Transport
for NSW

Tunnel urban design guideline

Design guideline to improve the customer and community experience of road tunnels

NSW GOVERNMENT

Urban Design Roads and Waterways

Acknowledgements

Prepared by: Urban Design Roads and Waterways.

Contributors: Michael Sheridan, Gareth Collins, Raeburn Chapman, Greg Jackson.
Nigel Casey, Peter Cuk, Steve Messenger, Paul McFarlane (Motorways). Peter Ellis, Jennifer Powrie (Engineering Services).
Jay Stricker (AECOM). Richard Nugent (Conybeare Morrison). Josh Small (Hassell). Matthew Calendar (WestConnex).
Bernard Connell, Richard Merritt, Rob Butler (NorthConnex).

Photography by: The Urban Design Roads and Waterways team and Peter Borrelli, unless otherwise credited.

Image — Interior of Northconnex
Cover image — M8 ventilation building at Bexley

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Foreword

Catalysed spurred by the high cost of land, innovation, Australian expertise in tunneling and the impacts of road transport on communities, NSW has become a centre of excellence for road tunnels.

This document was initially written in 2016/2017 to provide some advice gleaned from the tunnels that had been built and help guide the tunnels that were in development. It advocated good quality visual experiences in tunnels and well designed portals with good landscape architecture and architecture in the tunnel buildings and open space.

Since then 32km of tunnel has been completed (64km if you count each direction). This represents a leap forward in knowledge and experience. The recently completed M4–M8 tunnel joins up the M4 east and M8 tunnels to make a 23km long tunnel and the longest in Australia.

Tunnels are also being built in Sydney under Rozelle (Rozelle Interchange) and under Sydney Harbour (Western Harbour Tunnel) and also in Coffs Harbour where 3 short tunnels are being constructed through steep ridglines avoiding deep scarring cuttings.

This updated guideline reaffirms and refines the lessons of the first publication, is updated to reflect recent policy changes and also provides images of recently completed tunnels. It continues to sit within the *Beyond the Pavement* suite of documents alongside *Bridge Aesthetics* and other guidelines.

1 Introduction

1.1 The purpose of this guideline

The guideline sets out a best practice approach to the urban design of tunnels. It has been prepared to assist Transport project teams and their partners at the initiation phase of a tunnel project, as well as in the following development and implementation phases.

The design of tunnels is a detailed and specific area of work that, like bridges and noise walls, requires its own urban design guidance in addition to Transport's urban design guideline *Beyond the Pavement.*

Tunnels present a challenge and opportunity in urban design terms; they avoid the environmental impacts a major road can have above ground and also avoid the physical separation a surface motorway has on the community. However, tunnels physically and visually separate road users from the landscape and the areas in which they live.

Reconciling these contradictory aspects of tunnels is the purpose of this guideline. By designing the tunnel as a 'journey experience' rather than solely as an underground bypass, and by considering the *Beyond the Pavement* principles above ground, the construction of new tunnels will result in a positive contribution for both road users and the surrounding communities.

1.2 How to use this guideline

Beyond the Pavement is Transport's urban design policy, and is the primary document in a full suite of guidelines which also covers bridges, noise walls, shotcrete, landscape and this *Tunnel urban design guideline.*

Beyond the Pavement and any relevant guidelines should be applied to all projects Roads and Maritime builds or is ultimately responsible for.

It is critical to consider the urban design of tunnels at an early project stage, to ensure that the broad urban design principles set out in this document can be integrated in a cost-effective manner.

There are several urban design objectives and strategies that are relevant to every tunnel being designed — regardless of its length (short or long) or location (urban or rural). For ease of use for the reader of this guideline, five terms are used:

- All tunnels
- Short tunnels
- Long tunnels
- Urban tunnels
- Rural tunnels.

All tunnels — refers to all tunnels (including underpasses), regardless of their length, or location.

Short tunnel — these tunnels will provide a short subterranean journey and do not require vertical ventilation exhaust outlets. The longest current NSW tunnel that does not have a vertical ventilation exhaust outlet is the Mascot (Airport) tunnel at 550 metres.

Long tunnel — these tunnels will provide a longer subterranean journey, and will have a distinct and pronounced interior zone. In addition, such tunnels are likely to require vertical ventilation exhaust and possibly supply outlets. Of the tunnels operating at the time of writing this guideline, the Eastern Distributor at 1.7 kilometres is the shortest NSW tunnel that has vertical ventilation exhaust shafts.

Note that the requirement for vertical exhaust shafts may vary over time but will primarily be based on estimated vehicle emissions (calculated by forecast vehicle numbers), together with the vertical alignment and length of the tunnel.

Urban tunnel — refers to a tunnel within a built up metropolitan area.

Rural tunnel — refers to a tunnel away from urban and built environments.

Throughout this document, issues and constraints, and objectives and strategies are addressed to 'all tunnels' unless it is specifically stated otherwise. Where relevant, issues and constraints, objectives and strategies are addressed to short, long, urban and rural tunnels.

This document provides information about:

- Urban design challenges for all road tunnels – Chapter 2
- Urban design challenges specific to long tunnels – Chapter 2
- Urban design objectives for all road tunnels – Chapter 3
- Design strategies relevant to identified objectives – Chapter 3
- How the urban design objectives for road tunnels relate to the broader urban design principles set out in Roads and Maritime's *Beyond the Pavement* – Chapter 3
- Separating road tunnels into specific zones and applying the design strategies relevant to each zone — Chapter 4
- How the urban design strategies outlined in this document apply to the Transport's project management system phases — Chapter 5
- International case studies regarding best practice urban design for road tunnels — Appendix A.

1.3 Key messages

The key messages of this guideline are:

1. Well-considered urban design can make a positive contribution to the journey experience — particularly for long tunnels with regard to the potentially monotonous driving environment, disorientation and disconnection from the above ground environment, and difficulty wayfinding.
2. The urban design process needs to be initiated at an early stage in the tunnel planning process.
3. There are four primary urban design objectives to consider during the tunnel planning and design process.
4. Clear tunnel urban design strategies should be applied to meet the objectives.
5. The most straightforward way to apply these strategies is to separate the tunnel into four distinct zones.
6. How to apply urban design strategies through the Transport's project management system.
7. There are many examples of best practice tunnel design that should be used for reference, learnings and inspiration. Some of these are included in this guideline.

Tubular portal forms such as these on the St Helena Tunnel in Ewingsdale (NSW), are highly effective in rural areas: simple, sculptural forms integrating well with the local landform, against a backdrop of vegetation.

1.4 Why is urban design important to road tunnel design?

The planning and design of a road tunnel presents many unique challenges for the teams delivering the project. Three major areas where urban design has a prominent role are:

- Limiting the physical and visual impact of the tunnel on the surrounding environment — including for local residents, integrating local pedestrian and cycle connections and designing to enhance local landscape characteristics
- Improving the comfort and general driver experience, and to encourage intuitive driver decision making, which has the potential to enhance driver safety
- Ensuring that the tunnel delivers benefits to tunnel users, and the surrounding urban or rural environment.

A successful road tunnel project requires a joint approach to the task of sensitively fitting a tunnel into its built, natural and community environment, or 'context'. Urban design takes into consideration the many aspects involved in the planning and design of road tunnels; from road design and structural engineering, through to the various heritage, cultural, community and other environmental considerations.

1.5 What makes a successful tunnel in urban design terms?

Road tunnels generally offer a quicker alternative route for road users, whether to avoid areas of high congestion within city regions or to bypass residential areas or landscape features such as mountains, rivers or harbours. The true value of a tunnel, however, is much broader than this when viewed in terms of their contribution to city planning, traffic management, environmental sensitivity, community sustainability and liveability benefits.

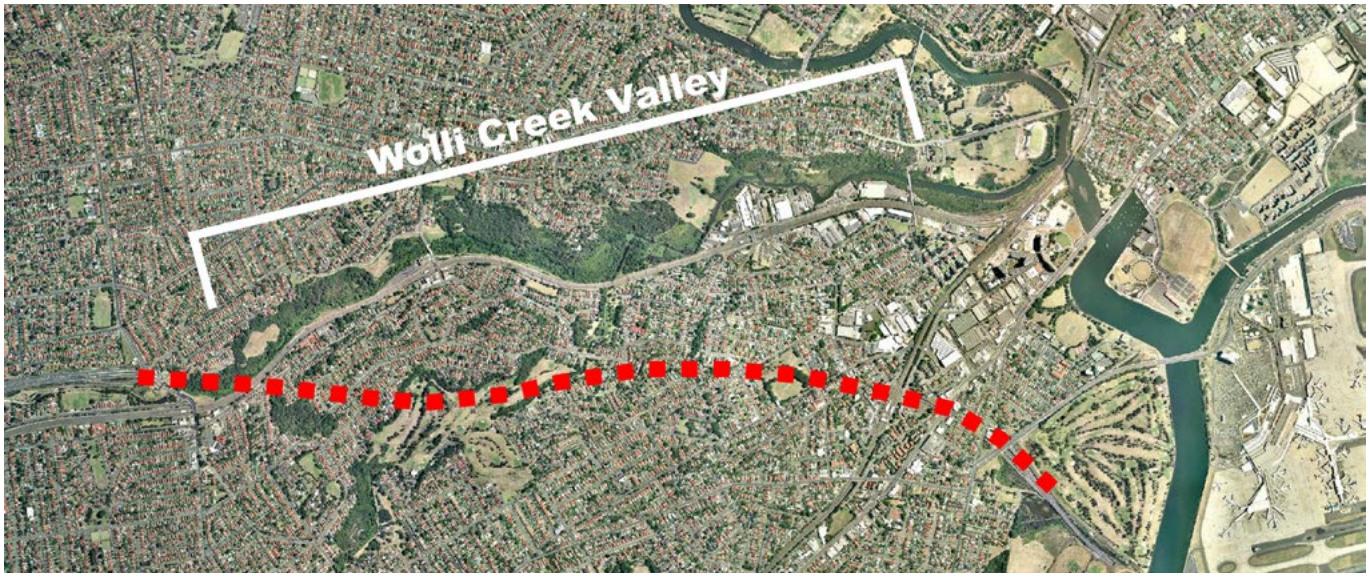
For example, the M5 East Tunnel in Sydney allowed for a more 'liveable' area above ground by diverting heavy traffic and retaining much of the valued parkland corridor along the Wolli Creek Valley.

A positive driver experience

The successful and safe design of road tunnels needs to consider the driver's experience in terms of the in-tunnel driving environment, legibility, ease of use and connectivity to the above ground environment.

Reduced traffic congestion and enhanced liveability

A successful road tunnel with strong driver appeal will have good patronage, which has positive benefits above ground including reduced congestion of existing roads, improved liveability of areas and better connectivity.



Careful planning of the M5 East tunnel (NSW) avoided impact on the Wolli Creek bushland valley, retaining its value as an important environmental and community asset.

A quality asset that requires minimal maintenance

Providing a quality infrastructure asset and the success of its integration with the local built or natural environment is recognised by its users and the general public.

Minimising maintenance needs and consideration of the tunnel's environmental footprint should be applied throughout the urban design process.

1.6 Long tunnels: a specific set of urban design challenges

The early design of road tunnels and underpasses in Australia, which were almost exclusively short in length, had their design emphasis on the tunnel portals and exits. Typical examples included the Cahill Expressway in Sydney's Domain (early 1960s) and the Kings Cross Tunnel (1975) in Sydney.

Even as the length of tunnel design increased with projects such as the Sydney Harbour Tunnel (1992), Eastern Distributor (1999) and M5 East Tunnel (2001) in Sydney, the design focus remained on the portal areas.

However Australia, and in particular NSW, is now building longer tunnels which introduces new urban design challenges. These challenges stem from the increased length of the tunnel itself and the resulting change to the tunnel journey experience for drivers and passengers.

1.7 Research into the challenges of long road tunnels

Research into the technical aspects of road tunnel design, construction, and operation is readily available. However, investigation into the use of long road tunnels and the effect of long road tunnel travel on driver behaviour is a lesser, though growing, field of study.

The World Road Association (PIARC) publishes reports and research materials that are used by road authorities around the world. In 2008 PIARC released a report entitled *Human Factors and Road Tunnel Safety Regarding Users* (Report 2008R17). Chapter 4 of this report focuses on design factors and general recommendations to improve road user safety. These are based on human behavioural studies monitoring real and simulated tunnel driving.

