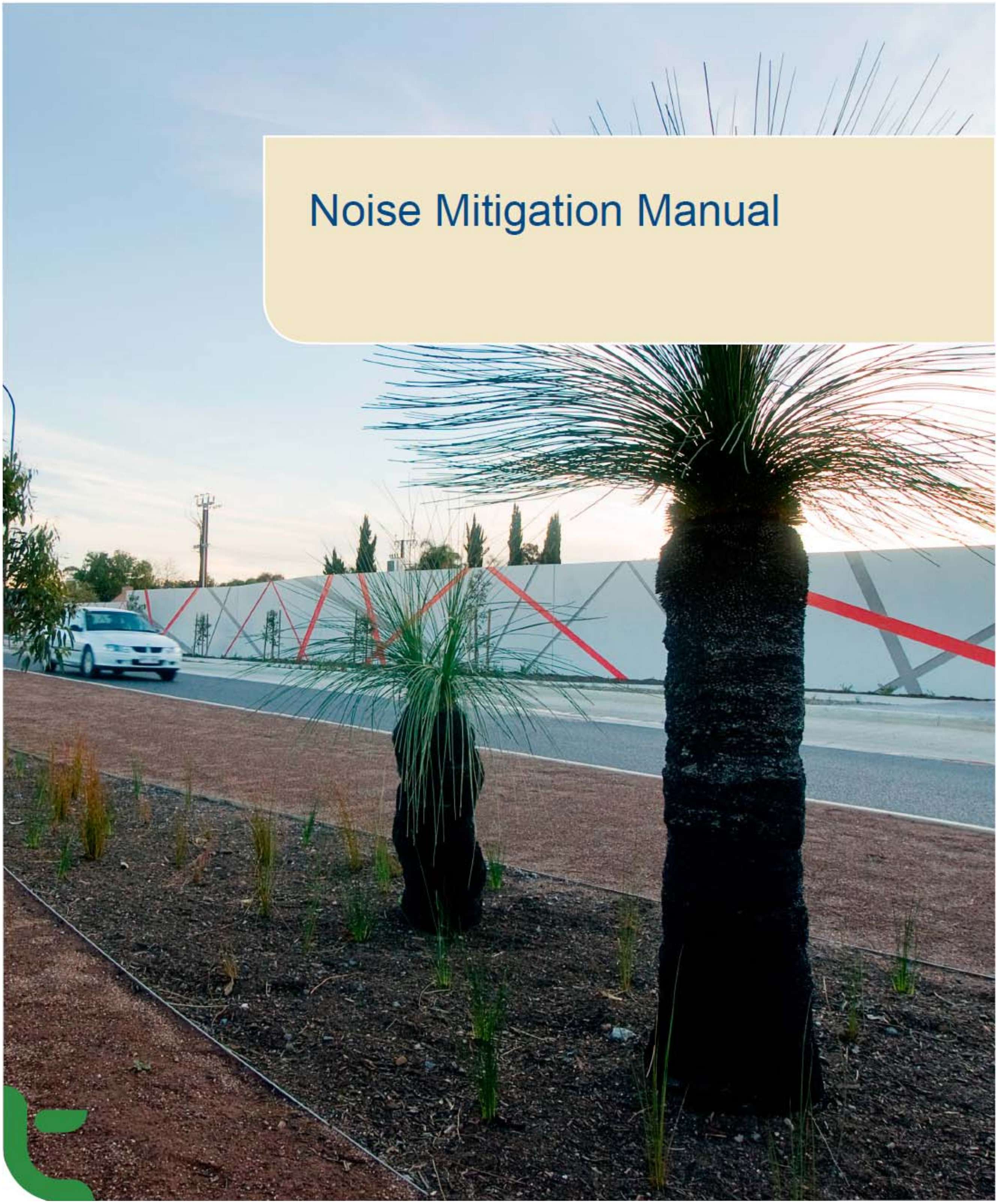
Noise Mitigation Manual



Government of South Australia
Department of Planning,
Transport and Infrastructure

Department of Planning, Transport and Infrastructure

Noise Mitigation Manual

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The manual was developed by the Safety and Service Division with the assistance of AECOM.

