NZ Transport Agency Guide to road tunnels

New Zealand supplement to the Austroads *Guide to road tunnels*

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WAKA KOTAHI

New Zealand Government

NZ Transport Agency Guide to road tunnels

(New Zealand supplement to the Austroads *Guide to road tunnels*)

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Document management plan

1) Purpose

This management plan outlines the updating procedures and contact points for the document.

2) Document information

Document name	*NZ Transport Agency Guide to road tunnels*
Document number	-
Document availability	This document is located in electronic form on the NZ Transport Agency's website at www.nzta.govt.nz.
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3) Amendments and review strategy

All corrective action/improvement requests (CAIRs) suggesting changes will be acknowledged by the document owner.

	Comments	Frequency
Amendments (minor revisions)	Updates to be notified to users by publication of a technical memorandum placed on the NZ Transport Agency's website.	As required.
Review (major revisions)	Periodic updates will be undertaken where amendments fundamentally changing the content or structure of the guide or new technology resulting from research or ongoing refinement have been identified.	As required.
Notification	All users that have registered their interest by email to info@nzta.govt.nz will be advised by email of amendments and updates.	Immediately.

4) Distribution of this management plan

Copies of this document management plan are to be included in the NZ Transport Agency intranet.

Record of amendments

This document is subject to review and amendment from time to time. Amendments will be recorded in the table below.

Changes since the previous amendment are indicated by a vertical line in the margin. The date of issue or amendment of a page appears in the header on each page. This page will be updated each time a new amendment is released.

Amendment number	Description of change	Effective date	Updated by
0	The *NZ Transport Agency Guide to road tunnels* 1st edition published.	December 2013	Nigel Lloyd

Contents

1.0 Introduction

1.1 Background

The NZ Transport Agency formally integrated the Austroads road engineering guides into their business from the 1st August 2010 including the *Guide to road tunnels*[(1)] (AGRT), which comprises:

- part 1: Introduction to road tunnels
- part 2: Planning, design and commissioning
- part 3: Operation and maintenance.

The AGRT[(1)] is a best practice guideline that impacts on processes or procedures, rather than physical works.

1.2 Purpose of this document

This *NZ Transport Agency Guide to road tunnels* is a supplement to the Austroads *Guide to road tunnels*[(1)]. It provides specific guidance regarding the design, operation and maintenance of road tunnels on state highways in New Zealand.

The principles and processes outlined in the AGRT[(1)] (and those standards and guidelines referenced in section 2 of this document) shall be adopted for planning new tunnels or refurbishing existing tunnels in New Zealand. This *Guide to road tunnels* provides specific definitions or exceptions to the requirements of the AGRT[(1)] and other guidance documents listed in section2.

1.3 Road tunnel definition

Clause 2.2 of the AGRT[(1)] part 1 (AGRT01) states:

> Any fully enclosed length of roadway may be called a road tunnel … Tunnels may be generally classified as short or long but there is no definitive cut-off point with various jurisdictions identifying a minimum length of between 80m and 150m as the length above which the structure is considered to be a tunnel. Whether a tunnel is considered to be short or long is based on the risks involved and can also be related to the function being considered (e.g. lighting; ventilation; fire and life safety).

NFPA 502: *Standard for road tunnels, bridges, and other limited access highways*[(2)] is a USA based fire safety standard for road tunnels longer than 90m. NFPA 502[(2)] requires conditionally mandatory mechanical ventilation for smoke control for tunnels over 240m in length. Tunnels between 90m and 240m may not require mechanical smoke control depending on traffic type and volume, and may also be able to achieve internal air quality standards through natural ventilation.

1.3 continued

The provisions of the AGRT[1] and this *Guide to road tunnels* shall be applied as follows:

- Any covered roadway less than 80m in length is considered an underpass and is therefore not covered by the AGRT[1] or this *Guide to road tunnels*.
- Any tunnel between 80m and 240m in length shall be assessed utilising the processes defined in this guide to determine what, if any fire safety provisions may be required.
- For all tunnels over 240m in length, the requirements of this guide shall apply.

1.4 Roles and responsibilities

The following roles and responsibilities are defined in the Transport Agency specification S8 *Tunnels management and inspection policy*[3]:

- tunnel manager
- safety manager
- tunnel inspection engineer (structures)
- tunnel inspection engineer (M&E)

The Transport Agency will appoint a tunnel manager to be consulted during the investigation and reporting (I&R) phase and subsequent tunnel design stages to give a whole of asset life overview of the tunnel, its role within the wider road network (by liaison with the operations manager) and its operation and maintenance.

The Transport Agency will designate a safety manager for the I&R phase, the construction stage, and the operation stage. In particular the safety manager shall be consulted in the preparation of the design philosophy statement prepared to address fire and life safety strategy as part of the detailed business case (refer to 2.6).

2.0 Design and construction of tunnels

2.1 Principles

The philosophy of this *Guide to road tunnels* can be summarised as follows:

- The performance and fire life safety of new and existing tunnels is dependent upon a complex interaction of various attributes that contribute to risk, consequence and cost. It is therefore not practical to specify particular standards for these attributes especially for the retrofit of existing tunnels. Each case needs to be considered on its individual attributes and merits.
- Suitably skilled and experienced personnel, as defined in S8 *Tunnels management and inspection policy*[3] need to be involved throughout the planning, design and construction, commissioning phases and also during subsequent operations and maintenance phases.
- Risk processes shall be adopted in accordance with AS/NZS ISO 31000 *Risk management - Principles and guidelines*[4] (and other references listed in 2.2) that identify specific characteristics of each tunnel and demonstrate the adequacy of proposed safety provisions (refer section 3).

2.1 continued

- Residual risks for existing tunnels may be higher than otherwise desirable even after refurbishment because opportunities to eliminate risks may not exist without disproportionate cost. The detailed business case process shall include the consideration of the 'do minimum' option together with a full range of incremental improvement options, risks, consequences and costs. The improvement options shall include consideration of operational measures, where appropriate, used to reduce risk rather than just infrastructure improvements.
- The final decisions regarding the acceptability of risks and value for money will rest with the Transport Agency Board.

2.2 New Zealand references

The planning, construction, operation and maintenance of road tunnels in New Zealand shall also comply with the following statutory and regulatory requirements:

- Building Act 2004
- Health and Safety in Employment Act 1992
- Health and Safety in Employment (Mining-Underground) Regulations 1999
- regional plan requirements.

The MinEx *Industry code of practice – Underground mining and tunnelling*(5), definitions and statements of preferred work practice shall be used in conjunction with the above documents.

2.3 New tunnels

Part 2 of the AGRT(1) (AGRT02) gives general principles and requirements for design and construction but does not address either the assessment of risk levels for existing tunnels, which may result in refurbishment, or the retro-fitting of components in order to improve safety. Section 3 of this *Guide to road tunnels* details the required risk assessment processes with respect to existing NZ road tunnels.

The following design principles shall be applied when considering tunnel designs in New Zealand for new build tunnels. The design and construction of underground structures shall:

- comply with the designation and resource consent conditions
- minimise whole-of-service-life costs
- include detailed risk assessments and risk management plans for all aspects of the proposed design, and construction (refer section 14 of the AGRT(1) part 2) in accordance with *A code of practice for risk management of tunnel works*(6) prepared by the International Tunnelling Insurance Group (the 'Code') and the International Tunnelling Association/AITES *Guidelines for tunnelling risk management: International Tunnelling Association, working group no. 2*(7).

Fire and life safety requirements shall be developed in accordance with AS4825 *Tunnel fire safety*(8) unless otherwise modified by this *Guide to road tunnels*.

2.4 Operations and maintenance requirements

2.4.1 General

The operations and maintenance requirements of tunnel infrastructure shall be explicitly addressed during the I&R, design and construction phases of road tunnels through consultation with the tunnel manager, and the tunnel safety manager.

The management and setting of performance standards for operations and maintenance of road tunnels is provided in part 3 of the AGRT(1) (AGRT03). This guidance should be followed for both new and existing tunnels in New Zealand.

Methods for risk assessment are discussed further in section 3.

2.4.2 Dangerous goods

Dangerous goods shall preferably be excluded from tunnels where there is an accessible diversion route, unless the risk assessment undertaken in accordance with the requirements in section 3 indicates an acceptable level of safety for the passage of dangerous goods.

Where dangerous goods are excluded, this shall be detailed in the tunnel bylaws.