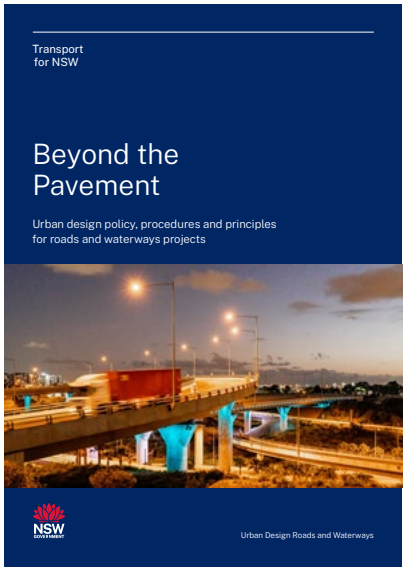
The 2008 PIARC report highlights the following design principles:

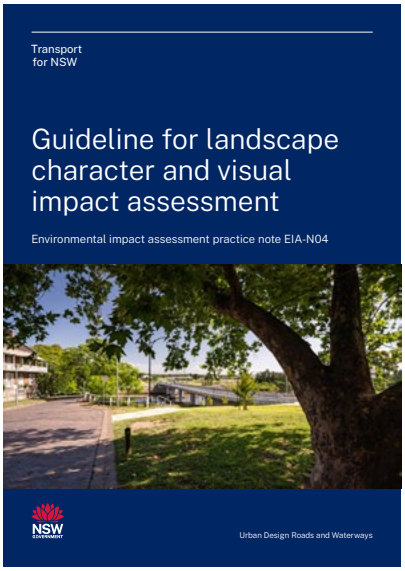
- Tunnel portal design should ensure a smooth transition from outside to inside, drawing the driver's full attention to the tunnel entrance, and ensuring the driver feels relaxed and safe when entering
- Particular attention should be given to the architectural design of the tunnel portal
- Avoid placing signs just before a tunnel entrance, and particularly not at the tunnel portal
- Tunnel interior design objectives should focus on safe and comfortable passage throughout the entire length of very long tunnels and there should be an emphasis on making the driver feel safe
- A driver's feeling of safety when driving in tunnels is determined to a large degree by the design of the interior, and long monotonous tunnels increase feelings of discomfort
- Tunnel users find it difficult to estimate how far they have driven in a tunnel; signage indicating the already travelled and remaining tunnel distance is recommended
- Additional landmarks reflecting above ground characteristics or artistic elements are recommended to assist driver orientation and add interest to the journey.

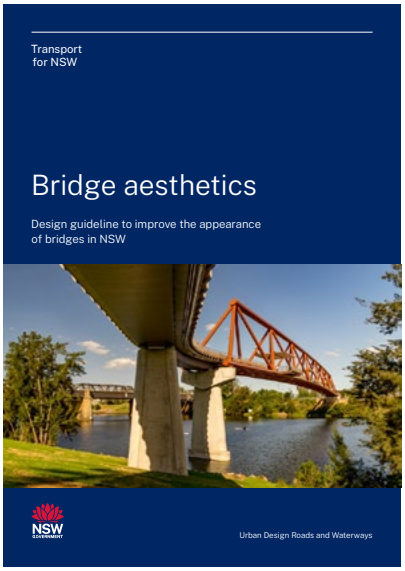
1.8 Scope of this guideline

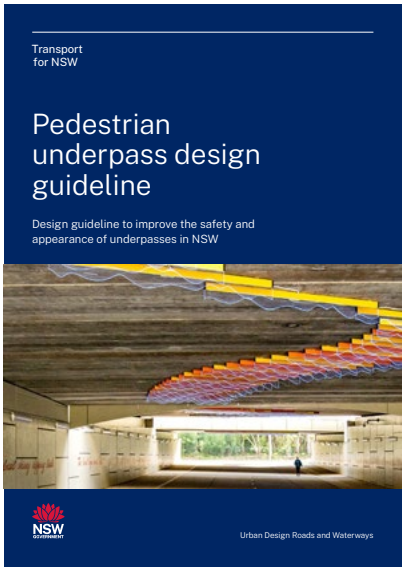
This guideline relates to the urban design approach to all types of road tunnel, encompassing short, long, urban and rural road tunnels, and their elements — including the tunnel portals and approaches, tunnel interiors, related public spaces and tunnel buildings, and ventilation outlets.

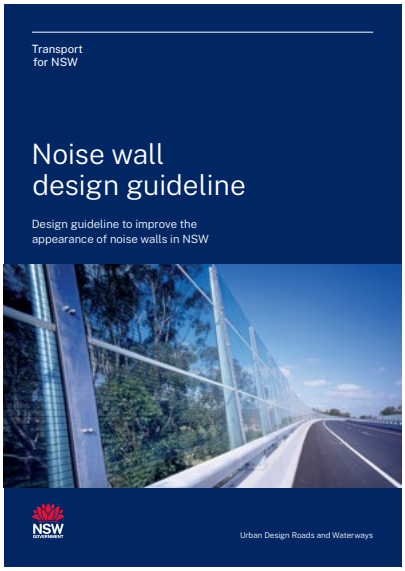
The guideline should be read in conjunction with *Beyond the Pavement*, which also contains more general advice on tunnels.

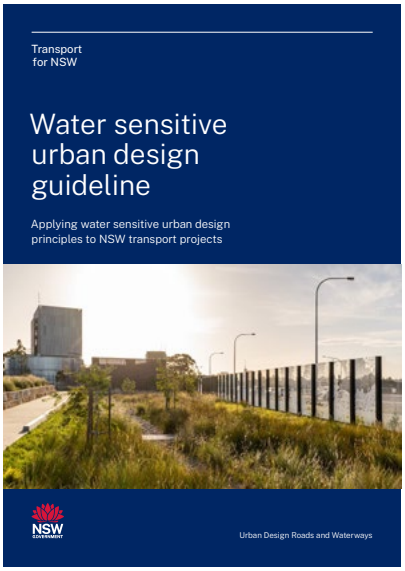


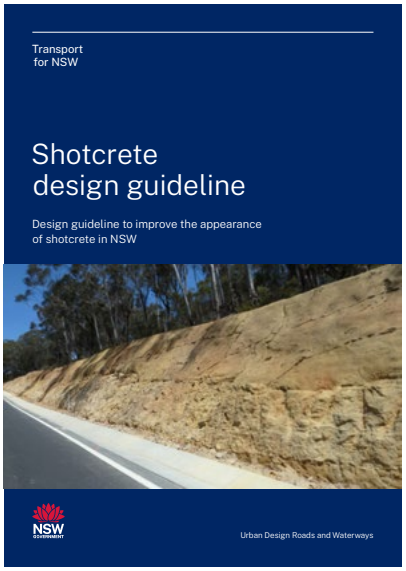












Top left: *Beyond the Pavement*

Top centre: *Environmental Impact Assessment Practice Note*

Top right: *Landscape design guideline*

Middle left: *Bridge Aesthetics*

Middle centre: *Underpass Design Guideline*

Middle right: *Noise wall design guideline*

Bottom left: *Water sensitive urban design guideline*

Bottom right: *Shotcrete design guideline*

2 Tunnel design — Urban design issues and constraints

2.1 Introduction

This chapter explains the urban design challenges common to all road tunnel projects. Where relevant, the specific challenges of long, urban or rural tunnels have been identified.

2.2 Urban design challenges common to all tunnels

The majority of road tunnels that have been built in Australia have been relatively short in length, with a journey time of two minutes or less. These tunnels have been designed to provide a quick and efficient underground journey. However, longer tunnels are becoming more common.

The following design challenges are relevant to the construction of tunnels of any length.

Tunnel approaches, dive structures and portal

The design of the portal area provides an opportunity to create an instantly recognisable and distinct design to this highly visible section of the tunnel. The tunnel approaches and portal include the design of the portal structure itself, and any elements and components that embellish, or are located nearby, the portal area (such as the design of the dive structures, water storage tanks, or water pump structures).

For all tunnels, the design challenges of portal areas include:

- Applying well-coordinated design that results in a portal area that is neat, attractive and inviting for motorists
- Ensuring that the design emphasis on the portal area doesn't detract from the design of the remaining tunnel system and components
- Effectively integrating signage to avoid a cluttered tunnel approach and entrance.

The M5 East tunnel approach and portal area in Sydney (including associated structures and elements) presents as a cluttered and uninviting experience for motorists.

Too many signs on the approach to a tunnel can be confusing for drivers. The appearance of this approach to the Lane Cove Tunnel in Sydney is unsightly and obscures the effort undertaken in designing the portal.

New entrance to the M4 East tunnel in Haberfield. A panelled approach with LED lighting creates a neat consistent, and distinctive finish across the tunnel system.

Integration of the tunnel into the local built context

Tunnels become a part of the landscape in which they are constructed and have an impact on the functionality of the urban or rural area being bypassed, as well as on the character of the area. In the case of urban road tunnels, locating buildings — including ventilation structures — too far from the tunnel portals spreads the impact of the tunnel infrastructure over a wider area, which can lead to increased community concerns.

Integration challenges common to road tunnel projects include:

- Reducing the impact on local private and public land uses
- Diminishing the impact on public open spaces
- Reducing the impact on local access and connectivity, including local vehicle movements, and pedestrian and cyclist activity
- The risk of separation and isolation of previously connected areas
- Ensuring the best possible integration of the tunnel with the character of the local area, local landform and landscape
- Reducing the visual impact of any associated buildings or structures.

Adopting an urban design approach to the planning and design of road tunnels will assist in the successful integration of a tunnel project into its local built, natural and community environments. An urban design approach should strive to achieve the main physical outcomes addressed in *Beyond the Pavement*, including:

- A sensitive fit with the existing built, natural and community context
- A contribution to the accessibility and connectivity of local communities
- A contribution to the overall quality of the public domain for the community, including road users.

Despite limited space for the approaches and portals to the Cross City Tunnel in Sydney, the adjacent streets and public spaces include well-considered design details and local access.

The creative design of the spaces around this Cross City Tunnel portal contributed pocket parks with good pedestrian pathways. (Sydney, NSW).

Careful design of this dive structure and portal to the Eastern Distributor tunnel (above two images) maintained essential landscape characteristics (including several large existing trees), as well as good local connectivity for motorists, pedestrians and cyclists.

2.3 Additional urban design challenges for long tunnels

The construction of long tunnels is becoming more common as technology advances and construction methods become more efficient, and as greater consideration is given to the impact of roadways on the natural and built environment.

Additional urban design considerations are required for long tunnels. Specifically, long road tunnel design requires a new emphasis on driver experience, and a more sensitive design response to best integrate more and larger above ground structures and buildings.

This is because long road tunnels can have the following issues:

- Substantial, externally visible air ventilation facilities and structures (usually vertical exhaust outlets and air intakes), as well as large fan and control buildings commonly located near to tunnel portals
- A repetitive and monotonous driving environment: the internal environment of a tunnel can be highly repetitive and monotonous, including its alignment when too straight or with little variation, and this can lead to driver safety concerns
- Disconnection from the above ground environment: whether it be urban or rural
- Difficulty wayfinding: such as successfully navigating tunnel entry, exit and merge points.

These issues are addressed in more detail below.

Ventilation facilities

In NSW, long road tunnels designed today will generally require large external air ventilation facilities and structures. These include vertical exhaust outlet and air intake structures, large ventilation fans and control buildings. The number and location of air intakes and exhaust outlets varies depending on factors including the level of vehicle emissions expected, tunnel length, number of lanes, gradients, topography and nearby land uses.

Tunnel ventilation facilities, in particular exhaust structures and operations buildings, can become contentious community issues which can have a strong impact on the planning and design of road tunnels. The successful integration of these potentially intrusive structures requires early engagement with local communities and stakeholders, together with a well-considered urban design approach to ensure that the ventilation infrastructure is designed to be relevant to, or consistent with, the characteristics of its surrounding environment.

Design challenges that arise during the planning and design of tunnel ventilation facilities include:

- Selecting a suitable site for the ventilation system, which is usually close to the tunnel portals
- Finding sites away from highly sensitive land uses, such as schools and daycare facilities
- Establishing early engagement with local communities and stakeholders to discuss project options and receive feedback
- Adopting an integrated design approach to ensure that the positioning, form, operation and overall appearance of the tunnel fits with the characteristics and qualities of the local area.

Repetitive and monotonous driving environments

Long tunnels increase the time drivers are required to stay alert and focused. In a long tunnel, remaining 'switched on' can become a challenge for drivers due in part to the unvarying visual environment, the sense of containment, and a lack of visual stimulation.

A monotonous tunnel environment may have design characteristics such as a seemingly endless straight alignment or one with a constant, very gentle curve over a long distance; unchanging and repetitive road edge conditions, barriers and tunnel linings; as well as unvaried overhead lighting. This can negatively affect the driver experience, which could potentially lead to driver safety concerns — particularly as tunnel lengths increase.

Driver disconnection from above ground environment

The lengthy periods spent travelling in long tunnels can lead drivers to experience a sense of disorientation. This can lead to driver confusion in terms of their whereabouts with respect to the above ground environment. The driver may also experience a sense of disconnection from the urban or rural environment through which they are travelling.

Difficulty wayfinding

Long tunnels often have multiple entry and exit points, and points for vehicles to merge or diverge. This can be confusing for drivers, particularly if signage is insufficient or even too cluttered, or if it is poorly integrated. A driving task such as navigating in a tunnel can become much more complex if a driver's wayfinding ability is affected.