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dB(A)	Sound pressure levels (or noise levels) are measured in decibels (dB). Decibels are usually expressed in terms of dB(A), measured using the "A-weighting" filter incorporated in sound level meters. This is an electronic filter with a frequency response corresponding to that of human hearing. It is most sensitive to sounds at mid frequencies (1000 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. The level of sound in dB(A) is a good measure of the loudness of that sound and hence different sounds having the same dB(A) level generally sound equally loud.
EPA	South Australian Environment Protection Agency.
Equivalent Noise Level - L_{eq}	Most noises vary over time, so units have been developed to describe that varying noise as a single number. A common means of describing that noise is the *equivalent noise level* (L_{eq}). The L_{eq} is the value of a steady noise that would have the same acoustic energy as the varying noise, over the same time period. As all references in this Manual are to A-weighted noise levels, L_{eq} rather than $L_{(A)\,eq}$ will be used throughout.
NRC	Noise reduction coefficient – a measure of the sound absorbed by a material, averaged over the 250, 500, 1000 & 2000 Hz octave bands. Values approaching 1.0 have the highest levels of absorption.
R_w	Weighted sound reduction index – laboratory test measurement procedure that provides a single number indication of the noise transmission loss through a material or building element. The higher the R_w, the greater the transmission loss through the material.
STC	Sound transmission class – laboratory test measurement that provides an equivalent rating to the R_w system. Although the R_w rating system is more recent and referred to in Australian Standards, the STC of a material or building element is still commonly quoted.

Introduction

1.0 Introduction

1.1 Purpose

Traffic noise can cause impacts on adjoining noise sensitive land uses.

These impacts can be managed by adopting a noise mitigation strategy tailored to each project.

The purpose of this Manual is to provide a practical understanding of the available noise mitigation options for both road and rail infrastructure projects to assist in developing a *Noise Mitigation Plan* (NMP).

Preparation of a project NMP providing an acceptable level of protection for affected sensitive land uses is part of the Department's 'duty of care' under the *Environment Protection Act 1999,* and should be undertaken where required, in accordance with the procedures outlined in the department's *Road Traffic Noise Guidelines* (RTNG) or the EPA (2013) *Guidelines For The Assessment Of Noise From Rail Infrastructure*.

1.2 Application of the Manual

This Manual has been divided into five main sections, covering:

- road design measures
- roadside barriers
- property treatments
- rail noise mitigation measures
- community consultation.

The process for determining when road traffic noise mitigation measures are to be undertaken as part of a new or upgraded road project, and the noise criteria to be applied, is outlined in the RTNG. The EPA Guidelines for Assessment of noise from rail infrastructure (2013) outlines the approaches for minimising and managing noise impacts from rail activity.

2.0 Road design

2.1 Overview

One of the most effective ways to minimise noise from road traffic is to apply appropriate road design measures such that the noise source (road traffic movements) contributes less noise at the receiver.

Major road alignment decisions affecting the noise impact are typically made during the route selection phase. However, other road design alterations can be made at later stages to assist with noise mitigation in specific areas.

2.2 Route selection phase

The majority of alignment decisions are made during the route selection phase of road projects. All new road projects, and some upgraded road projects, will incorporate a route selection phase and an initial noise impact assessment should be included at this stage.

Typically, a route selection phase noise assessment would consider several route options and broadly assess the noise impact of each option on sensitive receivers, including an indication of the likely noise mitigation that will be required.

During the route selection phase, the major road design factor affecting noise at sensitive receivers is the horizontal alignment. Doubling the distance from the road to the receiver will typically reduce L_{eq} traffic noise levels by about 3 dB(A).

In order to minimise the noise impact of a road project, it is generally preferable to select the route option that is the furthest distance away from large groups of sensitive receivers.

However, it is also important to consider the likely amount of noise mitigation required for each route option, as this will provide an indication of the associated noise mitigation cost. It may be preferable to provide a relatively small amount of treatment to a large number of receivers, rather than providing significant noise mitigation treatments to a few receivers.

2.3 Concept and detailed design

While the major alignment decisions are typically made during the route selection phase of road projects, smaller alignment modifications and other changes can be made to the road design at later stages in order to reduce or eliminate the need for other noise mitigation treatments.

For example, a different road surface could be selected in order to reduce the required noise barrier height adjacent the road.

During a new or existing road project the following measures may be considered to reduce noise emissions from the road:

- lower-noise road surfaces (Section 2.4)
- adjustments to the vertical and horizontal alignments
- modification to the road gradient
- removal of traffic signals
- traffic management measures.

These measures should only be implemented where there are no significant impacts on other road design considerations such as cost, access, security, community acceptance and safety.

Locating and lowering roads in cuttings will provide natural noise barriers.