2.5 Modifications to the Austroads *Guide to road tunnels* and AS 4825

This section includes required modifications to the AGRT(1).

a. Part 2 (AGRT02) section 8 Fire safety, details the use of AS 4825 *Tunnel fire safety*(8), which at the time the AGRT(1) was published was in draft. The following amendments to AS 4825(8) are required for the New Zealand context:

   i. AS 4825(8) section 1.5 – Referenced documents

   New Zealand and Australia have several joint standards. Further various Australian standards are commonly recognized and used by New Zealand regulations or related documents. New Zealand specific standards are listed below which may be used in lieu of or in conjunction* with the equivalent Australian Standard.

NZS 4503	*Hand operated fire-fighting equipment*(9)
SNZ PAS 4509	*New Zealand Fire Service firefighting water supplies code of practice*(10)
NZS 4510	*Fire hydrant systems for buildings*(11)
NZS 4512	*Fire detection and alarm systems in buildings*(12)
NZS 4541	*Automatic fire sprinkler systems*(13)

   New Zealand *Building code*(14)

   Building Act 2004

   Fire Safety and Evacuation of Buildings Regulations 2006

   Fire Service Act 1975

* In some cases the fire protection required in a tunnel is beyond the scope of the New Zealand Standards. In these cases it is typically acceptable to agree with the authority having jurisdiction (AHJ) that an Australian or international standard is used. For example NZS 4541(13) does not cover in sufficient detail deluge systems or water mist in tunnels and hence the relevant Australian or NFPA standards would normally be acceptable to the extent permitted by the authority having jurisdiction.

2.5 continued

ii. AS 4825[8] section 1.6 Definitions, 1.6.4 Dangerous goods

Dangerous goods are defined in accordance with the Land Transport Rule: Dangerous Goods 2005 and Dangerous Goods Amendment 2010.

iii. AS 4825[8] section 3.2 Stakeholders, 3.2.12 Transport safety agencies

There is not a comparable "Transport Safety Agencies" within the New Zealand context and hence this section should be deleted.

The local government body shall be added as a stakeholder and approving authority.

b. Other considerations – hydrant coverage

Hydrant coverage in Australia is based upon 30m hose length and hence a maximum 60m spacing between outlets. The NZ Fire Service use 25m hose lengths hence the required hydrant spacing from the NZ Fire Service is 50m.

This hydrant spacing is also likely to affect other parts of the design such as cross passage spacing and deluge zones.

2.6 Detailed business case considerations

Table 2.1 clarifies the requirements of this *Guide to road tunnels* with respect to the scope of the detailed business case.

Table 2.1 Detailed business case requirements

Detailed business case	*Guide to road tunnels* requirements
Detailed business case – general	All new and proposed tunnel upgrade projects shall meet the requirements of the Transport Agency detailed business case.
Social and environmental screen	All tunnel options are to be assessed in accordance with Transport Agency Minimum standard Z/19 – *Social and environmental management*[15].
Other client requirements	All tunnel upgrade projects shall prepare a do nothing option for comparison with other options.
Consultation	The consultant shall undertake consultation as part of the detailed business case phase with emergency services including the NZ Fire Service.
Risk	The fire and life safety risk analysis described in section 3 shall be undertaken in the detailed business case phase.
Design reports	The detailed business case shall include a: • draft fire engineering brief • preliminary structures options report as defined in the *Bridge manual*[16] appendix F.
Peer review	All detailed business cases for road tunnels shall be subject to a peer review.
Value assurance decision making approvals	A VAC report as described under this clause shall be prepared for all road tunnel projects. The executive scheme summary shall include a comparison to a do nothing option for all upgrade projects, and shall also address the key aspects of the fire and life safety risk assessment and draft fire engineering brief.
Statutory approvals	The requirements of this section will include air quality assessments for all road tunnels – refer to section 4.

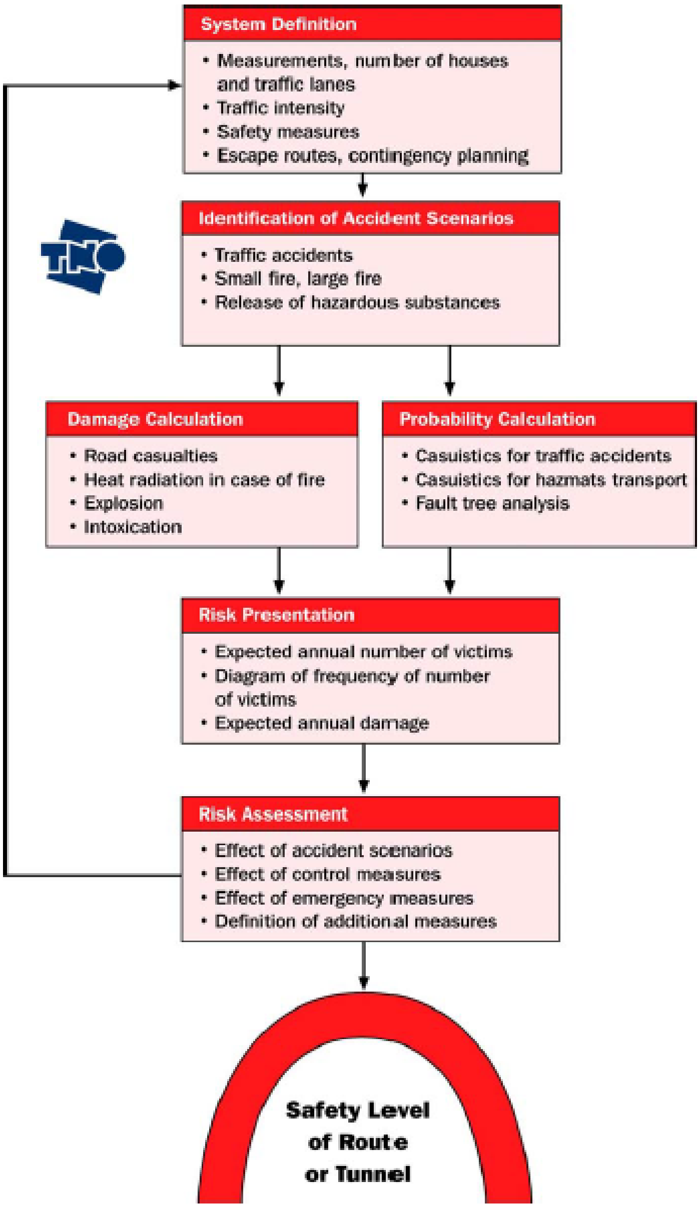
3.0 Fire and life safety risk management

3.1 Risk analysis

3.1.1 Background to the process

The risk assessment process for road tunnels is described in UPTUN Workpackage 5 *Evaluation of safety levels and upgrading of existing tunnels*(17) and the process is shown schematically in figure 3.1.

Figure 3.1 UPTON WP5(17) risk assessment process



PIARC, in section 5.1 of *Risk analysis for road tunnels*(18), summarises risk assessment processes as follows:

> [R]isk-based approaches make it possible to propose relevant additional safety measures in terms of risk mitigation and can be the basis for decision-making considering cost-effectiveness in order to assure the optimum use of limited financial resources. …

3.1.1 continued

> [T]he choice of the methods should be done by considering the respective advantages/disadvantages in the context of a specific situation. The selection of the appropriate method to investigate given issues has to match the specific problem, the required depth of assessment and the available resources. It has to be taken into account that quantitative methods (e.g. simulations or statistical analysis) are normally more complex and therefore involve more effort than qualitative methods (e.g. expert judgements). Furthermore, quantitative methods require specific quantitative input data which may not be available or may not be of the quality required. In addition, it has to be considered that methods cannot be chosen arbitrarily; certain components for risk evaluation require specific components for risk analysis. …
>
> [T]here is no doubt, that a risk-based approach in the context of road tunnel safety assessment is an appropriate and valuable supplement to the implementation of measures which are necessary to fulfil the requirements of prescriptive standards and guidelines.

However, in section 5.2 of *Risk analysis for road tunnels*(18) PIARC cautions:

> [T]he result of a quantitative risk analysis must be interpreted as an order of magnitude and not as precise number. Risk models inevitably deliver fuzzy results, so risk evaluation by relative comparison (e.g. of various safety measures or of an existing state to a reference state of a tunnel) may improve the robustness of conclusions drawn.