Formerly the longest road tunnel in Australia, the Airport Link Tunnel in Brisbane includes this well-detailed and striking portal design, assisting drivers find their bearings and identifying the tunnel ahead.

Despite good lighting features which enhance wayfinding, the nine minute drive within the Airport Link Tunnel has few other features or treatments to break up what can be a monotonous journey. This is similar to the majority of long tunnels within Australia.

With little indication of distance travelled within a long tunnel, or information about actual location, drivers can become disorientated and disconnected from the urban or rural environment through which they are travelling. (M5 East, NSW).

The Cross City Tunnel ventilation outlet in Sydney is a striking built form, carefully designed to integrate with the character of its surrounding urban setting.

3 Urban design objectives and strategies for road tunnels

3.1 Introduction

This chapter introduces four urban design objectives that support the successful design of all tunnels, including long tunnels, in both an urban or rural environment. Urban design strategies are introduced which link directly to the urban design objectives. Specific advice is provided, where relevant, for long, urban or rural tunnels. Short tunnels are encompassed completely by the objectives and strategies for 'all tunnels' and as such are not addressed separately.

The urban design objectives and strategies for tunnels have taken into consideration the work of PIARC, including recommendations and principles from the *PIARC Road Tunnels Manual (2015)*.

3.2 Urban design objectives for all road tunnels

The following objectives support the successful design of tunnels of any length, in either a rural or urban setting.

Objective 1
Provide a safe, comfortable and attractive journey experience.

Objective 2
Provide a legible, self-explaining journey which enables awareness of location.

Objective 3
Provide a road tunnel which is sensitive to its context.

Objective 4
Deliver a high quality public asset that requires minimal maintenance.

Whether in an urban or rural setting, a road tunnel can deliver benefits to city planning, traffic management, environmental sensitivity, community sustainability and liveability. Urban design objectives to improve customer and community experience support the delivery of a safe, easy to use, comfortable, and stress-less journey. (St Helena Tunnel, Byron Bay).

Relevance to *Beyond the Pavement* — road and maritime project urban design policy

It is important to note that this guideline does not supersede *Beyond the Pavement* — which outlines Roads and Maritime's urban design policy, procedures and design principles. This guideline should be read and implemented in conjunction with *Beyond the Pavement.*

The application of all four tunnel objectives should be applied with consideration to the 'physical design outcomes' and 'performance themes' detailed in *Beyond the Pavement.*

Physical design outcomes

The physical design outcomes that must be achieved are:

- Road and maritime projects, and the networks of which they are a part, must fit sensitively with the landform and the built, natural and community environments in which they are situated
- Road and maritime project planning and design must contribute to the accessibility and connectivity of communities and a general permeability of movement through areas
- The design and management of road and maritime projects must contribute to the overall quality of the public domain for the community, including transport users.

Performance themes

These physical design outcomes must be achieved in a **safe, cost-effective** and **sustainable** manner.

Design principles

How the road tunnel urban design objectives relate to urban design principles in *Beyond the Pavement*.

Objective 1
Provide a safe, comfortable and attractive journey experience relates to Principle 7 of *Beyond the Pavement* — Designing roads as an experience in movement.

Objective 2
Provide a legible self-explaining journey enabling awareness of location relates to Principle 8 of *Beyond the Pavement* — Creating self-explaining road environments.

Objective 3
Provide a road tunnel which is sensitive to its context relates to several principles of *Beyond the Pavement*: Principle 2 — Fitting into the built fabric, Principle 3 — Connecting modes and communities, Principle 4 — Fitting with the landform, Principle 5 — Responding to natural pattern, and Principle 6 — Incorporating heritage and cultural contexts.

Objective 4
Deliver a high quality public asset that requires minimal maintenance relates to Principle 9 of *Beyond the Pavement* — Achieving integrated and minimal maintenance design.

3.3 Objective 1: Provide a safe, comfortable and attractive journey experience

Good urban design ensures that a tunnel and its associated structures are visually appealing and well-integrated into their local context. It also takes into account how the driver experiences the full journey sequence from approach, travelling through and exiting the tunnel. This can contribute to driver reassurance and improved road safety.

The needs of all road tunnel users should be considered throughout the planning and design phases — including private vehicle drivers and passengers, heavy vehicles and other freight or commercial vehicles, and public transport.

Particular issues for long tunnels

With long tunnels, the effect of being in a tunnel on the driver's mindset and behaviour can be accentuated. A well-integrated urban design approach that provides a visually appealing travel experience that minimises boredom, restlessness and fatigue, and encourages appropriate driving behaviour, is very important in supporting a safe driving environment to maintain high levels of safety and feelings of comfort and security.

Design strategies relevant to Objective 1

Tunnel design for all tunnels should provide the following strategies:

- The widest, highest dimensions possible, to promote feelings of safety and comfort, and to minimise sensations of confinement, which is compatible with the above ground road experience both before and after the tunnel
- A varied and stimulating, though not distracting, travel experience that avoids extended monotonous tunnel conditions, to support driver attention and contribute to safe tunnel design
- Design highlights that enhance visual variety within the tunnel by considering operational spaces and fire and life safety features and elements, (such as safety bays and cross-passage accesses) as potential design features
- Light colours used for the interior tunnel walls to maximise light reflection and generate a feeling of spaciousness
- Ambient lighting to improve the visual experience of the tunnel and reduce or remove any potentially oppressive feeling of being underground
- Attractive, welcoming tunnel entrances that fit into the local built and natural fabric
- Tunnel transitions designed to reduce sudden contrasts in light conditions.

A generously proportioned, attractive portal greets motorists in the Cudgen Road tunnel. Journey safety is reinforced by the overhead lighting accentuating the curved alignment, and improving the visual experience of the tunnel. (Pacific Highway, Yelgun).

The 9km long Northconnex tunnel utilised a range of creative features to provide subterranean interest, visual comfort, support patronage and result in less vehicles on the surface in neighbourhoods.

In the M4–M8 tunnel Lighting and strong colours are important in making the total 23km journey visually stimulating. If they can be modified in the control centres to reflect a calender of events such as road safety week and the Mardi Gras then there is an added dimension to the visual interest.

Boldly coloured panels highlight tunnel safety exit points, and the tones of grey on the walls depict the local field patterns. The whole effect provides variation and subtle stimulation to the driving experience. (St Helena Tunnel, Byron Bay NSW).

3.4 Objective 2: Provide a legible, self-explaining journey which enables awareness of location

A successful road tunnel should be 'self-explaining' which means that the tunnel design promotes focused driving behaviour, which will encourage drivers to adapt their driving to the particular requirements of that tunnel.

Tunnel 'legibility' is an important feature of a self-explaining road tunnel. Good tunnel legibility means that drivers are able to interpret driving conditions and adapt their driving in advance of upcoming changes within the tunnel system. Good tunnel legibility is a contributor to improved tunnel safety.

Particular issues for long tunnels

When designing long tunnels in urban or rural areas, it is important to consider that the driver is disconnected from the above ground environment (eg the road network, urban or rural environment) for an extended period, which can lead to confusion and disorientation.

Design strategies relevant to Objective 2

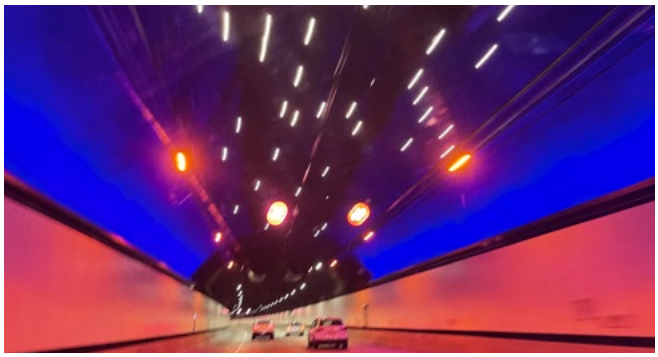
For all tunnels, the tunnel design should provide:

- Distinct physical and visual indication of the tunnel's approach and departure corridors (including tunnel dive structures) well in advance, such as through recognisably different corridor features, materials and finishes
- Well-considered signage that is clearly visible and easily legible.

For long or urban tunnels, the tunnel design should provide:

- Distinctive dive structure and portal design (and consideration should be given to these, reflecting the tunnel's destination or general direction of travel)
- Simple graphics or text to indicate at various points the location of the tunnel with respect to the surface level environment, or information about the driver's progress within the tunnel
- Easily distinguishable tunnel-ramp merge and diverge zones to assist in identifying different entry and exit points
- Variation in paneling design to define parts of the tunnel, such as approaching merge and diverge zones, safety bays and pedestrian emergency access passages.

These approaches to the Cross City Tunnel in Sydney are clearly differentiated from the local road network. Distinctive portal design resonates with the end destination of the tunnel.



Tunnel linings offer opportunities to introduce information, simple graphics, textures or colour variations to assist the motorist's journey through a long tunnel. Designs for the 9km NorthConnex Tunnel in Sydney include information about the above ground location at given points to help drivers retain a connection with the city above.

This portal on Brisbane's Airport Link is a striking landmark for motorists, providing a clear sense of direction. Its form and scale successfully announce the tunnel within a complex setting of multiple adjacent ramps and connections to linked tunnels and the local road network.

3.5 Objective 3: Provide a road tunnel which is sensitive to its context

An overarching goal when designing a tunnel's connection to the above ground context (the tunnel/surface interface), is to achieve a 'best fit' with its urban or rural context by enhancing local pedestrian and cycleway connectivity (active transport), minimising the project footprint, and designing the project to contribute to the local context through careful design of open spaces and landscape character.

Particular issues for rural tunnels

When designing tunnels in rural areas it is important to consider that rural and natural environments are defined by their landscape and landform, and large built elements such as tunnel portals and dive structures can have a substantial visual and physical impact. If not designed well they can be intrusive and unappealing.

Design strategies relevant to Objective 3

For all tunnels, the tunnel design should:

- Provide portal areas that add value to the community through: the provision of open space; improved connectivity for local vehicles, cyclists and pedestrians; and green infrastructure including site specific planting, trees and other vegetation
- Retain or reinstate plants, trees or other green infrastructure — as part of the approach corridor, dive structure and portal area to maximise the driver's experience of the landscape before entering the tunnel
- Include the use of texture, colour and external feature lighting to visually reduce the bulk and mass of the portal area; to incorporate some design variance; and to improve the driver's experience entering the tunnel
- Ensure well-considered signage placement that does not impact negatively on the portal design.

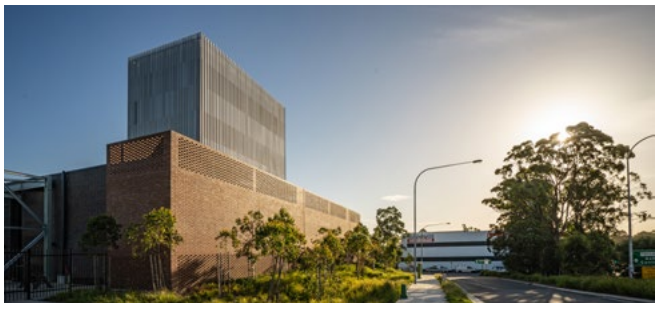
For long tunnels, the tunnel design should provide:

- Co-location of the tunnel portal and ventilation outlet to minimise the physical footprint and visual impact, where practicable. The tunnel ventilation outlets and other associated structures should be designed as high quality pieces of architecture, integrated with the portal area where practicable, and designed to best fit with the characteristics of the surrounding environment.

For rural tunnels, the tunnel design should provide:

- Tunnel entry and exit portals and approaches with a minimal physical and visual footprint, retaining or reinstating as much as possible of the surrounding landform and vegetation
- Simple, sculptural portal structures (preferably elliptical, parabolic or circular forms) against a backdrop of vegetation
- Portal structures with a noticeable protrusion and edge shadows to emphasise the effect. These should be coloured white, off-white or very light grey.

Haberfield Gardens at the entrance to WestConnex Tunnel was created from unused land from the project and provides a much needed local park.



The design of the ventilation buildings portals landscape and surrounding space in Haberfield in Sydney helps settle the development into the character of the place which has a predominance of street trees and brick structures.

The entrance to Westconnex in Sydney at Haberfield, utilises neat panels with a strip lighting that can be modified in the control centre.

3.6 Objective 4: Provide a high quality public asset that requires minimal maintenance

It is important that road tunnel projects deliver high quality public assets that require minimal maintenance. This ultimately benefits the tunnel users, the tunnel operators and the general community.