2.3.1 Vertical and horizontal alignment

Minor changes to vertical and horizontal road alignments may be able to be made during the concept and detailed design phases in order to reduce the noise impact on small groups of receivers. This can most often be achieved for roads in rural areas, but small changes in the alignment in urban environments may also reduce the noise mitigation measures required at individual receivers.

Increasing the horizontal distance between the nearest section of a road and a group of receivers, can be an effective noise mitigation measure where it does not significantly impact on other project considerations. Doubling the distance from the road to a receiver can reduce L_{eq} traffic noise levels by about 3 dB(A).

Small changes in the vertical road alignment will also have an effect on road traffic noise levels. Generally, increasing the height of a road relative to a sensitive receiver will increase the noise levels at the receiver as less ground absorption occurs between the source and receiver. Additionally, the effectiveness of any existing or proposed barriers located at the receiver will be reduced as the noise source height has been increased relative to the barrier height.

A decrease in the height of a road relative to a sensitive receiver will normally bring about a decrease in noise at the receiver as more shielding of the receiver typically occurs. This can be especially beneficial where the lowered road is located in a cutting with natural noise barriers on either side.

The noise mitigation achieved by existing or proposed barriers installed at the receiver may also improve when a road is lowered. However, care should be taken as the effectiveness of any roadside barriers may be reduced if their elevation is decreased along with the road.

Where grade separation of two roads at an intersection is required, road traffic noise levels at receivers will vary depending on whether a bridge or underpass structure is designed. The road traffic noise levels at receivers will be lower with an underpass than with an equivalent bridge structure installed.

Steep roads adjacent to receivers may result in additional acceleration and brake noise.

The installation of traffic signals may cause a noticeable change in road traffic noise character.

Traffic management measures such as roundabouts can be effective noise management tools but should be used carefully to avoid additional acceleration and braking noise.

2.3.2 Modifying the road gradient

Reducing the road gradient near sensitive receivers can have a positive effect on road traffic noise levels, as acceleration noise and brake noise are both reduced.

Typically, a five per cent reduction in the road gradient will reduce L_{eq} traffic noise levels by about 1.5 dB(A).

2.3.3 Removal of traffic signals

Although measurements conducted before and after the installation of traffic lights have shown that there is very little change in noise levels between a free-flowing road and a signalised intersection, there can often be a noticeable change in the character of traffic noise due to acceleration and brake noise.

Complaints about noise have been received after the installation of traffic signals, and free-flowing roads should be considered where possible.

2.3.4 Traffic management measures

Traffic management measures to reduce noise in certain areas can be effective if used appropriately. Street closures are able to divert traffic away from local roads onto arterial roads, and heavy vehicle access restrictions can reduce heavy vehicle noise adjacent to residential areas. Heavy vehicle restrictions could include both time and weight restrictions.

Traffic calming devices including roundabouts, speed humps and chicanes can all contribute to a reduction in traffic noise on local roads. However, the spacing of and use of the devices needs to be carefully considered as they can cause increases in noise levels where:

- heavy vehicles brake across the traffic calming device during the night time hours
- spacing between the devices is too large, encouraging drivers to accelerate and brake in between them.

Traffic calming devices will not be appropriate for high-speed, free-flowing motorways but can often be used on adjacent local roads to reduce noise from traffic exiting the motorway.

The road surface type can have a considerable effect on the overall traffic noise level from a new or upgraded road, and the noise mitigation measures that will be required.

Asphalt road surfacings are common in South Australia and normally provide the lowest noise option.

2.4 Differing road surfaces

Asphalt surfaces are generally less durable than concrete surfaces but are usually more durable than sprayed seal surfaces. SMA can be the most durable of the asphalt surfaces although additional care has to be taken with its mix design and placement to ensure this outcome. For most situations OGA is the least durable of the asphalt road surfacings.

Although they may produce higher noise levels than asphalt surfaces, concrete road pavements can be the most cost effective for very high traffic movements. Provided the correct concrete strength is specified and the surfacing is compacted and cured adequately, concrete surfaces should not require retexturing or resurfacing for the entire design life.

Thin slurry surfacings are usually applied as preventative or corrective maintenance treatments to restore surface texture, correct ravelling, and fill minor surface cracks and deformities. Their durability tends to be similar to thin open graded asphalt or small stone size sprayed seals.

Sprayed seal surfaces are typically considered to be less durable than asphalt and concrete, but are lower cost and hence normally used on the extensive rural or urban local road networks. When they are well designed and constructed, they can deliver service lives comparable to most asphalt surfacing treatment options. Depending on the aggregate size, the noise levels of sprayed seals can be high.

