment procedures, and (more importantly) to identify projects that do not require assessment. These thresholds are intentionally conservative because they need to capture relatively small projects that may have significant effects because of their location.

Assessments to date have generally focused on arterial roads and state highways. The Transit definition of an urban arterial road is “arterial and collector roads within urban areas carrying traffic volumes of greater than 7,000 vehicles/day”. This was taken as a starting point for developing an assessment threshold.

The Tier 2 assessment method was used to predict maximum contaminant concentrations for a range of scenarios. The results for a road with 3,000 vehicles under congested conditions, and a road with 7,000 vehicles under free-flow conditions, are summarised in Table A1.1. This shows the most conservative concentrations of various pollutants at various distances, based on the two scenarios (the detailed calculation examples are shown below). The grey shaded figures are below the significance criteria, as discussed in the Tier 2 methodology.

For these two scenarios the predicted concentration of CO and NO_2 is below the significance threshold within a few metres of the roadway, and PM_{10} is below the significance threshold within 10 to 20 m of the roadway. Given the conservatism in the calculations, these are considered to be appropriate assessment thresholds.

Table A1.1: Tier 2 screening method results showing effects due to two traffic flow scenarios at various distances from the road

Distance from roadside (m)	Maximum predicted concentration 7,000 vehicles per day (free flow)			Maximum predicted concentration 3,000 vehicles per day (congested)		
	PM_{10} 24-hr μg/m^3	CO 8-hr mg/m^3	NO_2 1-hr μg/m^3	PM_{10} 24-hr μg/m^3	CO 8-hr mg/m^3	NO_2 1-hr μg/m^3
1	6.8	1.3	38.1	4.8	1.0	24.0
5	4.7	***0.9***	26.3	3.3	***0.7***	***16.6***
10	3.5	***0.7***	***19.9***	***2.5***	***0.5***	***12.5***
20	***2.4***	***0.4***	***13.5***	***1.7***	***0.4***	***8.5***
50	***1.1***	***0.2***	***6.2***	***0.8***	***0.2***	***3.9***
100	***0.5***	***0.1***	***2.6***	***0.3***	***0.1***	***1.6***

Calculation examples for 7,000 vehicles per day (free flow)

Assumptions
Emissions factors: as provided in Table 7.1 (NZTER 2004 fleet-weighted average)
Road type: central urban
Congestion level: free flow
Cold start: 20%

Carbon monoxide (eight-hour)
Emission factor = (7.80 x 0.8) + (43.7 x 0.2) = 14.98 g/km
Assume that number of vehicles per eight hours = 40% of daily traffic = 2,800
Maximum predicted concentrations of CO calculated using equations above

Nitrogen dioxide (one-hour)
Emission factor = (2.12 x 0.8) + (2.83 x 0.2) = 2.26 g/km
Assume that the maximum number of vehicles per hour = 5% of daily traffic = 350
Maximum predicted concentration of NO_2 calculated using equations above

PM_{10} (24-hour)
Emission factor = (0.158x 0.8) + (0.332 x 0.2) = 0.193 g/km
Number of vehicles per 24 hours = 7,000
Maximum predicted concentration of PM_{10} calculated using equations above

Calculation examples for 3,000 vehicles per day (congested)

Assumptions
Emissions factors: as provided in Table 7.1 (NZTER 2004 fleet-weighted average)
Road type: central urban
Congestion level: congested
Cold start: 20%

Carbon monoxide (eight-hour)
Emission factor = (24.3 x 0.8) + (43.7 x 0.2) = 28.18 g/km
Assume that number of vehicles per eight hours = 40% of daily traffic = 1,200
Maximum predicted concentrations of CO calculated using equations above

Nitrogen dioxide (one-hour)
Emission factor = 3.32 g/km
Assume that number of vehicles per hour = 5% of daily traffic = 150
Maximum predicted concentration of NO_2 calculated using equations above

PM_{10} (24-hour)
Emission factor = (0.314 x 0.8) + (0.332 x 0.2) = 0.317 g/km
Number of vehicles per 24 hours = 3,000
Maximum predicted concentration of PM_{10} calculated using equations above

A1.12 Benzene emission factors

The impact of fuel specification on benzene emissions has been assessed for the *Review of Fuel Quality Requirements for Australian Transport* (Environment Australia, 2000b). According to this review, petrol engine exhaust is responsible for the bulk of benzene emissions, with relatively small contributions from petrol evaporative losses and diesel engine exhaust. Incomplete combustion of fuel benzene and other aromatics results in exhaust emissions of benzene. The introduction of catalyst technology has led to large reductions in benzene emissions.