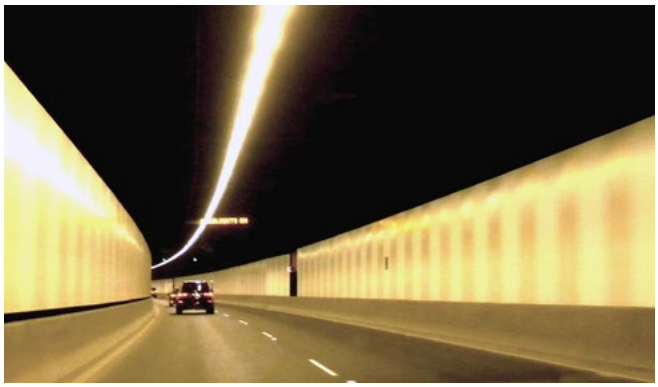
As stated in *Beyond the Pavement*, minimal maintenance is achieved through:

- Neat, uncomplicated and well-coordinated design
- The use of robust and durable material and forms
- Good accessibility, ease and safety for conducting maintenance.

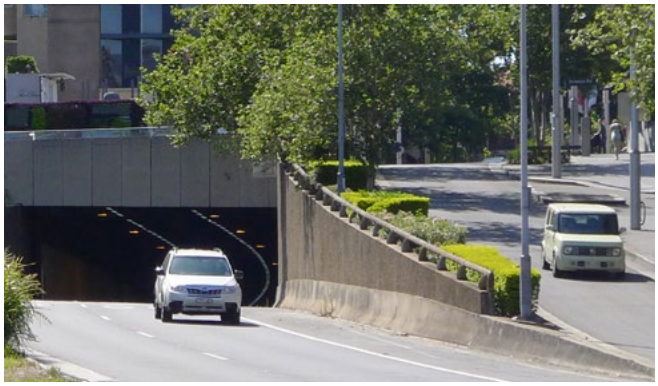
Design strategies relevant to Objective 4

For all tunnels, the tunnel design should:

- Provide neat, simple and refined design features and the considered integration of design elements, to avoid 'clutter'
- Eliminate the use of poorer quality visible finishes (such as shotcrete, unless used for the tunnel lining and concealed from view). This will help prevent the need for expensive, high maintenance add-on features to improve appearance
- Use robust, durable materials that can withstand the harsh tunnel environments and associated rigorous maintenance, and public use of adjacent accessible spaces
- Minimise opportunities for vandalism.



A simplified panel attached system in the Lane Cove Tunnel avoided unnecessary fixings and cover plates, which collect dirt and grime, making them easier to clean.



The robust design of Sydney's Kings Cross Tunnel (now over 40 years old) continues to stand the test of time. Materials, elements and details which feature as part of the adjacent public domain, demonstrate how well-considered design reduces vandalism potential and minimises maintenance requirements.

Wrapping the hillside around the portals at the Ewingsdale to Tintenbar tunnel on the Pacific Highway created a low impact design solution that respected the landform and landscape of the area.

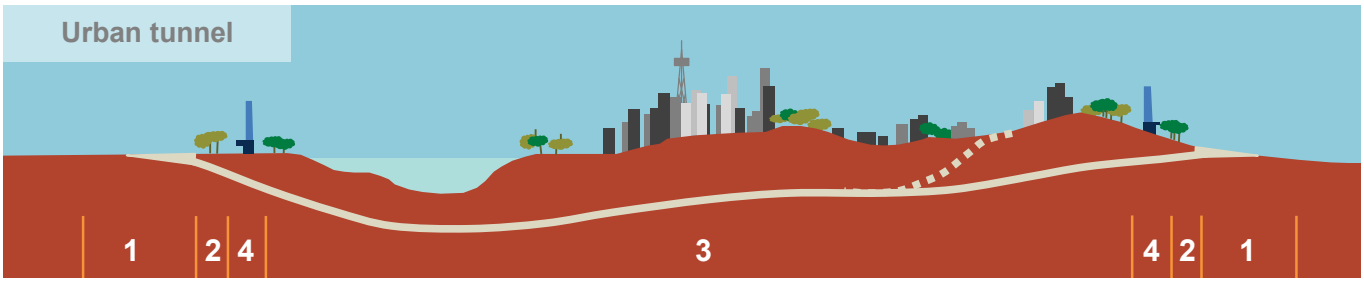
4 Applying urban design objectives and strategies to tunnel zones

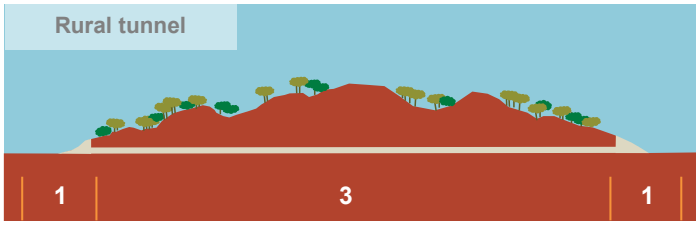
4.1 Introduction

This chapter describes how the tunnel urban design objectives can be achieved by implementing the relevant strategies outlined in the previous chapter.

Four tunnel zones are identified, and the specific design objectives and design strategies that apply to each zone are outlined in table format. Successful implementation examples are provided.

4.2 The zones and elements of a road tunnel





Please note rural tunnels generally only contain zones 1 and 3 as reflected in the diagram on the left.

Tunnel zone	Primary elements of the tunnel zone
1. Tunnel approach, dive structure and portal	Pre-and post-tunnel road corridors; surrounding landform; tunnel dive structures and walls; the portal face and the portal structure; transition structures and lighting; the landscape design of the approach corridor and portal area; and signage and gantries.
2. Public spaces and tunnel buildings	Tunnel control centres (usually located at the portal — see also ventilation facilities below); and any open space located near to the portal.
3. Mainline tunnel, internal merges and diverges	Entry or exit ramps and tunnel cross-section; internal merge and diverge zones; interior tunnel design including tunnel lining, lighting and signage; vehicle lay-bys/ safety bays, pedestrian emergency access passages.
4. Ventilation facilities (long tunnels only)	Ventilation outlet structures; air intake structures; associated operational buildings (if located by the ventilation facilities); parking facilities; and site landscape and streetscape design.

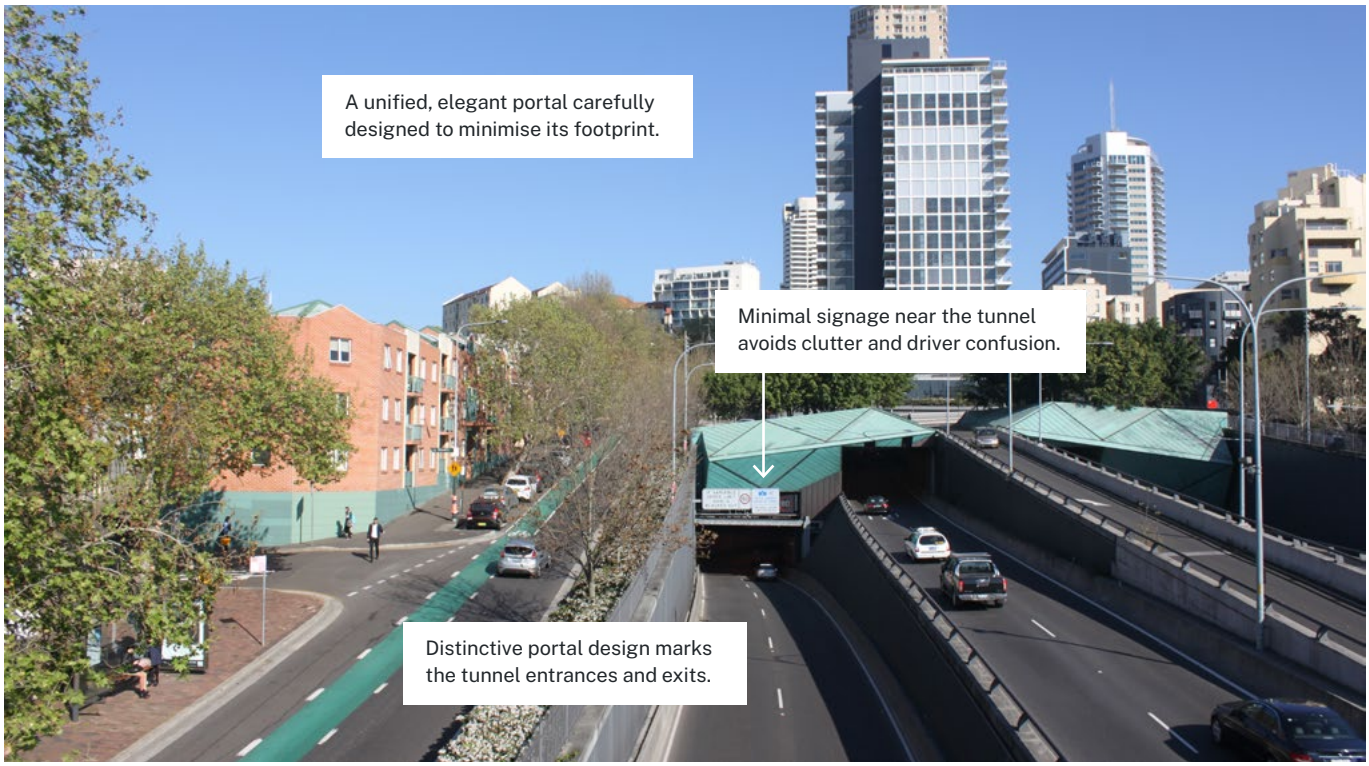
4.3 Applying design objectives to tunnel zones

In this section each tunnel zone is considered in isolation, and the relevant urban design objectives and strategies are identified. The specific tunnel elements that are relevant to these objectives and strategies are also identified. Each subsection concludes with a number of illustrative examples where the design objectives have been successfully applied.

Tunnel zone 1: Tunnel approach, dive structure and portal

Relevant urban design objectives and strategies	Relevant tunnel elements
Objective 1: Provide a safe, comfortable and attractive journey experience. ▸ Attractive, welcoming tunnel entrances that fit into the local built and natural fabric ▸ Tunnel transitions designed to reduce sudden contrasts in light conditions.	▸ Pre-and post-tunnel road corridors as transitional zones ▸ Portal dive structure/walls ▸ Portal face and portal structure ▸ Tunnel transition zones to adjust for internal/external light levels ▸ Landscape design ▸ Signage and gantries.
Objective 2: Provide a legible, self-explaining journey which enables awareness of location. ▸ Distinct physical and visual indication of the tunnel's approach and departure corridors (including tunnel dive structures) well in advance, such as through recognisably different corridor features, materials and finishes ▸ Well-considered signage that is clearly visible and easily legible.	
Objective 3: Provide a road tunnel which is sensitive to its context. ▸ Portal areas that add value to the community through: the provision of open space; improved connectivity for local vehicles, cyclists and pedestrians; and 'green space' plants, trees or other green infrastructure ▸ Retain or reinstate plants, trees or other green infrastructure as part of the approach corridor, dive structure and portal area to maximise the driver's experience of the landscape before entering the tunnel ▸ The use of texture, colour and external feature lighting to visually reduce the bulk and mass of the portal area; to incorporate some design variance; and to improve the driver's experience entering the tunnel ▸ Well-considered signage placement that does not impact negatively on the portal design.	
Objective 4: Deliver a high quality public asset which requires minimal maintenance. ▸ Provide neat, simple and refined design features and the considered integration of design elements, to avoid 'clutter' ▸ Eliminate the use of poorer quality visible finishes (such as shotcrete). This will help prevent the need for expensive, high maintenance add-on features to improve appearance ▸ Use robust, durable materials that can withstand the harsh tunnel environments and public use of adjacent accessible spaces ▸ Minimise opportunities for vandalism.	