The acoustic performance of different road surfaces is typically affected by:

- *texture*: positively textured rough and irregular surfaces produce more lower frequency tyre impact noise, while smooth surfaces can create more higher frequency “hissing” noise due to air trapped between the tyre and road surface
- *porosity*: negatively textured porous surfacing decreases road-tyre noise
- *stiffness*: increasing the mechanical impedance or stiffness of a road surfacing typically increases road-tyre noise levels.

The texture of a road surface is classified into the following ranges, depending on the texture wavelength (λ) of surface irregularities:

- microtexture, $\lambda < 0.5$ mm
- macrotexture, 0.5 mm $< \lambda <$ 50 mm
- megatexture, 50 mm $< \lambda <$ 500 mm
- unevenness, $\lambda > 500$ mm.

Road-tyre noise can be reduced by minimising the macrotexture depth at wavelengths of above 10 mm for cars and above 20 mm for heavy vehicles. The macrotexture depth in the wavelength range beneath that should be maximised to allow air to escape and reduce “hissing” noise.

Additionally, lower-noise surfacings can be attained by producing a uniform negatively textured surface, with aggregate having a high resistance to polishing, and a cubical shape. A high surface porosity, with greater than twenty per cent interconnecting air voids, also assists in reducing road-tyre noise.

Table 1 details typical values of noise level corrections for different road surfaces relative to a dense graded asphalt (DGA) surface. The values should be used as a guide only, as variations in vehicle speed, heavy vehicle percentage and road texture and porosity may also need to be considered.

Normally, roads surfaced with asphalt are quieter than those with a sprayed seal or concrete surface. However, exposed aggregate concrete surfacing has been found to result in similar noise levels to DGA.

The relative noise level from a concrete surface depends upon the surface texturing process applied after the concrete is in place. This is in contrast to asphalt surfaces, where the surface texture depends on the mix design and aggregates provided in the material.

It is important that the noise level improvement expectation values are considered during a road noise assessment. Lower-noise OGA and SMA surfaces can have significant variations in the noise level correction, especially over time. This is due to changes in the road surface aggregate mix size and variations as the surface wears with age.

Table 1: Typical values of relative surface noise levels

Surfacing type	Relative noise level, dB(A)
Spray seals, 10mm or larger	+4
Spray seals, 7mm	+2
Dense graded asphalt (DGA)	0
Stone mastic asphalt (SMA)	-1
Open graded asphalt (OGA)	-3
Tyned concrete only	+1 to +4
Broomed concrete	+1 to +4
Hessian dragged concrete	+2 to +4
Exposed aggregate concrete	-1 to +1

Source: Austroads, 2003

When specifying an OGA or SMA road surface for the purpose of road traffic noise reduction the following need to be considered:

- the change in the acoustic properties as the surface ages (refer Section 2.4.2). This variation in age has been taken into account in Table 1.
- specifying the road surface nominal mix size and binder type, manufacture and application method to achieve a lower-noise, durable road surface.

2.4.1 Other properties of road surface types

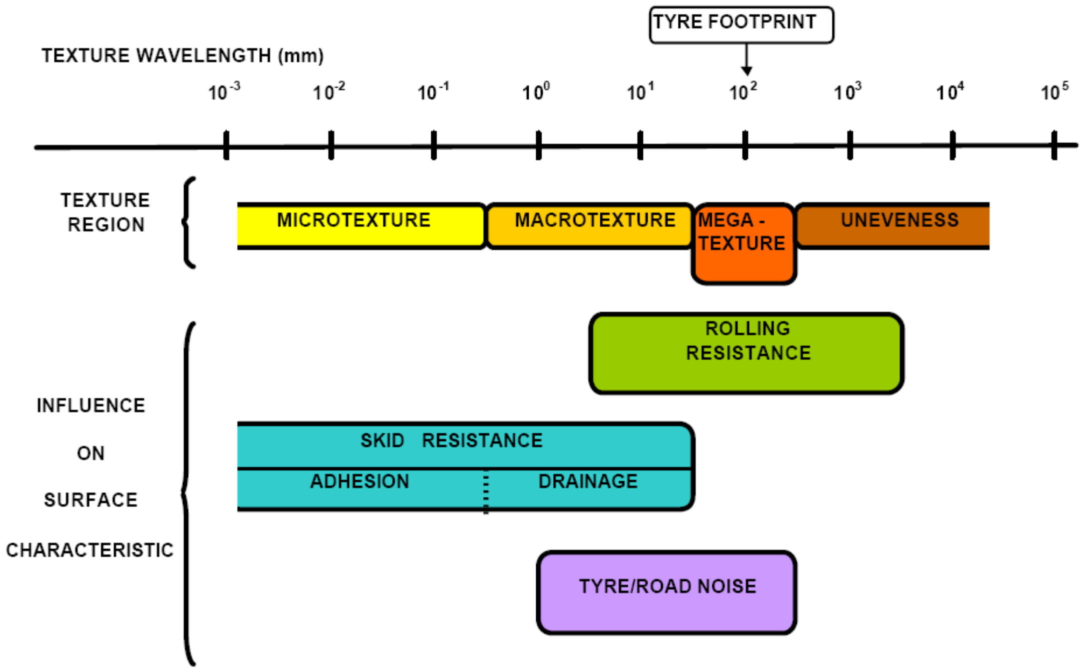
When assessing possible road surface types, it is also important to consider non-acoustic factors such as skid resistance and rolling resistance. The figure below demonstrates the influence of texture amplitudes at different wavelengths on road surface characteristics.