Relationships to estimate benzene emissions provided by the Environment Australia review are as follows.

- **Petrol catalyst equipped vehicles:**
  Percentage benzene of exhaust VOC = 1.077 + 0.7732 x % benzene (vol) + 0.0987 x {% aromatics (vol) – % benzene (vol)}
- **Petrol non-catalyst vehicles:**
  % benzene of exhaust VOC = 0.8551 x % benzene (vol) + 0.12198 x % aromatics (vol) – 1.1626
- **Evaporative:**
  % benzene (vapour, New Formulation) = % Benzene (liquid, New Formulation) x 0.9/2.6

Benzene emission factors have been estimated based on these relationships, and New Zealand fuel specifications are shown in Table A1.2.

Table A1.2: The fraction of total aromatics and benzene in New Zealand petrol fuels, including estimates of the percentage of volatiles (VOCs) emitted through exhaust and evaporation

Year of introduction	Petrol specifications			Benzene emission factor		
	Fuel type	% benzene (vol)	% aromatic (vol)	% exhaust VOC (catalyst)	% exhaust VOC (no catalyst)	% evaporative VOC (all)
1998	Regular 91	4.2	48.0	8.65	8.28	1.454
1998	Premium 95	4.3	48.0	8.71	8.37	1.488
2002	Regular 91	4.0	42.0	7.92	7.38	1.385
2002	Premium 95	4.0	48.0	8.51	8.11	1.385
2004	Regular 91	3.0	42.0	7.25	6.53	1.038
2004	Premium 95	3.0	48.0	7.84	7.26	1.038
2006	Regular 91	1.0	42.0	5.90	4.82	0.346
2006	Premium 95	1.0	42.0	5.90	4.82	0.346

For the sake of simplicity, it is recommended that the highest benzene percentage for any one year be adopted.

A1.13 Comparison of New Zealand and Australian emission factors

Table A1.3 shows ratios of emissions estimates based on different emissions factors compared with factors used in Australia (Environment Protection Authority Victoria, or EPA). Values less than 1 imply Ministry of Transport emissions estimates are higher than the EPAs, indicating that the New Zealand Ministry of Transport estimate is more conservative, in part reflecting the tighter emission standards applying in Australia (Auckland Regional Council, 2005a). The comparison shows that the NZTER emissions factors are conservative when compared with Australian factors.

Table A1.3: Comparison of the emissions factors used in Australia with those used in New Zealand

Pollutant	Ratios of total vehicle emissions based on different emission factors (EPA / MoT)		
	1998	2011	2021
CO	1.11	0.91	0.43
CO_2	0.99	0.99	0.99
NO_x	0.86	0.74	0.67
SO_2	0.69	0.52	0.44
TSP	0.90	0.66	0.62
VOC	0.66	0.57	0.45

Notes: EPA = Environment Protection Authority, Victoria; MoT = Ministry of Transport, New Zealand Transport Emissions rate database; TSP = total suspended particulate.

Source: Ministry of Transport.

Appendix 2: Traffic and Transport Data

A key part of undertaking an assessment of a new transport development is the calculation of the changes to the traffic flows within the transport system that will occur, and the resulting shifts and changes in pollutant loads. Traffic and transport models provide the base data in the form of traffic flows and speeds, which can be applied to an emissions database or emissions model to determine the emissions associated with the transport corridor in question.

Transport and traffic models are used for a wide range of planning and evaluation situations, ranging from regional strategic transport planning of large urban areas, to a very localised assessment of a proposed network or land-use change. The nature and extent of models are generally tailored to their use, and so the characteristics and capabilities of models vary as much as the range of situations examined.

The models used in evaluating a transport project need to be capable of producing the traffic outputs that can be used as inputs to the air discharges effects assessment. The models should also be consistent with other relevant documents, such as Transfund's (2004) *Project Evaluation Manual*.

A2.1 Types of traffic model

Traffic and transport models can be categorised and labelled in several ways, as follows.

Demand models

The main purpose of a demand model is to produce travel demands for use in more detailed (assignment-type) models. Such models are calibrated to generate demands from the key pressures and reasons that result in travel (eg, housing patterns, retail facilities, workplace locations, schools), and to be sensitive to those variables that influence changes in travel patterns. The model network representation and zone structure may be relatively coarse. In these models, generally all the travelling vehicles reach their destination during the modelled time period, and specific longer-term, secondary or detailed characteristics are usually not well represented.

Network assignment models

These are not capable of generating travel demands in themselves, and generally have more detailed network and zone structures. The representation of intersections, in particular, may be more specific and detailed, and the assignment procedures compatible with this level of detail.