Illustrative examples

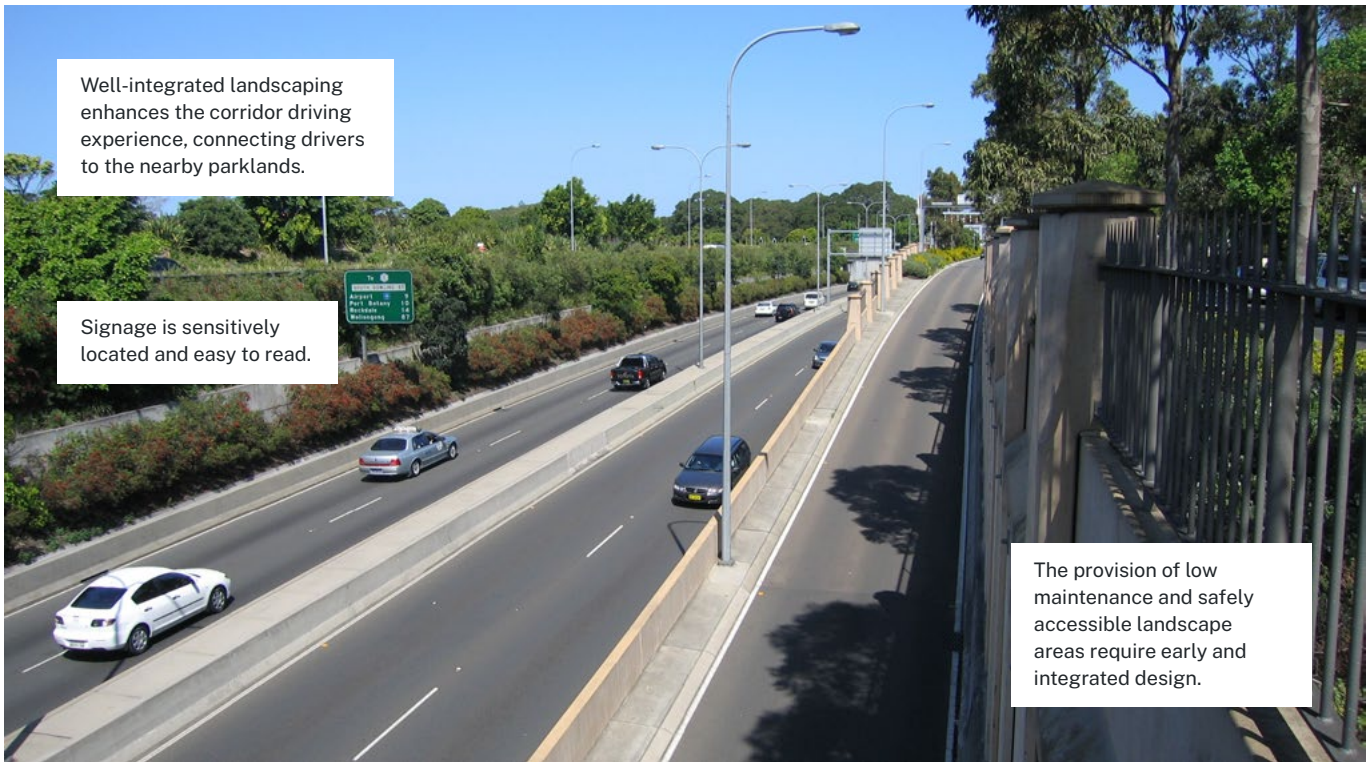


Cross City Tunnel, Sydney.

Cross City Tunnel, Sydney. (Urban design: Hassell. Photography: Rowan Turner).

St Helena Tunnel, Pacific Highway, Byron Bay.

Kings Cross Tunnel, Sydney.



Eastern Distributor Tunnel, Sydney.

Cahill Expressway, Macquarie Street Tunnel, Sydney.

Tunnel zone 2: Public spaces and tunnel buildings

Relevant urban design objectives and strategies	Relevant tunnel elements
Objective 3: Provide a road tunnel which is sensitive to its context. ▸ Portal areas that add value to the community through: the provision of open space; improved connectivity for local vehicles, cyclists and pedestrians; and 'green space' plants, trees or other green infrastructure ▸ Co-location of the tunnel portal and ventilation outlet, where practicable, to minimise the physical footprint and visual impact. The tunnel ventilation outlets and other associated structures should be designed as high quality pieces of architecture, integrated with the portal area where practicable, and designed to best fit with the characteristics of the surrounding environment.	▸ Public domain/open spaces associated with portal area ▸ Landscape design ▸ Public space lighting ▸ Tunnel control centre buildings ▸ Ventilation structures (if located at the portal).
Objective 4: Provide a high quality public asset that requires minimal maintenance. ▸ Provide neat, simple and refined design features and the considered integration of design elements, to avoid 'clutter' ▸ Eliminate the use of poorer quality visible finishes (such as shotcrete). This will help prevent the need for expensive, high maintenance add-on features to improve appearance ▸ Use robust, durable materials that can withstand the harsh tunnel environments and public use of adjacent accessible spaces ▸ Minimise opportunities for vandalism.	

Illustrative examples

Cross City Tunnel, Sydney.

Cross City Tunnel, Ward Avenue Park, Sydney.

East Link Tunnel, Melbourne.

Tunnel zone 3: Mainline tunnel, and internal merges and diverges

Relevant urban design objectives and strategies	Relevant tunnel elements
Objective 1: Provide a safe, comfortable and attractive journey experience. ▸ The widest, highest dimensions possible, to promote feelings of safety and comfort, and to minimise sensations of confinement, to be compatible with the above ground road experience both before and after the tunnel ▸ A varied and stimulating travel experience, without being distracting, that avoids extended monotonous tunnel conditions, to support driver attention and contribute to safe tunnel design ▸ Design highlights that enhance visual variety within the tunnel by considering operational spaces and fire and life safety features and elements, (such as safety bays and cross-passage accesses) as potential design features ▸ Light colours used for the interior tunnel walls to maximise light reflection and generate a feeling of spaciousness ▸ Ambient lighting to improve the visual experience of the tunnel and reduce or remove any potentially oppressive feeling of being underground.	▸ Mainline tunnel ▸ Entry/exit ramps ▸ Internal merge and diverge zones ▸ Tunnel alignment (curvature to add interest, avoiding continuous straight alignment) ▸ Tunnel/carriageway cross section ▸ Wall linings ▸ Tunnel ceiling ▸ Lighting (general visibility, ambient and highlight) ▸ Ventilation system ▸ Vehicle safety bays ▸ Emergency access/ egress points ▸ Pedestrian emergency access passages ▸ Signage.
Objective 2: Provide a legible, self-explaining journey enabling awareness of location. ▸ Simple graphics or text to indicate at various points the location of the tunnel with respect to the surface level environment, or information about the driver's progress within the tunnel ▸ Easily distinguishable tunnel-ramp merge and diverge zones to assist in identifying different entry and exit points ▸ Paneling with designs to denote approaching tunnel merges and diverges, safety bays and pedestrian emergency access passages.	
Objective 4: Provide a high quality public asset that requires minimal maintenance. ▸ Use robust, durable materials that can withstand the harsh tunnel environments ▸ Minimise opportunities for vandalism.	

Illustrative examples

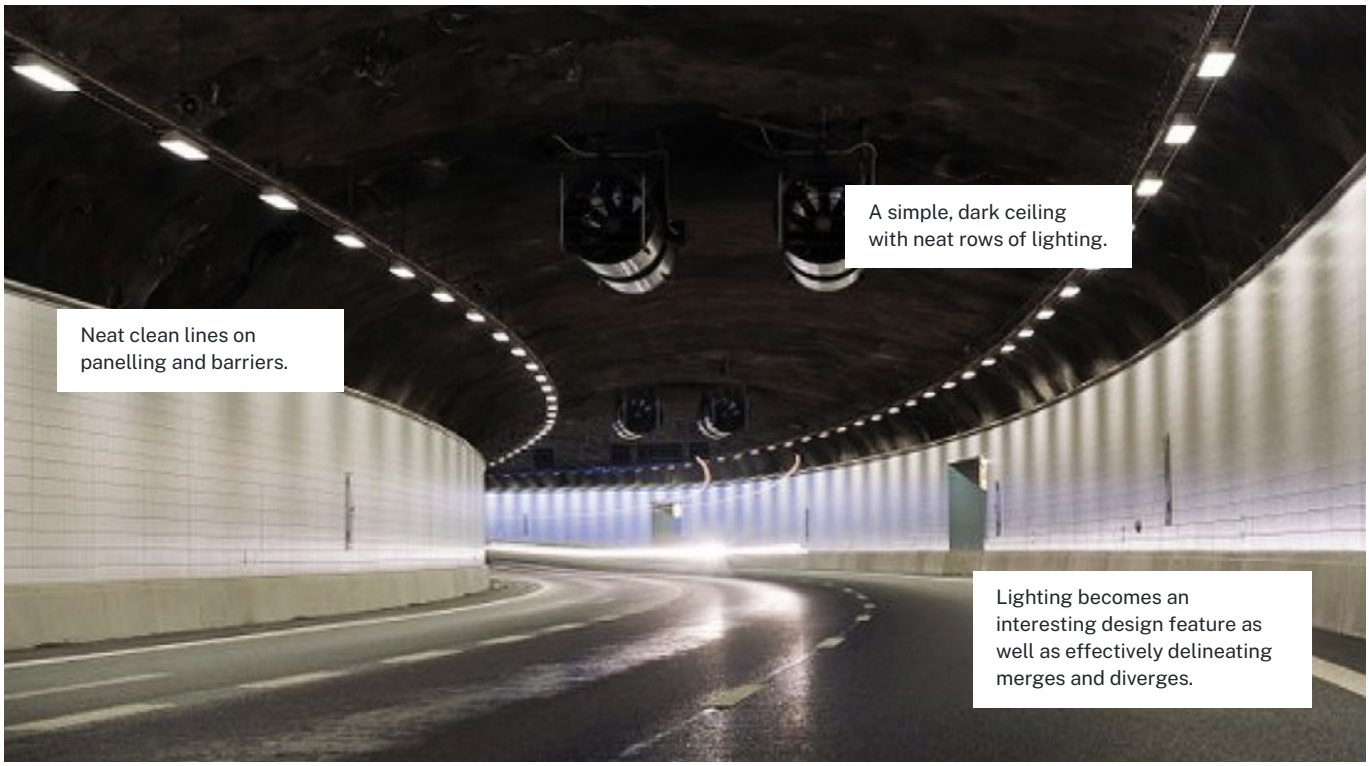
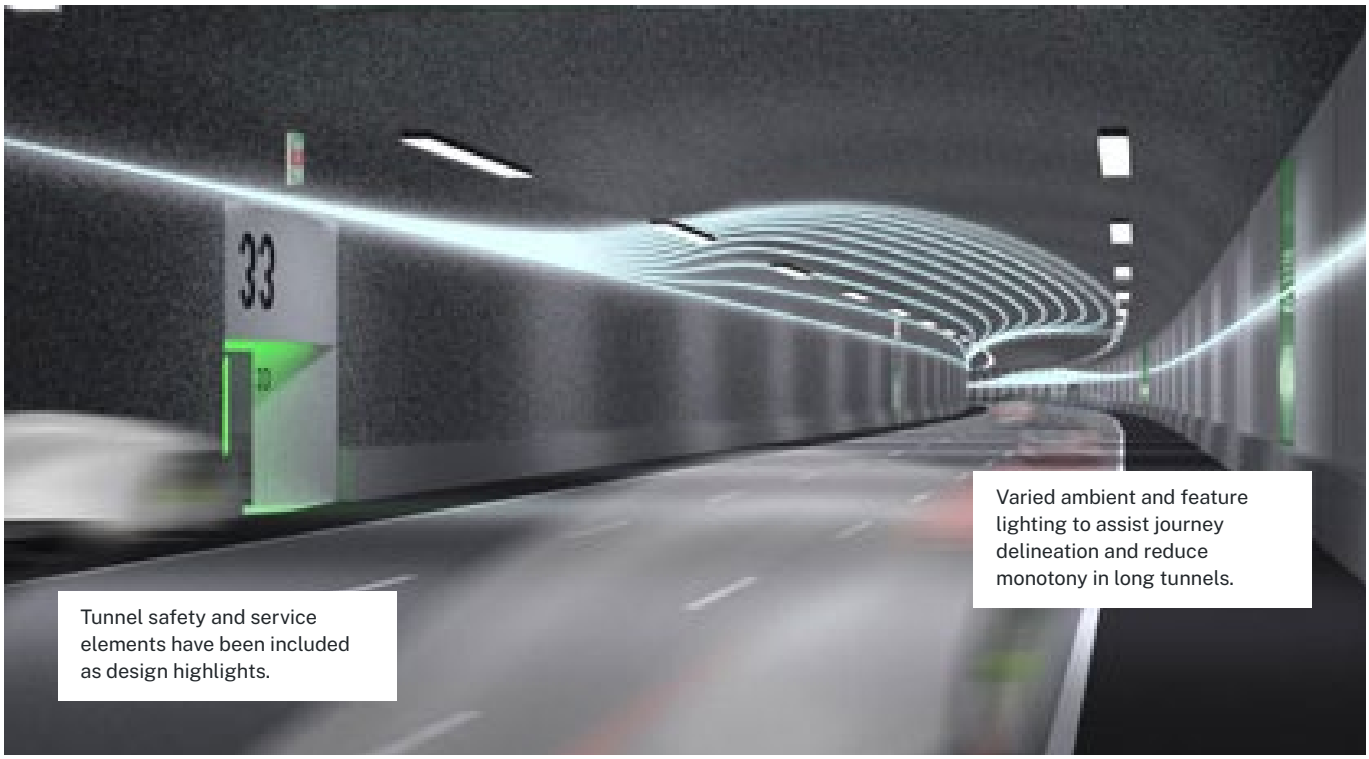