3.1.2 Requirements

Each risk analysis for road tunnels will address the following matters:

- Consideration of the risks for the safety of users of the road tunnel taking into account all design factors and traffic conditions that affect safety, including: traffic characteristics and type; the length of the road tunnel; the tunnel geometry; and the forecast of the number of heavy goods vehicles which are likely to use the tunnel each day.
- For existing tunnels evaluation of whether the proposed measures will result in equivalent or improved protection for users of the road tunnel compared to the existing situation.
- Identification of the potential hazards arising from the use of the proposed risk reduction measure.
- Identification of the users of the road tunnel who could be affected by the hazards and evaluation of the probabilities of harm to them.

3.2 Fire safety design

Fire safety design for new and existing tunnels shall address the following matters:

- minimising the likelihood of an incident occurring which could give rise to a fire
- minimising the impact of a fire event and providing adequate means of escape for occupants post fire incident
- providing adequate protection to the tunnel asset or other Transport Agency assets post fire incident
- providing adequate protection to non-Transport Agency property or land that could be affected by a tunnel fire.

3.3 New tunnels

Fire and life safety in new tunnels shall be designed in accordance with AS 4825 *Tunnel fire safety* [8] as modified by section 2.5 of this *Guide to road tunnels* for specific New Zealand considerations.

The key requirements shall be addressed in a new tunnel as follows:

- incidents are minimised through road design and operational procedures, which is covered in part 2 of the AGRT[1] (AGRT02)
- minimum levels of safety as defined by the Building Act 2004
- protection of the tunnel asset is governed by the Transport Agency's internal policies
- protection to neighbouring property to levels defined by the Building Act 2004 and Resource Management Act 1991 provisions, ie resource consent conditions.

Consideration is also given in tunnel design of the societal impact of a large scale fire event in the tunnel and its effect on road users' perception in using tunnels as a safe transport route. Hence for the above reasons, fire and life safety design in tunnels is expected to pose a lower risk compared to open road incidents or to buildings which comply with the minimum requirements of the *Building code*[14]. This is reflected in AS 4825[8] clause C6.4.4.2.1:

> The communities' perception of fire hazard in tunnels is greater than on open roads. Target levels of risk due to fire in tunnels may be compared to currently accepted risks from all causes on open roads. Suggested target due to fire death should be about two orders of magnitude lower than that generally from all accidents for the particular mode of transport.

With little real life fire data within New Zealand or Australia, fire and life safety provisions in new tunnels have historically been developed from international good practice into a precedent based design providing an ALARP (as low as reasonably practicable) risk profile for that particular tunnel.

AS 4825[8] outlines a methodology for assessing specific fire safety requirements of individual tunnels. Key issues for specific tunnels include:

- Bi-directional or uni-directional. Uni-directional tunnels are generally regarded to have a significantly lower risk profile than bi-directional tunnels due to the ease of smoke control.
- Smoke hazard management. The type and extent of smoke hazard management systems provided (such as longitudinal smoke control or a dedicated smoke duct) depend on specific characteristics of the tunnel such as type of vehicles permitted in the tunnel, likelihood of congestion, grade, length etc.
- Egress provisions. Number and spacing of tunnel exits dependent upon type of vehicles permitted in the tunnel, likelihood of congestion, grade, length etc.

3.4 Existing tunnels

3.4.1 Overview

Existing tunnels are governed by the Transport Agency's internal policies for incident prevention and property protection of the tunnel asset. The Transport Agency is not bound by legislative requirements to upgrade the fire and life safety within the tunnel.

The Building Act 2004 does not require the existing structure to be bought up to modern day standards unless an alteration occurs such as a refurbishment. Outside of refurbishment, any improvements which solely include life safety, would be expected to be favourably regarded by the regulatory authorities and the NZ Fire Service and would not enact an overall systems upgrade to modern standards. Hence decisions on providing significant upgrades to an existing tunnel generally will rest with the Transport Agency.

Existing tunnels also differ from new tunnels as data is obtainable on historical incident and fire events. This can provide insight into whether a significant fire event or accident leading to this event is likely or unlikely to occur compared with international norms. The Transport Agency has funding available for improving the safety of its entire transport network. Hence, upgrades for fire and life safety systems in existing tunnels shall be viewed in terms of cost/benefits to comparable risks on the open road. The desirable levels of risk for road tunnel fire death shall be between one and two orders of magnitude less than the road network.

3.4.2 Acceptable absolute risk levels for existing tunnels

Absolute risk within a transport network in New Zealand is considered in terms of collective risk or personal risk. Collective risk is the proportion of events in given time frame per length of road. The higher the usage of a road (or tunnel), the greater the collective risk.

$$Collective\ risk\ = \frac{Average\ number\ of\ serious\ and\ fatal\ events\ per\ year}{Length\ of\ road\ or\ tunnel}$$

Collective Risk highlights how likely a road or tunnel is to have a high number of fire events giving risk to fatal and serious injuries – this can be used to help determine how the risk of a fire in a particular tunnel compares to the risk of a crash event on the open road which gives rise to fatal and serious injuries.

Personal risk is the proportion of events per vehicle km travelled. Hence a busy urban road may have a low personal risk but a high collective risk.

$$Personal\ risk\ = \frac{Average\ number\ of\ serious\ and\ fatal\ events\ per\ year}{100\ million\ vehicle\ /\ km}$$

Risk levels have been assessed for New Zealand rural state highways on a five category rating system as shown in table 3.1.

3.4.2 continued

Table 3.1 KiwiRAP risk map ratings, rural roads

Risk description	Star rating	Collective risk (average annual fatal and serious injury crashes per km)	Personal risk (average annual fatal and serious injury crashes per 100 million vehicle-km)
Low	5	≤ 0.039	< 4
Low - medium	4	$0.04 \leq 0.069$	$4 \leq 4.9$
Medium	3	$0.07 \leq 0.10$	$5 \leq 6.9$
Medium - high	2	$0.11 \leq 0.189$	$7 \leq 8.9$
High	1	0.19 +	9 +

The KiwiRap review of 10,002 kilometres of state highway showed the following distribution of star ratings:

- 5 Star 0 % (Low risk)
- 4 Star 5 %
- 3 Star 56 %
- 2 Star 39 %
- 1 Star 0 % (High risk)

It is desirable that existing tunnels have an equivalent level of risk between 1 and 2 magnitudes lower than 95% of the road network (assessed by KiwiRAP), ie that existing tunnels should develop safety systems and be assessed to have an equivalent safety level of between 1 and 2 orders of magnitude higher than medium risk or 3 stars. Therefore with reference to table 3.1, the desirable risk levels for existing tunnels are shown in table 3.2.

Table 3.2 KiwiRAP risk map ratings converted to serious and fatal tunnel fires

Risk type	Desirable level of safety for existing tunnels
Collective risk (average annual significant fire event per km)	$0.01 \geq 0.001$
Personal risk (average annual significant fire event per 100 million vehicle-km)	$0.69 \geq 0.069$

Note:
A significant fire is defined as a fire which would be expected to result in fatalities or significant injuries. Significant injuries are defined as injuries requiring hospital admission

3.5 Fire and life safety assessment process

Any decisions regarding the fire and life safety design of a new tunnel or the upgrade of an existing tunnel, requires a robust process involving relevant stakeholders from preliminary design to commissioning. The "Fire Engineering Brief" process commences with the preparation of a fire engineering brief (FEB) and progresses to a fire engineering report (FER) prepared at the end of the design process. This fire engineering process is summarised in figure 3.2.

Third party reviewers (ie peer reviewers) and the New Zealand Fire Service need to be involved in the formation of the fire engineering brief to agree to the inputs, methodologies and approaches going forward, as shown in figure 3.3.