Depending on the software used, these models will assign all demand in the modelled time period and not be capable of passing over-capacity demand to another time period. Some territorial authorities and others have developed models of this type for evaluating specific roading projects, ranging from regionally significant projects to local network improvement works.

Demand and assignment models

An example of a demand and assignment model is the multi-modal transport model developed by North Shore City Council for the North Shore, which extends onto parts of the Auckland isthmus and CBD. This model produces travel demands and assigns traffic to the network.

Simulation models

These may be network models with simulation capability. They can simulate some detailed characteristics of traffic behaviour, such as representation of queues, and possibly passing of demand from one modelled time period to another. These features may be critical to a local-scale effect assessment. Some software packages are capable of both simulation and non-simulated network modelling, and users can switch between simulation within the immediate study area and non-simulation outside this.

Micro-simulation models

These represent the travel behaviour of individual vehicles, and can be of a network or an isolated situation. Operational characteristics such as lane-by-lane flows, queuing, weaving and merging can be modelled, and different characteristics given to different vehicle types. The use of such models is increasing given their ability to represent driver behaviour in congested and complex network situations.

Isolated models

Isolated models of a single element of the network can represent detailed traffic behaviour and the operational performance of the element. An example would be the model created to assess the upgrading of a single intersection. A combination of assignment and simulation or micro-simulation models is likely to be used for air quality assessments. The wider area may be evaluated with the assignment network model, and the local area or areas of the project are evaluated with the more detailed simulation or micro-simulation models, where the ability to better represent some aspects of driver behaviour is required.

A2.2 Model validation and performance

In the normal course of developing a model for a transport project, the model undergoes a calibration process and is validated against observed base-year data. Once the performance of the model is tested, the required forecasting capabilities are developed. This can be documented in a report. Transfund's *Project Evaluation Manual* sets out criteria and guidelines for the development and validation of traffic models.

Generally, if a traffic model has met the *Project Evaluation Manual* guidelines or has been deemed fit for use by the project's overseeing group, then it will be suitable for providing input data for the assessment of air discharges. However, it is the responsibility of those undertaking the air discharge assessment to provide the supporting information that shows the model is suitable for the assessment, setting out the basis of the model, and its validation, performance and forecasting.

In some cases, there may be a requirement to show that the model is performing adequately in a specific location where emissions are being assessed. This will be done through a validation exercise similar to that described above, and it is preferable for this to be included in the scope of works. This process will need to show that the model adequately reflects the changes between the base case and the option in respect of flows, speeds or delays.

A2.3 Measured traffic data

Traffic counting is undertaken via counting programmes and specific-purpose counts by the agencies involved in the management of the transport system. Transit New Zealand takes counts on the state highway network, and the various territorial authorities take counts on the road networks under their management. Counts are also undertaken by private organisations for their own purposes.

The standard methods for obtaining count data are as follows.

Tube counts

These are taken with a rubber tube laid across the width of a road and using a counting mechanism at the side of the road triggered by pulses of air created when vehicle tyres compress the tube. This method is used at mid-block sites on arterial roads. Two tubes are required to obtain counts by direction. Two tubes placed a specified distance apart across the same width of road can enable speed data and vehicle classification data to be obtained. The latter is based on calculation of the vehicle's wheelbase from the time between air pulses. Generally, tube count data can be obtained for one-hour intervals throughout the day, with the peak periods at 15-minute intervals, although the output format varies. The accuracy of tube counting declines as the levels of congestion increase due to slow-moving vehicles not creating an air pulse. This obviously has implications for air discharge assessments.

Loop counts

These are taken at, or near, intersections controlled by traffic signals with an inductive wire loop embedded under the surface of the road connected to the intersection operating system, called SCATS.[8] The count data can be recorded for a continuous period over some time if required. This method of counting can provide data for each loop, which may be separate for each traffic lane, and by time of day. Speed data are not available using this method. The accuracy of the counts is dependent on the calibration of the SCATS system.

Manual traffic counts

These are usually undertaken at intersections for a specific project to obtain the flows for each turning movement. The data can be segmented into different vehicle types as required for the

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[8] Sydney Coordinated Adaptive Traffic System, (SCATS) by RTA, NSW Australia. The SCATS software package is an area based traffic management intersection control system that responds to changes in traffic flow and conditions by adjusting the phasing at each traffic light cycle in real-time. Across New Zealand, more than 500 traffic signals are coordinated and managed with SCATS.

project. The counts are often taken for the peak periods and may also be for part of the inter-peak period. The use of count data with models varies with the type of model and the time horizon being modelled.