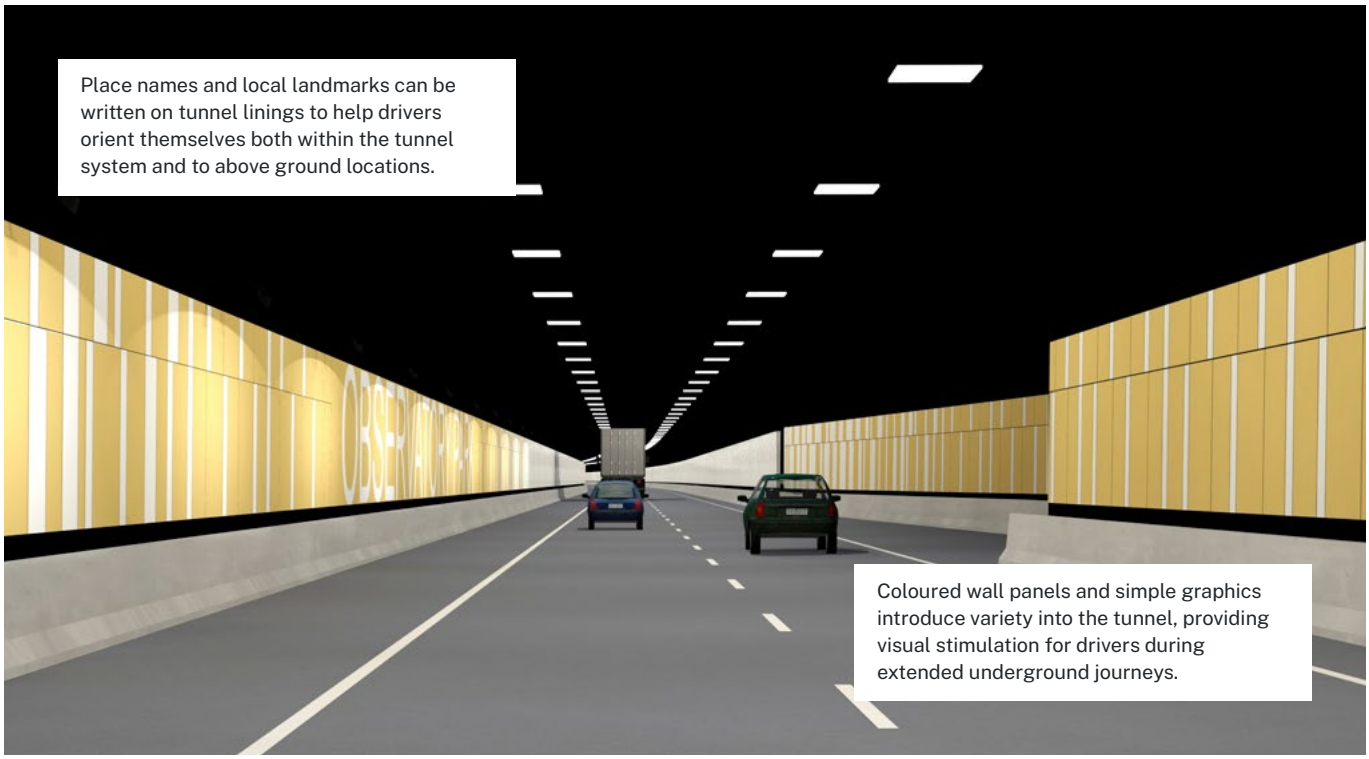
Image source: Thorn Lighting Catalogue.

Salaam Tunnel, Abu Dhabi, United Arab Emirates.

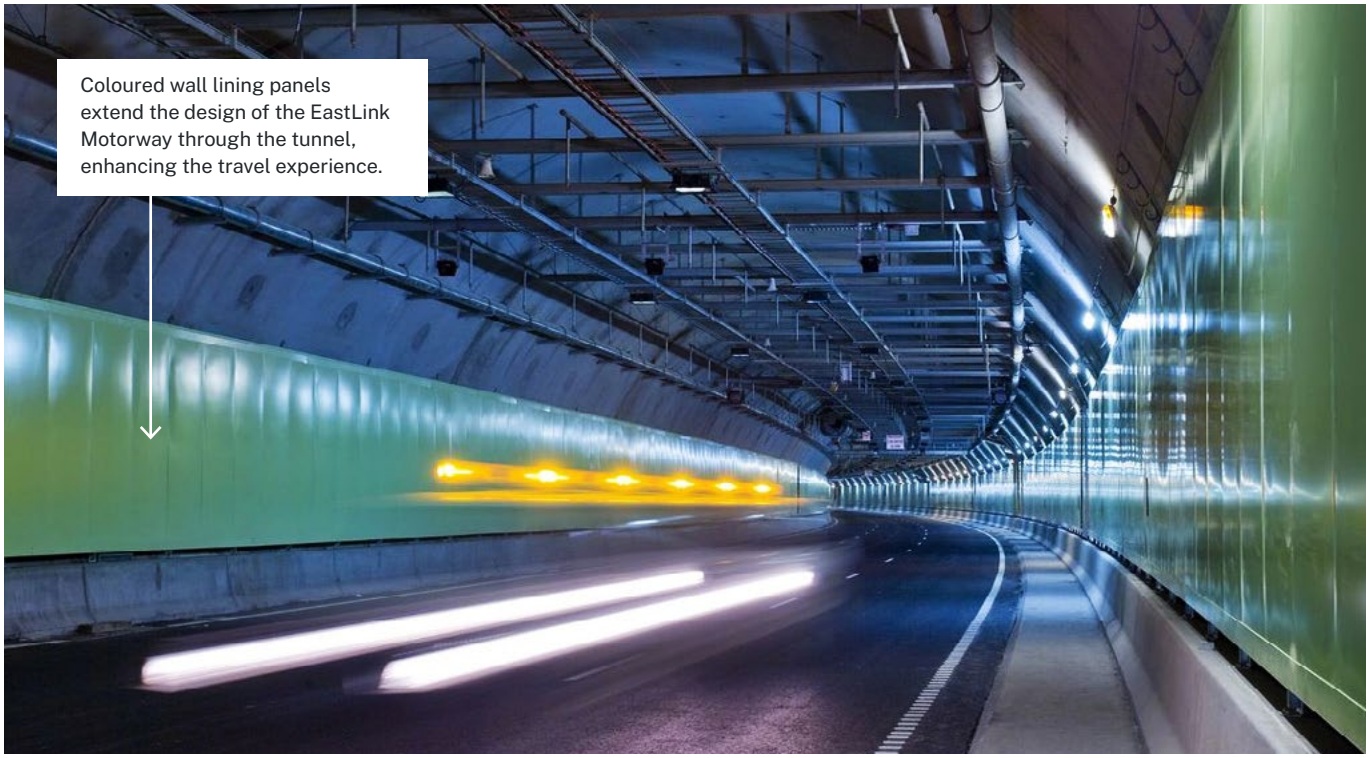


The E4 Stockholm Bypass Tunnel, Sweden. (Proposed project illustration).

Fehmarn Belt immersed Tunnel, between Germany and Denmark. (Proposed project illustration).



NorthConnex, Sydney. (Concept design — see completed design on page 15).



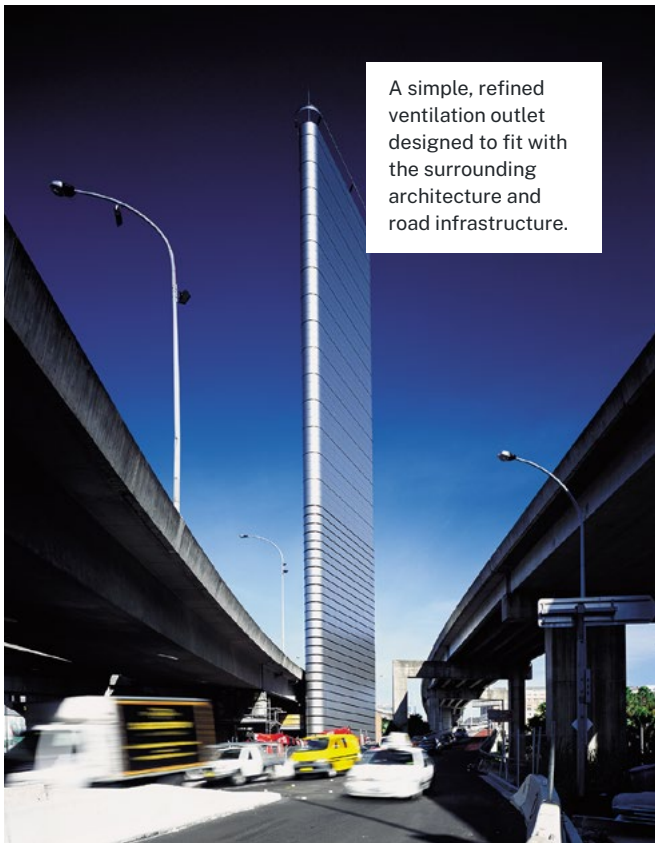
EastLink Tunnel, Melbourne.

Tunnel zone 4: Ventilation facilities (long tunnels only)

Tunnel zone 4, ventilation facilities, is distinctly different from the other tunnel zones in terms of its function and structure. Most of the road tunnel urban design objectives do not apply to this zone. Urban design strategies specific to the design of ventilation facilities are provided in the table below, as well as applicable Objective 4 strategies.

Design strategies	Relevant tunnel elements
▸ The visual impact of the ventilation facilities should be carefully considered. Design treatments should work to visually minimise the mass and bulk of the ventilation buildings, and should be sensitive to the local built fabric. Different materials and the layering of façade elements can help to reduce their visual scale ▸ Where possible the facilities should contribute to the surrounding built environment and public space. For example, the buildings and their curtilages should be integrated with streets and footpaths to contribute to streetscape character and to the urban tree canopy ▸ Consideration should be given to the inclusion of podium/boundary buildings, which can be used as offices, workshops and retail outlets. This will help reduce the visual impact by distributing the housing of the facilities across multiple, smaller buildings ▸ The design of the facilities should relate closely to the design of the motorway and the facilities should be located close to the motorway. This will create a strong visual tie between the facilities and the motorway, which should make the purpose of the facility buildings more apparent to the public ▸ The design and location of facility buildings and structures should take into account important local views, vistas and valued places. The effect of the facilities on these must be minimised.	▸ Ventilation outlets ▸ Associated operational buildings ▸ Parking facilities ▸ Ventilation facility site layout ▸ Street frontage design ▸ Landscape design.
Objective 4: Provide a high quality public asset that requires minimal maintenance. ▸ Provide neat, simple and refined design features and the considered integration of design elements, to avoid 'clutter' ▸ Eliminate the use of poorer quality visible finishes (such as shotcrete). This will help prevent the need for expensive, high maintenance add-on features to improve appearance ▸ Use robust, durable materials that can withstand the harsh tunnel environments and public use of adjacent accessible spaces ▸ Minimise opportunities for vandalism.	

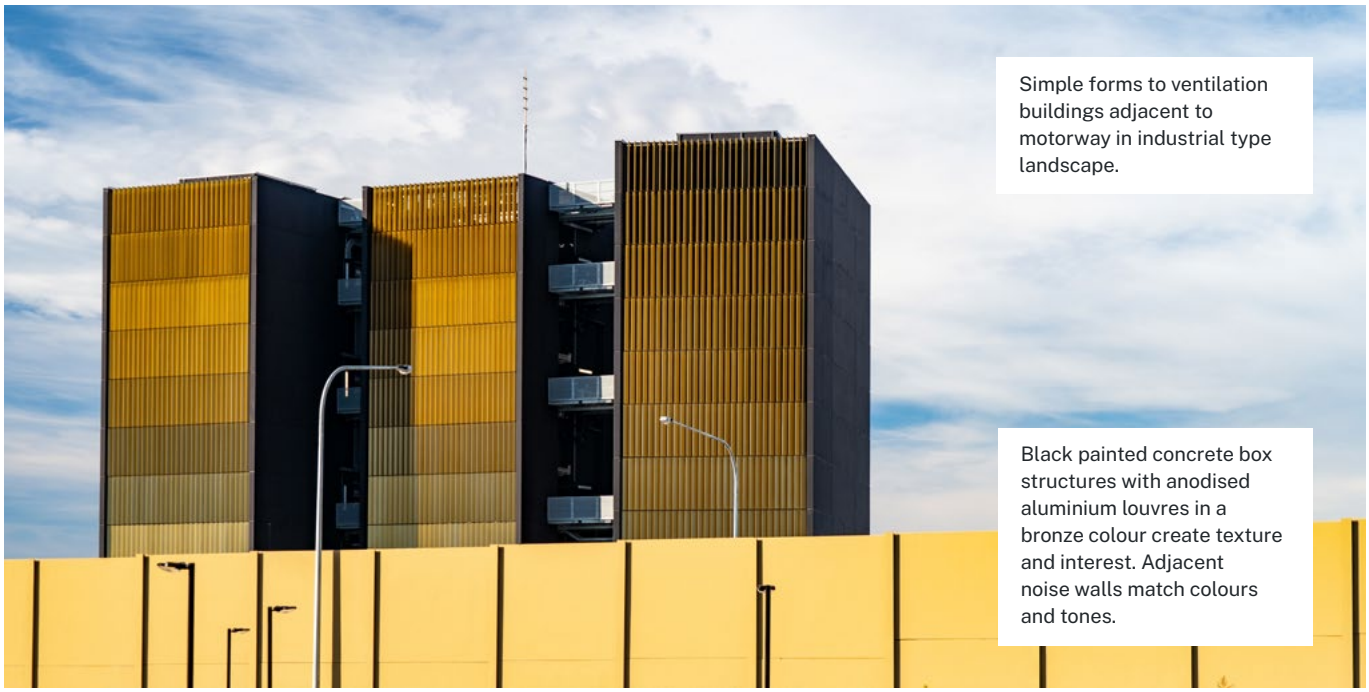
Illustrative examples



Cross City Tunnel, Sydney.
(Urban design: Hassell. Photography: Patrick Bingham Hall).