Figure 3.2 Key stakeholders involved in the fire engineering brief development

At the end of I&R phase the following information shall be available to enable decisions to be made on the adequacy and appropriateness of key proposed fire safety precautions particularly when these represent a high cost and / or benefit to the project:

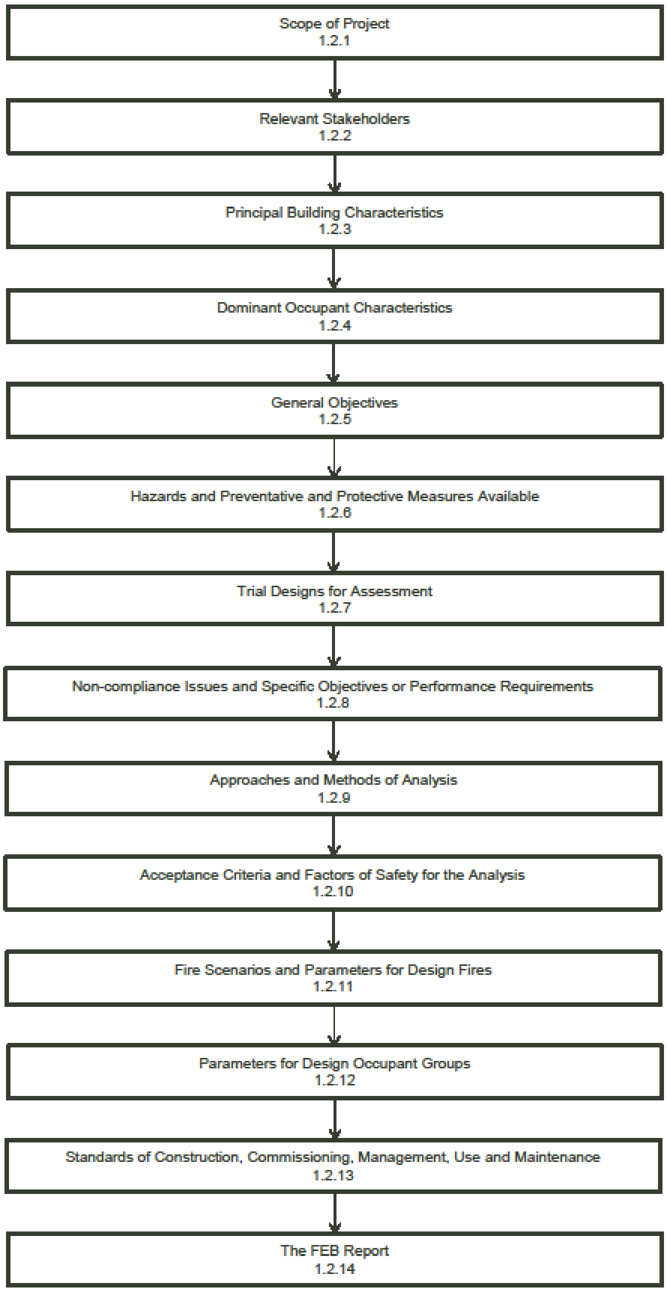
- development of a range options for key fire and life safety precautions
- risk profile definition allowing comparison between each option and to comparable open road collective and personal risk values
- costs associated with each option shall be prepared to enable cost benefit assessment.

These shall be documented in the detailed business case.

Risk profiles incorporate the risk of an event occurring and the consequences. These shall be preceded with a transparent and straight forward methodology so that a non-technical person can make an informed decision on which options are undertaken. This is of particular importance for existing tunnels. With little or no regulatory requirements for upgrade the decision on what is provided will largely rest with the Transport Agency on a value for money basis.

The agreed fire and life safety design provisions shall be documented in a preliminary fire engineering brief that shall be prepared to satisfy the requirements of a preliminary design philosophy report.

Figure 3.3 Fire engineering brief process as reproduced from *International fire engineering guidelines*[19]



4.0 Air quality

4.1 Introduction

Tunnels can be used to capture vehicle emissions and control their dispersion into the atmosphere providing a mechanism for reducing community exposure to elevated concentrations of air pollution. Conversely tunnels can also give rise to localised air quality issues. For example transport-related air pollution may become elevated near a tunnel portal or create localised 'hot spots' as a result of the discharge of emissions from ventilation points or stacks. (See *Managing air quality in and around road tunnels in New Zealand*[20].)

The air quality objectives associated with road tunnels that need to be addressed include:

- ensuring the safety of public users in tunnels
- ensuring the safety of workers in tunnels
- monitoring compliance with consent conditions
- identifying trends in emissions.

The operational costs of running tunnel ventilation systems can be significantly impacted by ambient (external) air quality requirements defined through the consenting process.

4.2 Statutory requirements

4.2.1 Regulations

The *National environmental standards for air quality* (NESAQ)[21] were issued as regulations under the Resource Management Act 1991 in 2004. The NESAQ[21] specify ambient air quality standards for a variety of air pollutants over various times ranging from one hour, to a year and a prescribed number of annual exceedances. The NESAQ[21] apply in open areas where people may be exposed over the relevant averaging period. They do not apply inside tunnels but may apply around tunnel portals or in locations where emissions from a tunnel ventilation stack may impact. In addition to the NESAQ[21], the Ministry for the Environment has published *Ambient air quality guidelines*[22] and various regional councils have set regional air quality targets, see www.mfe.govt.nz.

4.2.2 Model designation condition

The following model designation condition should be applied to all new road tunnel projects where it has been determined that there is likely to be a 'significant' air quality impact caused by the project (anticipated to be longer tunnels, >1km, that carry high volumes of traffic in urban areas):

> The tunnel ventilation system shall be designed and operated to ensure that any air emitted from the tunnel portals does not cause the concentration of nitrogen dioxide (NO_2) in ambient air to exceed 200 micrograms per cubic metre ($\mu g/m^3$). This should be expressed as a rolling 1 hour average at sites that border a highly sensitive, air pollution sensitive land use that are within 100m of the designation boundary.

4.2.2 continued

This model designation condition reflects the requirements of the national environmental standard for nitrogen dioxide (NO_2) concentration in ambient air. NO_2 is used as a 'marker' for transport-related air pollution (ie vehicle emissions). If NO_2 is managed appropriately around tunnel portals then levels of other air pollutants caused by emissions from vehicles using the tunnel are expected to be well within relevant criteria. The condition seeks to manage air pollution where the risk of prolonged exposure to transport-related air pollution is likely to be greatest, ie at the boundary of the state highway designation and any highly sensitive air pollution sensitive land uses.

4.3 Tunnel ventilation

Tunnel ventilation requirements depend on the length, grade and cross section of the tunnel, and the volume and mix of traffic. Tunnels may be ventilated either naturally or mechanically. Tunnel ventilation must achieve the following requirements:

- Air quality inside the tunnel meets relevant criteria.
- There is adequate visibility for road users inside the tunnel by diluting, dispersing and discharging to the external atmosphere particulates and other vehicle emissions.
- Discharges of vehicle emission to the external atmosphere comply with relevant ambient air quality standards, guidelines and targets.
- During fire events heat and smoke is managed and extracted from the tunnel, self-egress of road users is enabled and access for emergency services to deal with the fire is provided.

The ventilation requirements for road tunnels are generally controlled by fire life safety considerations, especially assumptions made about the design fire case and whether or not vehicles carrying dangerous goods will be permitted to use the tunnel. Air quality considerations are primarily concerned with the normal operation of a tunnel.

There are two air quality issues that need to be considered when planning, designing and operating a ventilation system:

- In-tunnel air quality.
- Ambient (external) air quality effects arise from the discharge of vehicle emissions generated inside the tunnel to the external ambient atmosphere either at the portals or from a vent stack. Emissions can be discharged to the external atmosphere at the portal via natural ventilation as a result of the piston effect in single direction tunnels caused by vehicles using the tunnel. By contrast forced ventilation will result in emissions being discharged either at the portal, from a vent stack or a combination of both.

Air quality in and around a tunnel is influenced by numerous factors including; tunnel geometry, tunnel length, traffic flow, vehicle fleet mix, vehicle emission standards, traffic speed, road gradient, tunnel ventilation system design and operation, tunnel traffic operation procedures, surrounding topography, background air quality, and local meteorology. The tunnel ventilation concept may also be influenced by the location of any highly sensitive 'air pollution' land uses near the tunnel, eg residences, schools and hospitals.

4.3 continued

Air quality effects associated with new and improved road tunnels should be assessed in accordance with the draft Transport Agency *Guide to assessing air quality effects for state highway asset improvement projects*(23). This document provides a risk-based approach to assessing such effects and identifies the need to consider undertaking a specific tunnel air quality effects assessment for tunnels greater than 90m in length. The assessment guide is aligned to this *Guide to road tunnels* and promotes the need for close co-operation between planners, air quality scientists and tunnel ventilation designers working on such projects.

4.4 Ventilation stacks and portal emissions

Discharges of vehicle emissions via appropriately designed vent stacks will ensure that emissions are dispersed and diluted so that there is minimal or no effect on local ambient air quality. The location, height, and efflux velocity of vent stacks largely controls their effectiveness in terms of air pollution control. In particular, to ensure adequate dispersion and dilution, stacks should be sufficiently (potentially up to two and half times) higher than surrounding buildings and should avoid being sited in valleys or other locations with unfavourable meteorological characteristics, eg street canyons.