Network models usually obtain initial base-year and forecast traffic demands from a larger network model. Count data are compared with modelled flows to measure how well the model validates. These count data or other independent count data may be used to assist in the adjustment of the demands so that modelled traffic flows better match count data. In these models, it cannot be expected the traffic flows in the base year will match observed counts to a high level of precision in all locations. If there are particular local emissions sites of concern, there may be a need to undertake specific checks on the model's validation at these sites and to use this information when making emissions assessments in future years.

Localised models of intersections or short sections of road may obtain their input traffic flows directly from count data. This is particularly the case where there is no route choice in the model. Hence the modelled flows should replicate the input observed flows.

A2.4 Vehicle classification systems

The vehicle classification systems commonly used in New Zealand are summarised in Table A2.1, as well as estimated equivalencies for NZTER vehicle classifications.

Table A2.1: Classification of vehicles for New Zealand

Axles	Distinguishing features or identification algorithm	Vehicle types in class	Length		Axle	Visual		Light or heavy?	NZTER
			Length range	TNZ length class[1]	TNZ class	PEM class[2]	LTSA class[3]		
2	Number of axles and wb < 3.2 m	o-o (short vehicle)		S	1	Car and LCV	Motorcycle, light vehicles	Light	Car and LCV
3	3 axles and sp ax1-ax2 < 3.2 m or 4 axles and (sp ax1-ax2 < 3.2 and > 2.2) and sp ax3-ax4 ≤ 1.0 m	o-o-o (short vehicle towing) o-o-oo (short vehicle towing)		S/M S/M	2	Car and LCV	Light vehicles	Light	Car and LCV
2	Number of axles and wb ≥ 3.2 m	o--o (long vehicle)	4–11 m	M	3	MCV	Bus, SU 2 axle	Heavy	HCV small (3.5–7.5 t)
3	Number of axles and sp ax1-ax2 ≥ 3.2 m and sp ax2-ax3 ≤ 2.2 m	o-oo	7–11 m	M	4	HCV1	Bus, SU 3+ axle	Heavy	HCV small (3.5–7.5 t)
3	Number of axles and sp ax1-ax2 ≥ 3.2 m and sp ax2-ax3 > 2.2 m	o-o--o	6–15 m	M/L	5	HCV1	Semi	Heavy	HCV medium (7.5–12 t)
4	Number of axles and sp ax1-ax2 ≤ 2.2 m	oo-oo	8–11 m	M	6	HCV1	Bus, semi	Heavy	HCV medium (7.5–12 t)

Axles	Distinguishing features or identification algorithm	Vehicle types in class	Length		Axle	Visual		Light or heavy?	NZTER
			Length range	TNZ length class[1]	TNZ class	PEM class[2]	LTSA class[3]		
4	Number of axles and sp ax1-ax2 > 2.2 m and sp ax3-ax4 > 1.0 m	o--o-o--o o-o-oo	8–19 m 10–17 m	M/L M/L	7	HCV1	Bus, TT	Heavy	HCV medium (7.5–12 t)
5	Number of axles	o--oo-o--o o-oo--oo	16–19 m 11–17 m	L/VL L	8	HCV2	Semi, TT	Heavy	HCV large (> 12 t)
6	Number of axles and sp ax1-ax2 > 2.2 m and sp ax4-ax5 ≤ 1.4 m	o-oo--ooo	15–18 m	L/VL	9	HCV2	Semi	Heavy	HCV large (> 12 t)
6	Number of axles and sp ax1-ax2 > 2.2 m and sp ax4-ax5 > 1.4 m	o-oo-o--oo	16–20 m	L/VL	10	HCV2	TT	Heavy	HCV large (> 12 t)
7	Number of axles and sp ax1-ax2 > 2.2 m	o-oo--oo--oo (B-train) o--oo-oo--oo (T & T) o-oo--oo-o--o (A-train)	18–21 m 18–21 m 18–21 m	VL VL VL	11	HCV2	Semi, TT	Heavy	HCV large (> 12 t)
6, 7, 8	Number of axles (6, 7 or 8) and sp ax1-ax2 ≤ 2.2 m	oo--oo-o--o oo--oo-o--oo oo--oo-oo--oo	15–20 m 17–21 m 18–21 m	L/VL VL VL	12	HCV2	TT	Heavy	HCV large (> 12 t)
8, 9	Number of axles and sp ax1-ax2 > 2.2 m	o-oo--ooo-oo (B-train) o-oo-ooo-o--o (A-train) o-oo-oo-o--oo (A-train) o-oo--ooo--ooo (B-train)	19–21 m 19–21 m 19–21 m 19–21 m	VL VL VL VL	13	HCV2	Semi, TT	Heavy	HCV large (> 12 t)

1 TNZ = Transit New Zealand; S = small (0–5.5 m); M = medium (5.5–11 m); L = large (11–17 m), VL = very large (> 17 m).

2 PEM = Transfund New Zealand *Project Evaluation Manual*; LCV = light commercial vehicle, two axles < 3.5 tonnes; MCV = medium commercial vehicle, two axles > 3.5 tonnes; HCV I = heavy commercial vehicle, type 1 trucks with three or four axles; HCV II = type 2 trucks with five or more axles.