Lane Cove Tunnel, Sydney.

EastLink Tunnel, Melbourne.

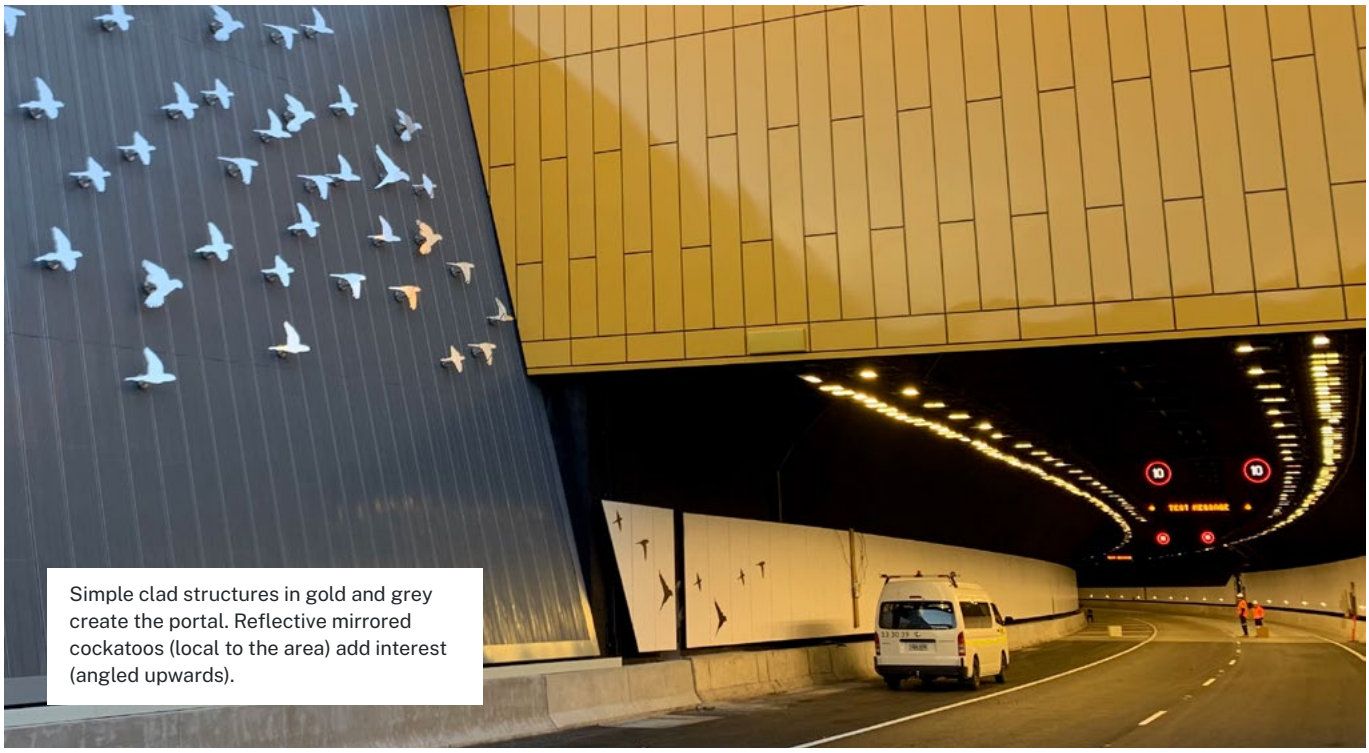


Westconnex M8 at Bexley

Westconnex St Peters Interchange M8-M4 portal

Westconnex M4 East portals at Haberfield

WestConnex Rozelle Interchange (under construction)



Westconnex M4 East portals at Haberfield

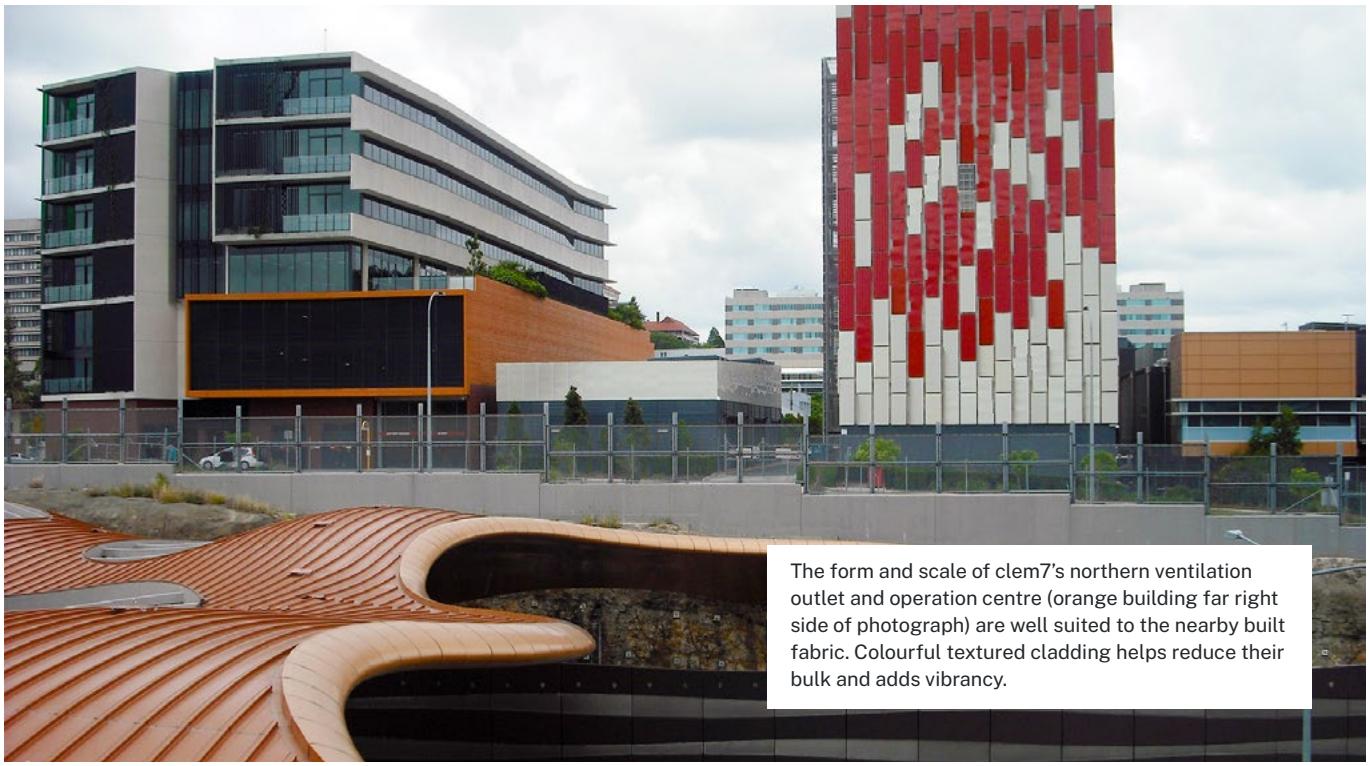
WestConnex Rozelle Interchange

Cross City Tunnel Control Centre, Sydney.

Eastern Distributor Control Centre, Sydney.

Hugenwald Tunnel, Freiburg Germany.

Waterview Connection proposal, New Zealand. (Project illustration).



Clem Jones Tunnel (Clem7) northern ventilation outlet, Brisbane.

5 Applying urban design strategies to project phases

There are four sequential phases in the life of a road project, as set down in Transport's project management system. These are the initiation, development, implementation and finalisation phases. The road tunnel urban design strategies outlined in this document apply to each of these phases as follows.

It is the approach of Transport to consider urban design at all stages of tunnel design, from initiation, through delivery and to finalisation.

Project phase	Relevant stage (within project phase)	Urban design strategies
Initiation	Business case	Apply tunnel objectives to the scoping of the project to ensure that appropriate estimates of cost and land take are made.
Development	Options and concept design	Urban Design Roads and Waterways to input and review throughout route options development and selection. Use the broad urban design objectives set out in *Beyond the Pavement* to assist in route selection and to guide strategic concept design.
	Concept design development	Develop concept design in accordance with *Beyond the Pavement* and the *Tunnel urban design guideline*. Urban Design Roads and Waterways to review concept design and urban design report for the environmental assessment.
Delivery	Delivery readiness	Include objectives and principles set out in the *Tunnel urban design guideline* in Scope of Works for project tendering. Urban Design Roads and Waterways to assist in reviewing tenders and developing the detailed design.
	Delivery	Urban Design Roads and Waterways to assist in monitoring of delivery.
Finalisation and operation	Finalisation	Ensure that the vegetative landscaping is established. Urban Design Roads and Waterways landscape asset advisor to review.

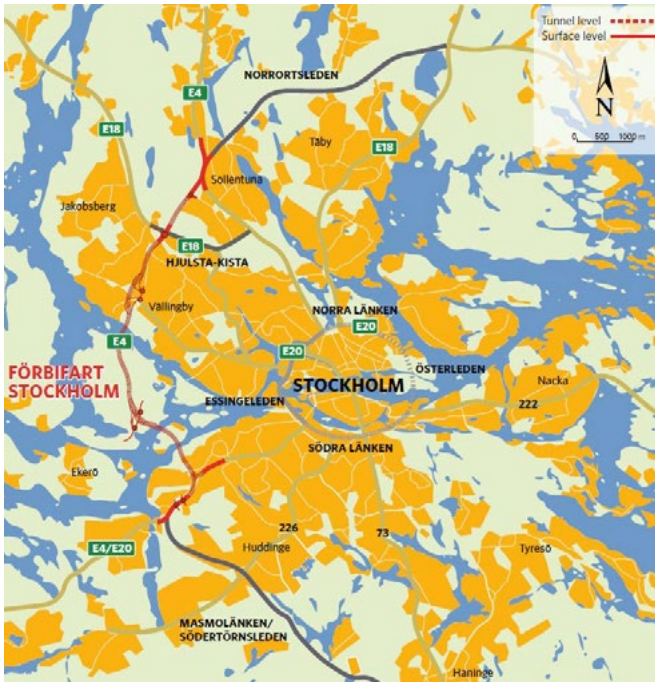
Appendices

Appendix A: International road tunnels

There are excellent examples of long road tunnels currently in operation or under construction internationally where best practice urban design has been applied, with particular focus on the issues of the monotonous driving environment, driver disconnection and difficultly wayfinding. While several design components have been used, the following are examples of the application of 'best practice' urban design principles for long road tunnels. These particular case studies have primarily addressed driver comfort and the journey experience through the creative use of lighting.

E4 Stockholm Bypass Project | Sweden
Bypass 21 kilometres, tunnel 18 kilometres, planned to open by 2025

This road tunnel will take 10 years to build and will connect the southern and northern parts of Stockholm county, creating a bypass of the city of Stockholm.