Vent stacks are generally only required for longer tunnels (typically longer than 1km) in urban areas with high traffic flows due to the potential for elevated levels of vehicle emissions to accumulate inside the tunnel at certain times. Estimates suggest only 1% of all tunnels world-wide are fitted with stacks.

Even when a vent stack has been constructed, when traffic is free-flowing and volumes are relatively low and external weather and air quality conditions are favourable, it may be appropriate to limit the use of the stack and discharge emissions via the portals. Depending on the location and design of a vent stack (and associated ventilation system buildings) such structures can have a significant visual effect and create the perception of adverse air quality effects associated with a road tunnel (see urban design details in 5.4).

Short tunnels will generally not need a vent stack where one or more of the following characteristics are met; free-flowing traffic, relatively low traffic volumes; few, if any, highly sensitive air pollution land uses nearby; or located where there is good background ambient air quality. In such circumstances, portal emissions are the most appropriate means of discharging vehicles emissions to the external atmosphere.

Designation conditions need to provide for portal emissions to avoid unnecessary and excessive design and operating costs for ventilation systems. The capital and operational costs of tunnel ventilation systems are considerable. Significant cost savings can be made by avoiding inappropriate ventilation system design requirements, for example ‘no portal emissions’ and through the energy efficient use of the ventilation system during normal operation.

For many single direction tunnels a lot of the time the piston effect is sufficient to ensure compliance with in-tunnel air quality criteria and the use of the ventilation system can be minimised. It is essential that the use of the ventilation system is carefully managed and monitored to ensure efficient and effective operation.

4.5 In-tunnel air quality

Following a review of the current NZ regulatory environment and international air quality standards the Transport Agency has developed the criteria for air quality in tunnels detailed in tables 4.1 and 4.2.

Table 4.1 NZ Transport Agency in-tunnel air quality (carbon monoxide and nitrogen dioxide) criteria

Air pollutant	Criterion (ppm)	Averaging period	Protection	Application
Carbon monoxide	200	15 min	Workplace	Design and compliance monitoring criteria
	30	8 hours	Workplace	
	87	15 min	General population	
Nitrogen dioxide	1.0	15 min	Workplace and general population	Design criterion only

Note:
All Transport Agency criteria are exposure limits and are based on NIWA recommendations (*Guidance for the management of air quality in road tunnels in New Zealand*[24]) apart from the nitrogen dioxide criterion which is based on the NIWA recommended level (1ppm) and the averaging period adopted for road tunnels in France (15 min).

Table 4.2 NZ Transport Agency in-tunnel air quality (visibility) criteria

Traffic situation	Criterion	Averaging period
	Extinction coefficient K/m	Transmission (beam length: 100m) %
Fluid peak traffic 50 – 100 km/h	0.005	60
Daily congested traffic, Standstill on all lanes	0.007	50
Exceptional congested traffic, Standstill on all lanes	0.009	40
Planned maintenance work In a tunnel under traffic	0.003	75
Closing of the tunnel	0.012	30

Note:
The Transport Agency visibility criteria are based on recommendations in *Road tunnels: Vehicle emissions and air demand for ventilation*[25]. The criteria provide a surrogate measure for particulate matter and are primarily intended to manage potential road safety issues inside tunnels by ensuring adequate visibility is maintained in front of vehicles.

4.6 Monitoring of in-tunnel air quality

It is recommended that operational in-tunnel air quality monitoring is undertaken in accordance with the following requirements:

- Air quality monitoring sensors shall be installed, calibrated and monitored by suitably qualified specialists in accordance with the manufacturers' requirements and relevant good practice.
- The siting of air quality monitoring sensors shall be determined by the tunnel manager in consultation with the Transport Agency's environmental and urban design team. The tunnel manager shall demonstrate that due consideration has been given of the need to demonstrate compliance with relevant in-tunnel air quality criteria in locations representative of the air breathed by tunnel users as well as maintenance, power, data capture, safety and security requirements relating to the equipment.
- Data shall be reviewed, analysed and reported by a suitably qualified specialist. A continuous record of results shall be routinely archived. Performance requirements for data capture and reporting frequencies shall be determined on a case by case basis by the tunnel manager, in consultation with the Transport Agency's environmental and urban design team, as part of the tunnel asset management plan.

4.7 Air pollution control

Air pollution control technology has been used to clean air in a very small number of tunnels (estimated to be <0.01% of all tunnels world-wide – see *Road tunnels: A guide to optimising the air quality impact upon the environment*[(26)]) in a few countries overseas including Norway, Austria, Germany, Japan and during a trial in Australia. This includes the use of electrostatic precipitators to remove particles as well as catalytic and biological processes and adsorption technologies to remove nitrogen oxides.

Evidence to date (see *Road tunnels: A guide to optimising the air quality impact upon the environment*[(26)]) suggests that the effectiveness of such controls when applied to road tunnels is questionable. Technologies are pollutant specific, only address local and not regional road transport-related air pollution, generate chemical waste and have significant capital and operational costs.

The most effective form of vehicle emission air pollution control is to minimise emissions at source, ie from the exhausts of the vehicles using a road tunnel. This could be achieved by regulating the traffic using a tunnel, for example in terms of vehicle types, emission standards, time of use, vehicle speed and tolls.

In the future the in-tunnel nitrogen dioxide criterion will be potentially more demanding as trends in emissions of nitrogen oxides (including primary emissions of nitrogen dioxide) since 2003 do not show any clear downward trend. This is in contrast to trends in carbon monoxide vehicle emissions that have reduced significantly since 2003 (see *Are the harmful emissions from New Zealand's light duty vehicle fleet improving?*[(27)]). Carbon monoxide and not nitrogen dioxide has historically been used as the primary air pollutant to regulate in-tunnel air quality.

4.7 continued

Emissions of carbon monoxide are generally associated with petrol vehicles whereas emissions of nitrogen oxides are typically dominated by diesel vehicles, especially heavy commercial vehicles. The vehicle emission prediction model (VEPM) is generally used to predict vehicle emissions in New Zealand (see www.air.nzta.govt.nz for more information).

5.0 Environmental and social responsibility

5.1 Introduction

New and improved road tunnels can provide a means of addressing environmental and social issues which may otherwise be created by a surface road. For example a tunnel may avoid severance issues and ensure access is maintained and/or enhanced to community facilities such as shops, schools, etc or perhaps adjoining areas of farmland and/or environmentally sensitive sites.

In urban situations, new road tunnels may provide a means of addressing environmental issues such as exposure to elevated levels of noise and air pollution and loss / restoration of open space. The justification for new tunnels to address such environmental and social issues needs to be carefully balanced against the whole-of-life costs of a tunnel to ensure value-for-money outcomes are achieved.

Tunnels can create environmental issues of their own such as air quality and visual concerns which can be mitigated through good planning and scheme design. Consenting and property purchasing strategies can be used to good effect to address such matters. For example, air quality around tunnel portals can be managed by designating sufficient land to create a buffer between the portal and any adverse effect on air pollution sensitive receivers.

5.2 Statutory requirements

The Transport Agency is required to comply with various statutes relating to environmental and social responsibility in particular:

- The Land Transport Management Act 2003 requires the Transport Agency to "contribute to an effective, efficient and safe land transport system in the public interest". Also, "[i]n meeting its objective and undertaking its functions, the [Transport] Agency must exhibit a sense of social and environmental responsibility…"
- The purpose of the Resource Management Act 1991 "is to promote the sustainable management of natural and physical resources", which requires "avoiding, remedying or mitigating any adverse effects of activities on the environment".

The Transport Agency has developed policy, standards and guidelines which assist in meeting the Agency's statutory obligations, as described in more detail in 5.3.

5.3 NZ Transport Agency environmental and social responsibility policies, standards and guidelines

5.3.1 Environmental and social responsibility policy

The Transport Agency's *Environmental and social responsibility policy*[28] details how the Transport agency is "committed to: protecting and enhancing the natural, cultural and built environment, enhancing the quality of life for New Zealanders by improving community livability including land transport safety, taking appropriate account of the principles of the Treaty of Waitangi, providing meaningful and transparent engagement with stakeholders, customers and the general public and providing customer focused services that are fair, trusted and efficient."

5.3.2 NZTA State highway environmental and social responsibility manual

The Transport Agency's *HNO environmental and social responsibility manual*[29] contains the Transport Agency's E*nvironmental plan*[30] as well as all environmental, social and urban design standards and guidelines.