3 LTSA = Land Transport Safety Authority; TT = rigid truck with trailer, semi-articulated semi-trailer; SU 2 = single unit truck with two axles; SU 3+ = single unit truck with three or more axles.

Appendix 3: Vehicle Emissions and Effects

Transport activities have the potential to discharge a large number of different contaminants. Table A3.1 lists those identified by Environment Australia as typically discharged from motor vehicles (Environment Australia, 2000a).

Table A3.1: Substances present in motor vehicle emissions

Acetaldehyde	n-hexane
Acetone	Lead and compounds
Benzene	Manganese and compounds
1,3-butadiene	Nickel and compounds
Cadmium and compounds	Oxides of nitrogen
Carbon monoxide	Particulate matter ≤ 10 μm (PM_{10})
Chromium (III) compounds	Styrene
Cyclohexane	Polycyclic aromatic hydrocarbons (PAHs)
Chromium (VI) compounds	Sulphur dioxide
Cobalt and compounds	Toluene
Copper and compounds	Total volatile organic compounds (VOCs)
Ethylbenzene	Xylenes
Formaldehyde	Zinc and compounds

The health effects associated with some of the key emissions are briefly described below. Comprehensive information is available from a range of sources, including:

- WHO (2005) *Air Quality Guidelines: Global Update 2005*, which includes a comprehensive review of health effects for particulate matter, ozone, nitrogen dioxide and sulphur dioxide
- Ministry for the Environment, 2003a, *Health Effects of CO, NO_2, SO_2, Ozone, Benzene and Benzo(a)pyrene in New Zealand*
- Ministry for the Environment, 2003b, *Health Effects of PM_{10} in New Zealand*.

Carbon monoxide

Carbon monoxide is an odourless gas formed as a result of incomplete combustion of carbon-containing fuels, including petrol and diesel. Carbon monoxide is readily absorbed from the lungs into the bloodstream, which then reacts with haemoglobin molecules in the blood to form carboxyhaemoglobin. This reduces the oxygen-carrying capacity of blood, which in turn impairs oxygen release into tissue and adversely affects sensitive organs such as the brain and heart. Motor vehicles are the predominant sources of carbon monoxide in most urban areas.

As a consequence of the age of the vehicle fleet, New Zealand has relatively high urban air concentrations of carbon monoxide. Nearly 50% of the New Zealand car fleet is more than 10 years old, and only one in five vehicles is less than five years old. It is estimated that 71% of the vehicle fleet is fitted with catalytic converters. However, 10% of these were fitted before leaded petrol was phased out, and it is unlikely that these catalytic converters would still be effective (Ministry of Transport, 2006b).

Long-standing international (and national) ambient air quality standards/guidelines for carbon monoxide are based on keeping the carboxyhaemoglobin concentration in blood below a level of 2.5% to protect people from an increased risk due to heart attacks. This has led to little variation in the standards/guidelines, being typically 10 mg/m^3 as an eight-hour average, and 30 mg/m^3 as a one-hour average. That situation may soon change, because there is emerging research that indicates adverse health effects at carboxyhaemoglobin levels less than 2.5%. This new information is especially relevant to New Zealand, because of the relatively high urban air concentrations of carbon monoxide.

Nitrogen dioxide

Nitrogen oxides (primarily nitric oxide and lesser quantities of nitrogen dioxide) are gases formed by oxidation of nitrogen in air at high combustion temperatures. Motor vehicles are usually the major sources of nitrogen oxides in urban areas. Nitric oxide is oxidised to nitrogen dioxide in ambient air, which has a major role in atmospheric reactions that are associated with the formation of photochemical oxidants (such as ozone) and particulates (such as nitrates). Nitrogen dioxide is also a serious air pollutant in its own right. It contributes both to morbidity and mortality, especially in susceptible groups such as young children, asthmatics and those with chronic bronchitis and related conditions.