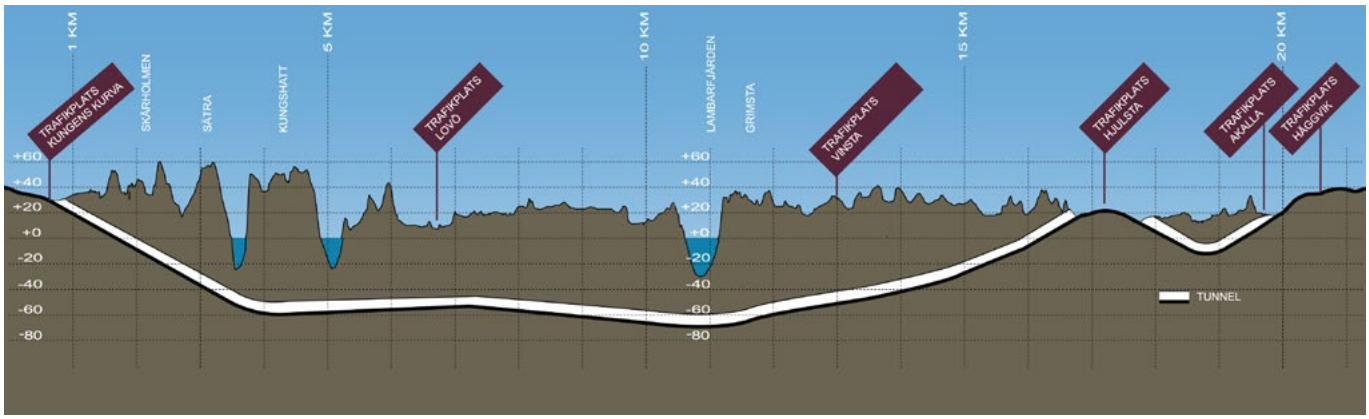


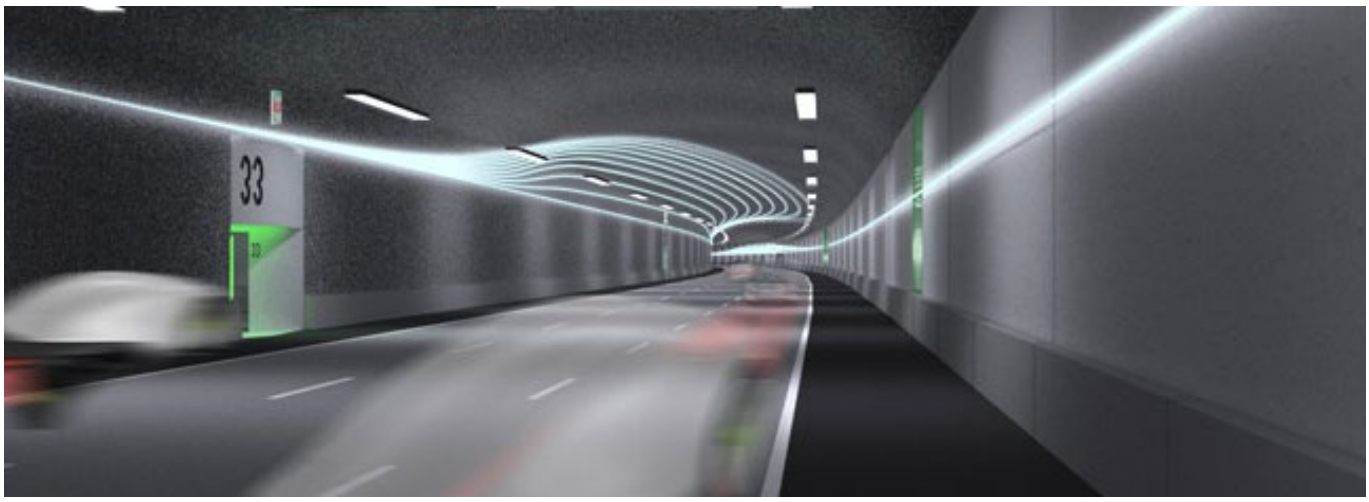
As part of the planning process for the E4 Stockholm Bypass Project, the Swedish National Road and Transport Research Institute (VTI) conducted human behavioural studies, which included the use of a driving simulator. The study's aim was to describe how human behaviour is affected by a complex traffic system, and to examine how the normal driving experience is affected by visual design strategies. Driving aspects that were evaluated include visual distraction, lateral deviation (for example if the driver stays in the middle lane), average speed and differences in speed (for example if there any sudden speed changes), steering wheel movements and braking behaviour.

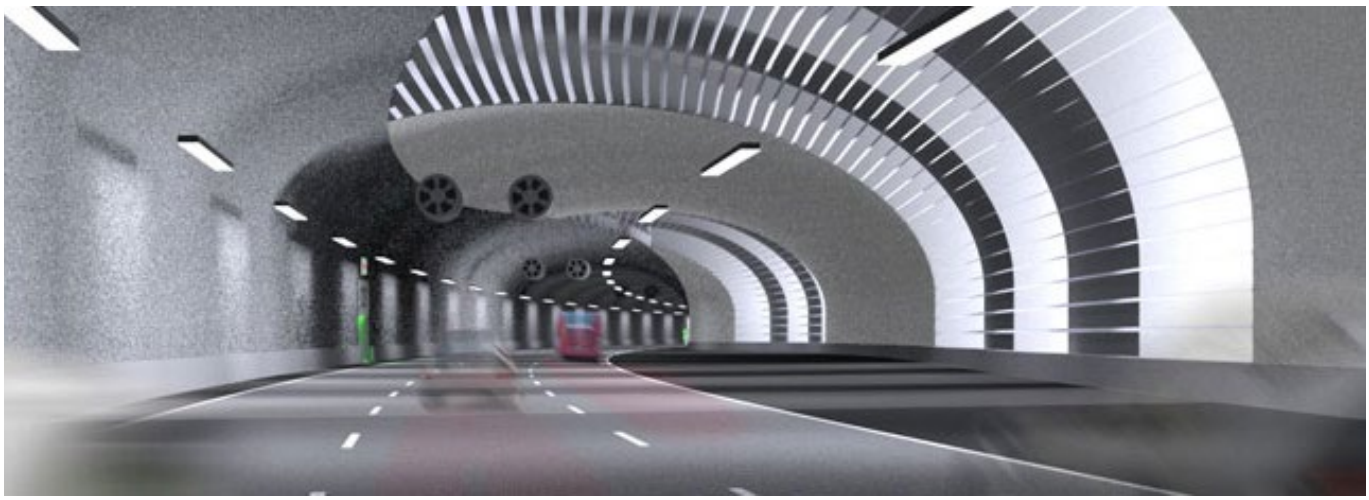
These studies led to a user-centred design program aimed at preventing crashes. Design principles were developed with a focus on the tunnel driving experience and driver orientation within the tunnel system.

Design strategies include:

- Varied and stimulating lighting design to reduce driver monotony
- The provision of information through design, such as unique artwork to be used at each traffic interchange. Also markers, or indicators, will show how far the road users have travelled in the tunnel, to provide a connection with the above ground environment.







The tunnel's aesthetic design includes artistic lighting; unique artwork associated with each traffic interchange; and markers or indicators describing how far drivers have travelled through the tunnel. (Project proposal illustrations).

Fehmarnbelt Tunnel | Connecting Germany and Denmark
18 kilometres in length, planned to open in 2021

This is proposed as an under-sea immersed car and rail tunnel between Germany and Denmark, and the driving journey will be about 10 minutes.

Some of the most effective design strategies outlined for the Fehmarnbelt Tunnel relate to driver orientation and connection with the exterior landscape. Driver experience has influenced the concept design and appearance of the tunnel's interior to ensure a feeling of quality and safety during the journey. These include:

- Wall motifs, each 1.5 kilometres long, that will be repeated at entry, exit and midway points
- Twenty-two different coloured illuminated zones are planned to break up the 'standard' white light throughout the tunnel. Each coloured zone will be 50 metres long, and the spacing between these zones gradually decreases from one kilometre apart at the tunnel entrances to 180 metres apart at the tunnel midpoint.

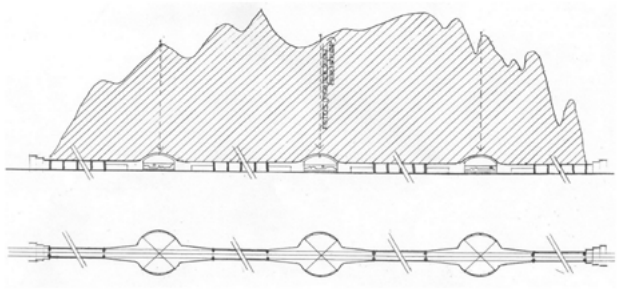
The objective of the coloured zones is to give the driver an indication of their progress through the tunnel, so they are aware when they have reached the midpoint of the tunnel and which also subtly lets them know that they are getting closer to the exit. The intention behind this design is to give drivers the impression of passing through a mountainous area with numerous tunnels, effectively dividing the journey into less monotonous sections.

Coloured zones and illustrations on the walls of the road tunnel will help to provide drivers with a varied journey during their 10 minute drive through the Fehmarnbelt Tunnel. (Proposed project illustration).

The tunnel's aesthetic design includes artistic lighting; unique artwork associated with each traffic interchange; and markers or indicators describing how far drivers have travelled through the tunnel. (Proposed project illustration).

Lærdal Tunnel | Norway
24.5 kilometres, opened in 2000

The Lærdal Tunnel stretches between Lærdal and Aurland in Norway, and is the world's longest road tunnel. The journey through this tunnel is about 20 minutes.



Three rock caverns are referred to as 'mountain halls'

Design strategies for the Lærdal Tunnel combat driver fatigue and also address the driver's orientation with the above ground landscape:

- The tunnel is divided into four sections in order to break the monotony. This is achieved through the creation of three large caverns known as 'mountain halls', which are located every six kilometres. This means there is a cavern that signifies the midpoint of the tunnel, making drivers aware of their progress through the tunnel
- Special attention has been paid to lighting in this tunnel design. White light is used in each of the three sections of the tunnel, but for the mountain halls blue and yellow light is used, giving the illusion of driving into daylight. Golden light around the floor of the caverns gives the illusion of sunrise.

The glowing colours in one of the 'mountain halls'.

Appendix B: References and further reading

- *Austroads Guide to Road Tunnels*,
  Part 1: Introduction to Road Tunnels (July 2010);
  Part 2: Planning, Design and Commissioning (November 2010); Part 3: Operation and Maintenance (August 2010) — Austroads.
  www.austroads.com.au/road-construction/road-tunnels/guide-to-road-tunnels
- *Beyond the Pavement: Urban design policy, procedures and design principles*.
  www.rms.nsw.gov.au/documents/projects/planning-principles/beyond-pavement.pdf
- Connection between human behaviour and tunnel design — Swedish Transport Administration (website updated 2014 Aug 26):
  www.trafikverket.se/en/startpage/projects/Road-construction-projects/the-stockholm-bypass/A-safe-journey---E4-The-Stockholm-bypass-Project/Connection-between-human-behaviour-and-tunnel-design
- E4 The Stockholm Bypass Project (project website) — Swedish Transport Administration:
  www.trafikverket.se/en/startpage/Projects/Road-construction-projects/the-stockholm-bypass
- Fehmarnbelt Tunnel Project website:
  www.femern.com
- *Human factors and road tunnel safety regarding users* (Report 2008R17) — World Road Association (PIARC) Technical Committee C3.3. Available via:
  www.piarc.org/en/publications
- *Stockholm Bypass Tunnel — Design concept evaluation (VTI rapport 759)*, Christopher Patten and Selina Mårdh — Swedish National Road and Transport Research Institute (VTI), 2012.
- The Road Tunnels Manual (last update v1.1 October 2015) — The World Road Association (PIARC).
  tunnels.piarc.org/en

Glossary

Term	Definition
Cross passage	Cross-passages (also cross-connections, cross-connecting passages) are for pedestrian access between adjoining tunnel tubes during evacuation, or for maintenance and inspection personnel. They are usually located at regular intervals throughout the tunnel system.
Dive structure	Refers to the section of road grading down to and approaching (or departing) a tunnel portal, formed by retaining walls.
Green infrastructure	Green infrastructure is defined as natural vegetation and vegetative technologies — like urban forests, greenways, restored and constructed wetlands, green roofs, green walls, bio-swales, and more that provide society with benefits like enhanced liveability, improved energy efficiency, improved air and water quality, reduced flooding and increased recreational opportunities.
Portal	A tunnel portal is the actual point of entry into the tunnel system, and is often referred to as a portal structure.
Tunnel	For the purpose of this guideline, a tunnel can also refer to a vehicle underpass, which is generally quite short in length.
Tunnel approach	Refers to the road corridor leading to and from tunnel entrances, prior to the tunnel dive structures.
Tunnel types	
Short tunnel	These tunnels will provide a short subterranean journey and do not require vertical ventilation exhaust outlets. The longest current NSW tunnel that does not have a vertical ventilation exhaust outlet is the Mascot (Airport) tunnel at 550 metres.
Long tunnel	These tunnels will provide a longer subterranean journey, and will have a distinct and pronounced interior zone. In addition, such tunnels are likely to require vertical ventilation exhaust and possibly supply outlets. Of the tunnels operating at the time of writing this guideline, the Eastern Distributor at 1.7 kilometres is the shortest NSW tunnel that has vertical ventilation exhaust shafts.
Urban tunnel	Refers to a tunnel within a built up metropolitan area.
Rural tunnel	Refers to a tunnel away from urban and built environments.

Term	Definition
Tunnel lining	The visible lining of a tunnel's internal walls is typically either a structural concrete lining or a secondary lining material (such as building wall panels), needed to achieve lighting reflectivity levels and for maintenance purposes.
Tunnel/surface interface	A tunnel's point of connection to the ground surface. For the purpose of this guideline, it includes the tunnel infrastructure (eg. portal and dive structures, retaining walls, noise walls) and immediate surrounding urban or rural context.
Vehicle lay-by	A vehicle refuge or stopping bay providing space for a vehicle to stop clear of the traffic lane.
Ventilation outlet	Refers to vertical air intake and exhaust outlets or structures associated with mechanical (or forced) ventilation systems, for either fresh air or smoke extraction. They are usually co-located with large buildings housing ventilation fans, and control buildings.
Wayfinding	Refers to knowing where you are in a particular environment, and how to get to your desired location from your present location. In a tunnel environment, signage, feature lighting, graphics, and other elements, feature treatments and location information can assist a driver's wayfinding ability, reduce confusion and improve their association with the above ground environment.

For further enquiries
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