5.3.3 NZTA State highway environmental plan

The environmental plan is structured by environmental impact, for example air quality, visual quality and vibration and provides methods for addressing each impact that align with state highway planning, design, construction and maintenance activities.

Application of the 'planning' and 'designing' methods listed in the environmental plan are particularly relevant to road tunnel projects as they describe relevant environmental assessment methods, performance criteria and design standards.

5.3.4 Environmental and social responsibility standard

All road tunnel projects must comply with the requirements of the Minimum standard Z/19 – *Social and environmental management*[15] and Minimum standard Z/4 – *Contractor's social and environmental management plan*[31].

An environmental and social management plan is required to ensure a successful environmental management system is established. An individual management plan for the tunnel or the tunnel requirements being incorporated in a wider network management plan is required.

5.4 Urban design

The Transport Agency, as a signatory to the *New Zealand urban design protocol*[32], is committed to planning and delivering quality urban design. The Transport Agency guide *Bridging the gap*[33] details how projects can be developed and delivered utilising urban design best practice to achieve positive urban design outcomes. Various urban design details for tunnels are discussed throughout *Bridging the gap*[33] with specific issues discussed in section 4.20.

5.5 Environmental, social responsibility and urban design resources

The Transport Agency's environmental and urban design team should be consulted (environment@nzta.govt.nz) for further advice and resources about environmental, social responsibility and urban design matters

6.0 Operations and maintenance requirements

6.1 Objectives

The primary operations and maintenance objectives include:

- optimising whole of life asset maintenance and renewals costs
- providing agreed performance and levels of service at least cost, including ensuring safe tunnel operations at all times.

This section provides general guidance on how this can best be achieved recognising that each tunnel has its own specific demands and characteristics that require individual consideration.

Value for money must be a primary consideration in the development of operations and maintenance practices for each tunnel. In particular the specification of levels of service and performance measures can incur major costs that need to be understood and judged to be good value before they are agreed.

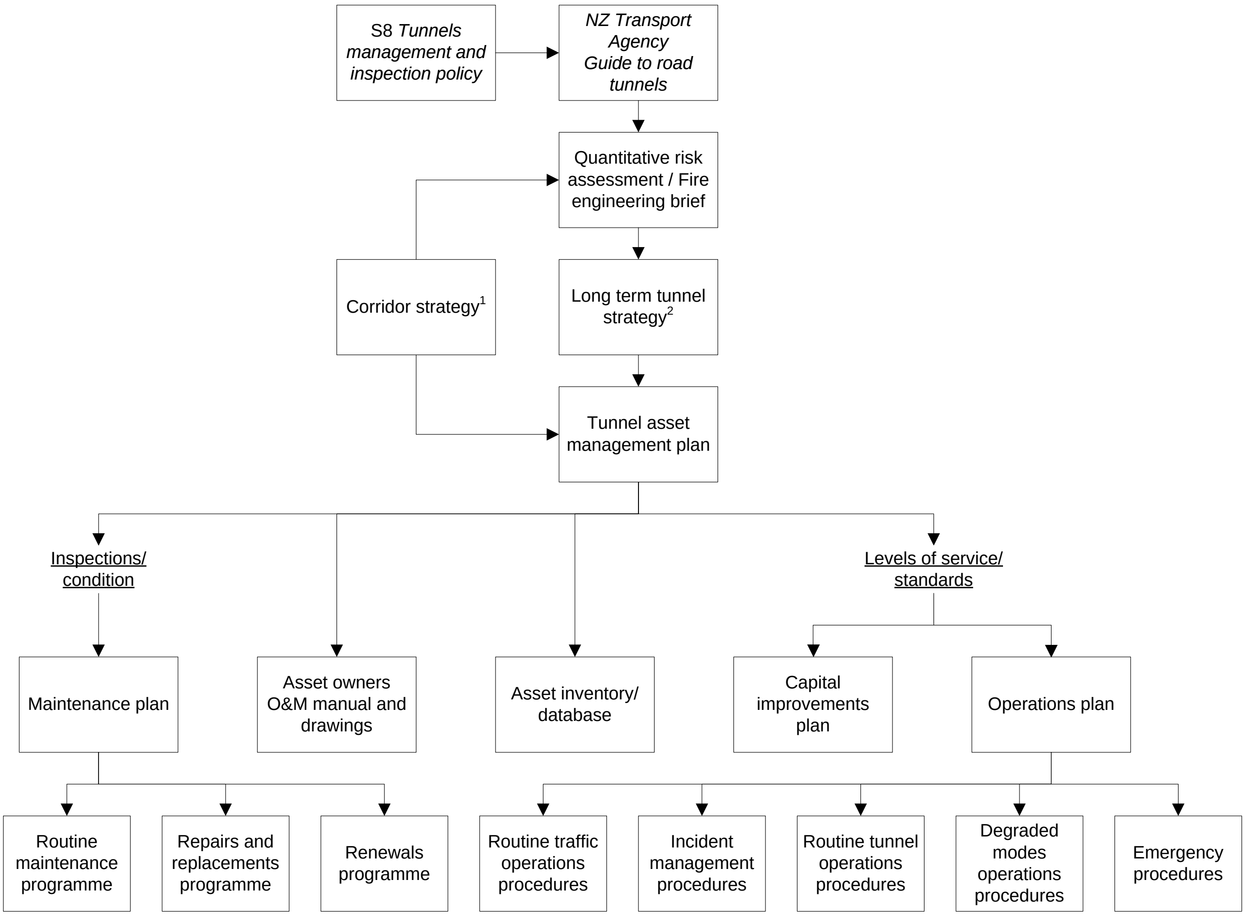
6.2 Management practices

Recommended management practices for tunnels will include but may not be limited to the following, as appropriate for each tunnel:

- appointment of a tunnel manager and safety manager as defined in S8 *Tunnels management and inspection policy*(3)
- execution of inspections as also defined in S8 *Tunnels management and inspection policy*(3)
- annual safety inspections undertaken by the independent safety manager
- preparation of a fire life safety risk assessment with updates also typically at three yearly intervals
- preparation of an asset management plan that documents the performance and condition of the tunnel together with associated life cycle management plans etc generally in accordance with the *International infrastructure management manual* (IIMM)(34) and typically updated every three years
- preparation of an operations and maintenance manual in accordance with the proposed contents as outlined in appendix B
- use of an asset management database system (such as MEX) as appropriate to support the various tunnel management functions. It is proposed that a standard Transport Agency system be adopted.

Figure 6.1 shows the hierarchy of various management documents that are likely to be required for the management of tunnels.

Figure 6.1 Tunnel management documents hierarchy



Notes:

1. A corridor strategy is a technical report, outlining potential long-term transport solutions for the highway under consideration. It is likely that any such report will be written by parties not involved in the management of tunnels.
2. The long term tunnel strategy shall be a brief and very high level document that effectively documents the business case for the tunnel levels of service into the future. It will be based upon the outcomes of the quantitative risk assessment that define fire life safety levels of service and regional strategies that define future traffic demands and lane requirements etc.

6.3 Operational practices

6.3.1 Traffic system integration

If a tunnel traffic monitoring and control system (TTMCS) is required, the system will be expected to integrate to existing advanced traffic management systems (ATMS) that form part of a wider comprehensive motorway management system that comprises the following elements:

- traffic flow monitoring
- surveillance
- lane controls
- variable signage and ramp metering
- travel time information
- congestion monitoring
- incident management/detection.

6.3.1 continued

Any tunnel control room and traffic operations centre interface must:

- have the ability to be operated with or without human intervention
- interface fully with DYNAC to enable control of other intelligent transport system (ITS) equipment
- provide status reports on all components inside and outside of the tunnel and raise alarm within DYNAC of any failures.

The design and installation of all components of intelligent transport systems must be in accordance with the Transport Agency ITS specifications and the standards listed below:

Austroads *Guide to road design*(35)

AS 1742.14	*Manual of uniform traffic control devices - Traffic signals*(36)
AS/NZS 2144	*Traffic signal lanterns*(37)
AS/NZS 4230.2	*Information technology - Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbit/s - Video*(38)
ACA TS 015	*General requirements for analogue video equipment connected to a telecommunications network*(39)
AS 4418.1	*Supervisory control and data acquisition (SCADA) - Generic telecommunications interface and protocol - General*(40)

NZ Transport Agency ITS specifications(41).