Nitrogen dioxide appears to exert its effects directly on the lung, leading to an inflammatory reaction on the surfaces of the lung. Ambient air quality standards/guidelines for nitrogen dioxide are set to minimise the occurrence of changes in lung function in susceptible groups. The lowest observed effect level in asthmatics for short-term exposures to nitrogen dioxide is about 400 $\mu g/m^3$. Although fewer data are available, there is increasing evidence that longer-term exposure to about 80 $\mu g/m^3$ during early and middle childhood can lead to the development of recurrent upper and lower respiratory tract symptoms. A safety factor of two is usually applied to these lowest-observed effect levels, giving air quality standards/guidelines for nitrogen dioxide of 200 $\mu g/m^3$ as a one-hour average, and either 40 $\mu g/m^3$ as an annual average or 100 $\mu g/m^3$ as a 24-hour average.

Volatile organic compounds

Volatile organic compounds are a range of hydrocarbons, the most important of which are benzene, toluene, xylene, 1,3-butadiene, polycyclic aromatic hydrocarbons (PAHs), formaldehyde and acetaldehyde. The potential health impacts of these include carcinogenic and non-carcinogenic effects. According to the World Health Organisation, benzene and PAHs are definitely carcinogenic, 1,3-butadiene and formaldehyde are probably carcinogenic, and acetaldehyde is possibly carcinogenic. Non-carcinogenic effects of toluene and xylene include damage to the central nervous system and skin irritation. Heavier volatile organic compounds are also responsible for much of the odour associated with diesel exhaust emissions.

Motor vehicles are the predominant sources of volatile organic compounds in urban areas. Benzene, toluene, xylene and 1,3-butadiene are all largely associated with petrol vehicle emissions. The first three result from the benzene and aromatics contents of petrol, and 1,3-butadiene results from the olefins content. Evaporative emissions, as well as exhaust emissions, can also be significant, especially for benzene.

Motor vehicles are major sources of formaldehyde and acetaldehyde. These carbonyls are very reactive and are important in atmospheric reactions, being products of most photochemical reactions. PAHs arise from the incomplete combustion of fuels, including diesel.

Of the volatile organic compounds, the most important in the New Zealand context is benzene. The benzene content of petrol was dropped to 1% in 2006 and, as a result, ambient levels have fallen. Health effects data and standards/guidelines for hazardous air pollutants include recommended ambient air quality guidelines for benzene of 10 $\mu g/m^3$ (now) and 3.6 $\mu g/m^3$ (in 2010), both guidelines being annual average concentrations. The implied cancer risks (leukaemia) corresponding to those air concentrations are, respectively, 44 to 75 per million population and 16 to 27 per million population, based on World Health Organisation unit risk factors for benzene.

Sulphur dioxide

Sulphur oxides (primarily sulphur dioxide and lesser quantities of sulphur trioxide) are gases formed by the oxidation of sulphur contaminants in fuel on combustion. Sulphur dioxide is a potent respiratory irritant, and has been associated with increased hospital admissions for respiratory and cardiovascular disease, as well as mortality. Asthmatics are a particularly susceptible group. There appears to be a threshold concentration for adverse effects in asthmatics from short-term exposures to sulphur dioxide at a concentration of 570 $\mu g/m^3$ for 15 minutes. Ambient air standards/guidelines are based on this figure; for example, the national ambient air quality standard is 350 $\mu g/m^3$ as a one-hour average, and the national ambient air quality guideline is 120 $\mu g/m^3$ as a 24-hour average. Sulphur dioxide concentrations in New Zealand are relatively low. However, WHO have significantly reduced their air quality guideline for sulphur dioxide in the 2005 review. At time of publication, the implications of this for New Zealand have not been reviewed.

Sulphur oxides from fuel combustion are further oxidised to solid sulphates, to a certain extent within the engine and completely in the atmosphere. The former inhibits the performance of exhaust emission control equipment for nitrogen oxides and particles, and this is a major reason why the sulphur content of petrol and diesel is being reduced internationally. Many countries are moving to 'sulphur-free' petrol and diesel (less than 10 ppm). It is an unfortunate reality that unless the sulphur content of fuel is less than about 120 ppm, vehicles with advanced emission control systems are actually net producers of additional PM_{10} because of oxidation of the sulphur oxides to sulphates.

Until recently, New Zealand had high-sulphur-content diesel (up to about 2,500 parts per million by volume). However, this was reduced to 50 ppm in 2006, and will be reduced to 10 ppm by 2009. The sulphur content of petrol will be reduced in 2008 from the current level of 150 ppm to 50 ppm. The Government has not introduced a date for the introduction of 10 ppm sulphur petrol.

Particulates

Particulate such as sulphates cause increased morbidity and mortality. The evidence on airborne PM and public health is consistent in showing adverse health effects at exposures experienced by urban populations in cities throughout the world, in both developed and developing countries. The range of effects is broad, affecting the respiratory and cardiovascular systems and extending to children and adults and to a number of large, susceptible groups within the general population. The risk for various outcomes has been shown to increase with exposure, and there is little evidence to suggest a threshold below which no adverse health effects would be anticipated. In fact, the lower range of concentrations at which adverse health effects has been demonstrated is not greatly above the background concentration. The epidemiological evidence shows adverse effects of particulates after both short- and long-term exposures.

Recent preliminary research is showing that it is probably the finer particles causing greater effects ($PM_{2.5}$), and particles from diesel emissions possibly having greater effects than those from other sources.

Ozone

Ozone is a natural substance found in the atmosphere. At lower levels (in the troposphere, up to about 10 km altitude) it occurs through natural reaction with oxygen and is present in concentrations between about 30 and 60 µg/m^3 depending on the latitude and season. At higher levels (in the stratosphere, above 10 km altitude) it forms an important barrier to dangerous ultraviolet light from the sun, and its loss, in the so-called 'ozone-hole', is detrimental to life on Earth. There is very little relationship between tropospheric and stratospheric ozone.

Ozone is also a secondary, urban air pollutant formed by reactions of nitrogen oxides and volatile organic compounds in the presence of sunlight. These primary emissions arise mainly from motor vehicles. Ozone is only one of a group of chemicals called photochemical oxidants (commonly called photochemical smog), but it is the predominant one. Also present in photochemical smog are formaldehyde, aldehydes and peroxyacetyl nitrate.

Ozone is another air pollutant that has respiratory tract impacts. Its toxicity occurs in a continuum in which higher concentrations, longer exposure and greater activity levels during exposure cause greater effects. It contributes both to morbidity and mortality, especially in susceptible groups such as those with asthma and chronic lung disease, healthy young adults undertaking active outdoor exercise over extended periods, and the elderly, especially those with cardiovascular disease. Substantial acute effects occur during exercise with one-hour exposures to ozone concentrations of 500 µg/m^3 or higher.

Ozone, like particulate, is an air pollutant for which there is no indication of a threshold concentration for health effects. More than any other air pollutant there is considerable variation in air quality standards/guidelines for ozone because of the complexities involved in reducing ambient concentrations. In New Zealand a relatively pure approach has been taken and a national ambient air quality standard for ozone of 150 µg/m^3 as a one-hour average, and a national ambient air quality guideline of 100 µg/m^3 as an eight-hour average, have been established.

Appendix 4: Valuation and Comparison of Community Air Pollution Effects

Two approaches are recommended, depending on the level of detail available. These are based on the UK Department for Transport's (2004) *Transport Analysis Guidance* and the *Design Manual for Roads and Bridges* (National Roads Authority and DEFRA, 1992/2003).

- At a strategic or spatially coarse level (where individual link traffic flows and speeds may not be available), quantify the change in total emissions and relate it to the local population density. This method provides a spatially coarse exposure index, and does not provide for the valuation of effects.
- At a project level, quantify the change in exposure at nearby properties. This provides the data necessary to estimate the 'value' of the effects, based on Land Transport New Zealand methodology.

These approaches are discussed in more detail below.

A4.1 Strategic level – health effects index

It is recommended that a strategic-level assessment be used for preliminary comparison of project options if there is not enough information to undertake a project-level assessment. The recommended approach for option assessment at a strategic level will provide a relatively crude *index* of likely health effects, which can be used to compare options, as follows.

1. Select study areas.
2. Calculate *total emissions* (tonnes per year) of PM_{10} for each study area.
3. Estimate the *population* for the study area.
4. Determine the area under study (km^2).
5. For each study area, calculate *emissions per* km^2 *x population density*.

This may provide better information than simply comparing total emissions, because there is some consideration of population density. However, this will depend on the variability of population density and the size of the study areas selected. If the 'study area' is unchanged in each scenario, then the population density will not be relevant. However, if the study areas are carefully selected, the approach will allow two options that may yield the same total benefits, in terms of the change in tonnes of emissions, to be differentiated if one tends to favour emissions savings in populated areas.

This method is also useful when making any comparison with standard emissions inventories, which are available for many regions. These can generally be obtained directly from the relevant regional council or through their website.

This method should only be relied on for preliminary studies (Tier 1). The health effect index provides an indication of likely relative effects, but relies on the assumption that a reduction in emissions will lead to a reduction in the population exposure across the study area. This may not always be the case; for example, options that have a bigger separation distance between the road and adjacent residences may result in lower overall exposure than options with lower emissions and smaller separation distances.