6.3.2 Phased incident response

A phased incident response plan (IRP) shall be developed that:

- identifies the incident responses including degraded tunnel operation parameters (DTOP), without jeopardizing the safety of motorists and staff
- details procedures for the escalation of incident response management to NZ Fire Service, NZ Police and emergency services agencies and other relevant authorities, according to the type of incident; the scale of the incident; or, any other safety criteria
- assists and supports the NZ Fire Services, NZ Police, emergency services agencies and other relevant authorities
- is at all times compatible with and complements the relevant plans and procedures of the Transport Agency, NZ Fire Service, NZ Police and emergency services agencies.

6.3.3 Emergency response exercises

An emergency response exercise that includes field simulation testing of the incident response plan shall be undertaken in conjunction with the emergency services prior to tunnel opening, one year after opening and following any significant upgrading of tunnel systems.

Emergency response exercises may also be undertaken in conjunction with tunnel inspections – refer to 6.5.

The incident response plan shall be tested annually with a desk top exercise in conjunction with the emergency services when a field simulation test is not undertaken.

6.3.4 Environmental monitoring

In addition to traffic and ventilation monitoring systems there will also be a number of requirements for monitoring environmental and meteorological parameters in and around tunnels, for example air quality, noise, wind speed and direction.

It is essential that monitoring instrumentation is sited, commissioned, operated, maintained and calibrated in accordance with the relevant manufacturer's instructions and appropriate monitoring standards and guidance, for example:

6.3.4 continued

- *Traffic monitoring for state highways*[42]
- BD 78 *Design of road tunnels*[43]
- *Good practice guide for air quality monitoring and data management*[44].

All monitoring data must be subject to an appropriately documented quality assurance and control regime. Raw and processed data should be securely stored and archived for future analysis. Further advice on monitoring should be sought from the Transport Agency's HNO Network Outcomes (in particular the structures team, asset management team and environment and urban design team).

6.4 Maintenance practices

The Transport Agency requires a specific asset management plan for each tunnel. The plan shall adopt the following principles:

a. The frequency of unplanned maintenance interventions shall be minimised through regular planned maintenance.

b. The tunnel shall be safe for motorists and the tunnel operational staff at all times as a result of cleaning, maintenance, repair, replacement, rehabilitation, upgrade and refurbishment the tunnel and associated assets.

c. A code of maintenance standards shall be developed consistent with the design assumptions, manufacturers' advice and as-constructed documentation that includes the details as described in appendix B. The code of maintenance information shall cover all asset elements and sub-elements.

d. Maintenance safety and frequency of maintenance shall be addressed through the following hierarchical design process:

   i. Eliminate the maintenance process through the deletion of equipment where possible.
   ii. Select materials with the longest design life, and maintenance free period.
   iii. The provision of safe access to all items requiring maintenance.
   iv. The provision of replacement options for all infrastructure and equipment.

Environmental management consent monitoring provisions are to be addressed in the above operational plan.

The requirements for operations and maintenance manuals are included in appendix B.

6.5 Inspections

In response to the *Inspection manual for highway structures*[45]and as a partner document to S6 *Bridges and other highway structures inspection policy*[46], the Transport Agency has developed the S8 *Tunnels management and inspection policy*[3].

S6 and S8 define the requirements for routine, general, principal and special inspections for the structures covered by them as well as definitions of competent personnel required to undertake the inspections. S8 gives details of which state highway tunnels in New Zealand the policy applies to. Any tunnels not covered by S8 (typically shorter tunnels) are covered by S6.

7.0 References

(1) Austroads (2010) *Guide to road tunnels*. Sydney, NSW, Australia.
  Part 1: Introduction to road tunnels (AGRT01/10)
  Part 2: Planning, design and commissioning (AGRT02/10)
  Part 3: Operation and maintenance (AGRT03/10)

(2) National Fire Protection Association (2014) NFPA 502: *Standard for road tunnels, bridges, and other limited access highways*. Quincy MA USA.

(3) NZ Transport Agency (2013) S8 *Tunnels management and inspection policy*. Wellington.

(4) Standards Australia and Standards New Zealand jointly AS/NZS ISO 31000 *Risk management - Principles and guidelines.*

(5) MinEx Health & Safety Council (2010) *Industry code of practice – Underground mining and tunnelling*. Wellington.

(6) International Tunnelling Insurance Group (2006) *A code of practice for risk management of tunnel works*. Last accessed 13 November 2013. <www.imia.com/wp-content/uploads/2013/05/EP24-2006-Code-of-Practice-for-Risk-Management-of-Tunnelling-Works.pdf>

(7) International Tunnelling Association/AITES (2004) *Guidelines for tunnelling risk management: International Tunnelling Association, working group no. 2*. Tunnelling and underground space technology 19 (2004) pp. 217-237.

(8) Standards Australia AS4825-2011 *Tunnel fire safety*.

(9) Standards New Zealand NZS 4503:2005 *Hand operated fire-fighting equipment*.

(10) Standards New Zealand SNZ PAS 4509:2008 *New Zealand Fire Service firefighting water supplies code of practice*.

(11) Standards New Zealand NZS 4510:2008 *Fire hydrant systems for buildings*.

(12) Standards New Zealand NZS 4512:2010 *Fire detection and alarm systems in buildings*.

(13) Standards New Zealand NZS 4541:2007 *Automatic fire sprinkler systems*.

(14) Parliamentary Counsel Office (1992) Building Regulations 1992. Schedule 1 *The building code*. Wellington.

(15) NZ Transport Agency (2010) Minimum standard Z/19 – *Social and environmental management*. Wellington.

(16) NZ Transport Agency (2013) SP/M/022 *Bridge manual*. Wellington.

(17) UPTUN (2008) Workpackage 5 *Evaluation of safety levels and upgrading of existing tunnels*.
  D50 Holistic tunnel fire safety evaluation and upgrading procedure: overview
  D51 Comprehensive inventory of tunnel safety features
  D52a Evaluation of safety level criteria
  D52b Fire growth models: water-based suppression systems
  D53 Description of real tunnels for examples

D54a Manual upgrading: heat and mass flow analysis
D54b Manual upgrading: combined smoke movement and egress analysis
D54c Manual upgrading: risk analysis
D54d Manual upgrading: socio-economic impact
D55a Automatic upgrading: tunnel description documents
D55b Automatic upgrading: development of Intelligent systems
D55c1 Automatic upgrading: comments on intelligent systems and egress analysis
D56 Global approach to tunnel safety

(18) World Road Association (PIARC) (2008) *Risk analysis for road tunnels*. La Défense, France.

(19) Australian Building Codes Board (2005) *International fire engineering guidelines*. Canberra, ACT, Australia.

(20) Hannaby R and Wright B (2013) *Managing air quality in and around road tunnels in New Zealand*. 21st International clean air and environment conference, Clean Air Society of Australia and New Zealand, Sydney, NSW, Australia.

(21) Parliamentary Counsel Office (2004) Resource Management (National Environmental Standards for Air Quality) Regulations 2004. Wellington

(22) Ministry for the Environment (2002) *Ambient air quality guidelines*. Wellington.

(23) NZ Transport Agency (2012) *Guide to assessing air quality effects for state highway asset improvement projects*. Draft version 0.6. Wellington.

(24) National Institute of Water and Atmospheric Research (2010) *Guidance for the management of air quality in road tunnels in New Zealand*. NIWA research report for the NZ Transport Agency. Wellington.

(25) World Road Association (PIARC) (2004) *Road tunnels: Vehicle emissions and air demand for ventilation*. La Défense, France.

(26) World Road Association (PIARC) (2008) *Road tunnels: A guide to optimising the air quality impact upon the environment*. La Défense, France.

(27) National Institute of Water and Atmospheric Research (2011) *Are the harmful emissions from New Zealand's light duty vehicle fleet improving?* Research report 441, NZ Transport Agency, Wellington.

(28) NZ Transport Agency *Environmental and social responsibility policy*. Last accessed 13 November 2013. <www.nzta.govt.nz/resources/environmental-and-social-responsibility-manual/docs/environmental-and-social-responsibility-policy.pdf>

(29) NZ Transport Agency (2012) SP/M/023 *HNO environmental and social responsibility manual*. Wellington.

(30) NZ Transport Agency (2008) *Environmental plan: Improving environmental sustainability and public health in New Zealand*. Version 2. Wellington.

(31) NZ Transport Agency (2010) Minimum standard Z/4 – *Contractor's social and environmental management plan*. Wellington.

(32) Ministry for the Environment (2005) *New Zealand urban design protocol*. Wellington.

(33) NZ Transport Agency (2013) *Bridging the gap*. Wellington.

(34) New Zealand Asset Management Support (2011) *International infrastructure management manual*. Wellington.

(35) Austroads (2006 et seq) *Guide to road design* (in 15 parts). Sydney, NSW, Australia.

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(37) Standards Australia and Standards New Zealand jointly AS/NZS 2144:2002 *Traffic signal lanterns*.

(38) Standards Australia and Standards New Zealand jointly AS/NZS 4230.2:1994 *Information technology - Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbit/s - Video*.

(39) Standards Australia ACA TS 015-1997 *General requirements for analogue video equipment connected to a telecommunications network*.

(40) Standards Australia AS 4418.1-1996 *Supervisory control and data acquisition (SCADA) - Generic telecommunications interface and protocol - General*.

(41) NZ Transport Agency *Intelligent transport systems specifications*. Last accessed 13 November 2013 <www.nzta.govt.nz/resources/intelligent-transport-systems/>

(42) NZ Transport Agency (2004) SM/052 *Traffic monitoring for state highways*. Version 1.2: November 2011. Wellington.

(43) Highways Agency (1999) BD 78/99 *Design of road tunnels*. TSO, London, United Kingdom.

(44) Ministry for the Environment (2009) *Good practice guide for air quality monitoring and data management*. Wellington.

(45) Highways Agency (2007) *Inspection manual for highway structures*. TSO, London, United Kingdom.

(46) NZ Transport Agency (2011) S6 *Bridges and other highway structures inspection policy*. Wellington.

Appendix A Comments on existing NZ road tunnels

The projects listed in table A1 are either recently constructed, being commissioned or at the beginning of detailed design at the time of writing. They have all been designed in recognition of recent Australian practises with respect to fire life safety and tunnel ventilation and are considered compliant with the AGRT(1). Significantly they are all uni-directional which greatly simplifies the fire life safety issues.

Table A1 Recent New Zealand state highway tunnels (uni-directional)

State highway	Locality	Opening date	Name	Length	No. of bores x lanes	Speed limit (kmh)	AADT*
1N	Auckland	2009	Johnstone's Hill	360	2 x 2	100	13,000
1N	Auckland	2011	Victoria Park	455	1 x 3	80	80,500
20	Auckland	2017	Waterview	2500	2 x 3	80	83,000

* Average annual daily traffic

By contrast the existing state highway tunnel portfolio in New Zealand are bi-directional and were designed and constructed without the benefit of modern approaches to tunnel fire life safety. As a result and in general these older tunnels do not comply with modern best practise. However, all of the tunnels are being re-appraised with respect to safety upgrades. Both Mt Victoria and Terrace Tunnel are in the planning stages of becoming uni-directional and have recently been refurbished with improved safety measures, particularly the Terrace Tunnel. Both Lyttelton Tunnel and Homer Tunnel are being considered for safety refurbishments.

Nonetheless asset management plans and associated risk assessments for operations and maintenance are being updated for the entire existing NZ state highway tunnel portfolio including introducing further speed reductions.

Table A2 Older New Zealand state highway tunnels (bi-directional)

State highway	Locality	Opening date	Name	Length	No. of bores x lanes	Speed limit (kmh)	AADT
1N	Wellington	1931	Mt Victoria	625	1 x 2	50	39,000
43	Taranaki	1936	Moki	173	1 x 1	100	120
94	Milford	1954	Homer	1200	1 x 1	100	600
74	Christchurch	1964	Lyttelton	1950	1 x 2	50	11,000
1N	Wellington	1978	Terrace	462	1 x 3	70	46,000

Appendix B Operations and maintenance documentation and management systems

B1 Operations and maintenance manual

The following are minimum requirements for operations and maintenance manuals for state highway tunnels.

B1.1 Tunnel description and records

The tunnel records in the operations and maintenance manuals shall include a description of the physical elements of the tunnel, the plant and equipment, and the operational and security systems including a comprehensive set of all as-constructed records.

B1.2 Code of maintenance standards

A code of maintenance standards shall be developed for the operations and maintenance manuals that is consistent with the design assumptions, manufacturers' advice and as-constructed documentation. The code of maintenance information shall cover all asset elements and sub-elements.

The code of maintenance standards shall include the following requirements:

Information	Description
Reference no.	A unique code reference number
Asset element	The asset element to which the standard applies
Primary outcome	The outcome to which the asset element makes its primary contribution
Maintenance rationale	The purpose for the maintenance of the asset element
Defects	A listing of the principal defects likely to occur and the associated risk of their occurrence and the appropriate remedial action
Performance standards	The performance standard to be provided by the asset element, and by asset items and asset sub-items within that asset element, at various specified times up to the end of the operations and maintenance period
Inspection procedure	A reference to the procedures used to inspect the condition of the Asset element and monitor the durability performance
Intervention standard	The intervention level and response time for maintenance work on the Asset element
Inspection plan	The frequency of inspection of the Asset element. The plan must cover both regular inspections and less frequent but more comprehensive inspections and tests
Maintenance activity	A listing of the principal maintenance activities

B1.3 Operation and maintenance organisations

A description of the operation and maintenance organisation shall be developed for the operations and maintenance manuals, that includes:

a. key roles and responsibilities

b. any special vehicles, plant and equipment to be used in the various operations

c. nominated subcontract arrangements (if any), and each of the sub-contactor's authorities and responsibilities

B1.3 continued	d. contact details e. training requirements f. performance standards.
B1.4 Permanent plant and equipment inventory	A permanent plant and equipment inventory shall be developed for the operations and maintenance manuals that details all plant and equipment together with associated data, including handbooks and spare parts lists for items of plant and equipment. The plant and equipment inventory must include the asset elements of the asset management system.
B1.5 Environmental management during operations and maintenance activities	The operations and maintenance manuals should include details of all requirements to comply with operational consent conditions.
B1.6 Durability and residual design life	The operations and maintenance manuals must address the on-going durability of the tunnel and compliance relating to design life and handover and any construction non-conformance impacting on asset performance or durability.
B1.7 Knowledge management and continuous improvement	The operations and maintenance manuals shall detail knowledge management and continuous improvement including: a. operations and maintenance manuals continuous improvement procedure b. event analysis and incident debrief procedures c. program for tunnel safety drills d. any subsequent agreement reached with NZ Police and emergency services.

B2 Other operations and maintenance documentation

B2.1 Forecast maintenance programme	A forecast maintenance programme shall be developed that details routine maintenance, repairs and replacements, and renewals. The programme shall be developed in accordance with the requirements of the Transport Agency's *State highway annual plan instructions manual*[(1)].
B2.2 Special purpose manuals	Special purpose manuals are overview documents that summarise the equipment available and how it is used in an incident. These manuals shall be produced for use by the Transport Agency, NZ Police and other emergency services agencies. They must contain a brief description of all systems and equipment with illustrations, diagrams, and sketches, particularly in relation to incident operating procedures and must be incorporated into the incident response plan.
B2.3 Tunnel safety records	Tunnel safety records shall be maintained including: a. a tunnel safety records system b. road safety audits documentation or crash study reports (where available)

(1) NZ Transport Agency (2013) SM018 *State highway annual plan instructions manual*. Wellington.

B2.3 continued

c. provision of a fire safety systems condition report that shall be provided annually to demonstrate that the tunnel life safety systems will function as designed for the next 12 months. The fire safety systems condition report shall include:

   i. the annual Building Warrant of Fitness (Form 12) supplied to the territorial authority concerned and associated correspondence, together with copies of all Form 12As received from the independent qualified persons (IQPs) for the specified systems

   ii. copies of any agreed changes with the territorial authority to the compliance schedule should also be included

   iii. confirmation that any conditional assumptions and limitations imposed by the tunnel designers relevant to the safe and continued operation of the tunnel are still valid. If these conditions are not valid, the condition report shall make a clear recommendation that a fire risk assessment be undertaken as soon as possible.

B3 Operations and maintenance management systems and procedures

B3.1 Asset management system

The asset management system shall include:

a. the asset management system supported by the Transport Agency for all relevant tunnels and containing asset description, performance, condition, valuation and associated data

b. the maintenance workflow processes including inspections

c. location and storage of data such as but not limited to condition, as-built surveys, and mechanical and electrical readings

d. mandatory data fields in system

e. overview of integration and capture of external electronic documents

f. verification and validation reports of operations and maintenance activities.

B3.2 Condition monitoring of assets

The condition monitoring of assets will generally involve the identification of defects and the optimum scheduling and forecasting of maintenance and renewal activities to achieve least whole of life cost.