A4.2 Project level – valuation of community air pollution effects

At the project level, the aim is to calculate the likely health effects as a result of change in exposure at properties for each option. This needs to take account of all changes in exposure, whether on existing or new routes. The recommended approach provides an indication of the likely cost associated with overall health impacts. This can assist in comparing project options.

To compare options, it is recommended the likely health costs associated with the 'do minimum' option and each other option are calculated using the following equation from section A8.2.5 of the *Project Evaluation Manual* (Transfund, 2004). This is a simplified approach, but is accepted as a standard method in many countries, and it is the approach used by the World Health Organisation when making international assessments. The Transfund methodology relies on PM_{10} to estimate health effects. This is a valid approach in most cases because the effects of PM_{10} tend to dominate. However, the same approach could be applied to other pollutants (for example, NO_2 in Auckland).

Equation A4-1

Effect = health effect factor x ΔPM_{10} x population exposed x normal death rate x value of life

where:

- health effect factor is the percentage increase in daily mortality for a 1 $\mu g/m^3$ increase in PM_{10} concentration (it is currently recommended that a value of 0.43% be used; Fisher et al, 2005)
- ΔPM_{10} is the change in annual average PM_{10} concentration ($\mu g/m^3$)
- normal death rate is taken from the published life tables in New Zealand and is currently 7.53 per year per thousand people, calculated in 2003 (normal death rate data are available from www.stats.govt.nz)
- value of life is derived from the analysis conducted by the Land Transport Safety Authority (LTSA) and Ministry of Transport in relation to crash deaths. It is not the same as a crash death, because air pollution affects people differently to crashes (see Fisher et al, 2005). It is recommended that a value of $750,000 be used.

The above relationship is simplified and is given here to demonstrate the process. Some evaluations use a threshold value, assuming that for low values of annual PM_{10} the effect is negligible. This has been set at 7.5 $\mu g/m^3$ in some work, and also nominally accounts for natural background levels (although, in the cases being examined here this would not generally apply, since in most urban areas the concentration is already above 7.5 $\mu g/m^3$ and the incremental effect needs to be quantified. **The relationship should also be used only on the population over 30 years old, since the work it is based on used this population.**

The average change in PM_{10} concentration across the population exposed can be determined through dispersion modelling studies. Alternatively, the following methodology adapted from the *Design Manual for Roads and Bridges* (National Roads Authority and DEFRA, 1992/2003) can be used to calculate ΔPM_{10} concentration x population exposed.

1. Estimate the roadside annual average PM_{10} concentration for the 'do minimum' and for each option, for each road or link being considered. Annual average PM_{10} concentrations can be calculated based on the method described in Appendix 1.

2. For each affected road (new road and existing), calculate the difference in roadside levels of PM_{10} (ΔPM_{10} roadside) between the 'do minimum' and proposed scenarios. A positive value should be assigned where an increase in concentration has been identified, and a negative value for a decrease in concentration.

3. For each affected road, estimate 'banded' property counts. The properties should be banded and the number of properties within each band recorded. These property counts should then be weighted using the factors below. This weighting accounts for the reduction in pollutant concentration with distance from the road. It is assumed that beyond 200 m the contribution of vehicle emissions from the roadside to the local ambient air concentrations is not significant.

Table A4.1: Banding and weighting of property counts

Bands (measured from edge of the carriageway)	Weighting*
Roadside to 50 m from roadside	1.00
51 to 100 m from roadside	0.20
101 to 150 m from roadside	0.10
151 to 200 m from roadside	0.05

* Weightings are based on the annual average dispersion curve developed by Scoggins et al, 2004.

4. The overall health cost for each option can then be estimated based on the following equation:

Equation A4-2

Effect = health effect factor x normal death rate x value of life x $\Sigma_{\text{each link}}$ {ΔPM_{10} roadside x number of weighted properties on link x property occupancy rate}

Key Data Sources and Models

BEPM

The Bus Emissions Prediction Model (BEPM) is available on CD-ROM from the Auckland Regional Council (www.arc.govt.nz).

Meteorological data

Standard meteorological data can be obtained from the National Climate Database, run by NIWA (www.niwa.co.nz).

Normal death rate

National and regional figures are available from the Statistics New Zealand website (www.stats.govt.nz).

NZTER

The New Zealand Transport Emissions Rate database (NZTER) is available on CD-ROM from the Ministry of Transport (www.transport.govt.nz).

VFEM

The Vehicle Fleet Emissions Model, available from the Ministry of Transport.

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