To improve the skid resistance of road surfaces on low speed roads, it is important to consider increasing the microtexture as this increases the adhesive friction between the tyre and the road surface.

Increasing texture amplitudes at micro-texture wavelengths in the surface will have little influence on road-tyre noise generation.

At higher speeds or on wet surfaces, skid resistance is controlled by macrotexture which provides hysteretic friction as well as drainage paths for any water film. Increasing the texture amplitudes in the macrotexture wavelength range will improve skid resistance for wet surfaces and higher speed roads but may increase the noise level produced by the surface if the increased texture amplitude is at wavelengths near the transition between the macrotexture and megatexture regions.

Another important design factor for road surfaces is to reduce rolling resistance in order to improve fuel economy and exhaust emissions. Fortunately, rolling resistance is typically controlled in the high macrotexture and megatexture wavelength range, and reducing texture amplitudes at wavelengths in this range will reduce both rolling resistance and road-tyre noise.



Source: Sandberg & Descomet, 1980

2.4.2 Durability

Asphalt surfaces are generally less durable than concrete surfaces but more durable than sprayed seal surfaces. SMA can be the most durable of the asphalt surfaces although additional care has to be taken with its mix design and placement to ensure this outcome.

Although they may produce higher noise levels than asphalt surfaces, concrete road pavements can be the most cost effective for very high traffic movements. Provided the correct concrete strength is specified and the surfacing is compacted and cured adequately, concrete surfaces should not require retexturing or resurfacing for the entire design life.

Thin slurry surfacings are usually applied as preventative or corrective maintenance treatments to restore surface texture, correct ravelling, and fill minor surface cracks and deformities. Their durability tends to be similar to thin open graded asphalt or small stone size sprayed seals.

Sprayed seal surfaces are typically considered to be less durable than asphalt and concrete, but are lower cost and hence normally used on the extensive rural or urban local road networks. When they are well designed and constructed, they can deliver service lives comparable to most asphalt surfacing treatment options. Depending on the aggregate size, the noise levels of sprayed seals can be high.

The acoustic performance of lower-noise surfaces tends to degrade over time due to trafficking and weathering causing physical deterioration in the physical quality of materials and changes in the texture of the surface. Conversely, the acoustic performance of higher noise concrete surfaces tends to improve slightly over time as the texture of the surface, the major contributor to tyre noise from the surface, is worn with use.

For porous road surfaces, such as OGA, the clogging of voids in the surface by dirt, dust or other clogging agents from tyres and oil products can also reduce the acoustic performance over time. This can be somewhat reduced by programmed maintenance and cleaning, but leads to an increase in costs and cannot be carried out indefinitely.

Asphalt road surfaces are less durable than concrete surfaces, but normally produce less noise and can reduce noise mitigation costs.

Image: Abigroup, Bonville Upgrade (NSW)

Concrete road surfaces are often noisier than asphalt surfaces but can have a lower whole-of-life cost. They are in common usage interstate and overseas.

If an OGA surface is to be considered or used on a project, it may be preferable to adopt a more conservative improvement expectation than that specified in Table 1 where it is to be used in a noise critical application.

It is important that the acoustic performance of any road surfacing being assessed as a possible noise mitigation measure be considered not just on the initial performance but also over the whole lifetime of the surfacing.

To this end, if a particular surface type has been selected to deliver noise mitigation, this should be recorded in the handover report to Road and Marine Assets to ensure that, when the road is due to be resurfaced, the re-seals unit is aware of the need to replace like-for-like.

2.4.3 Cost

Difficulties arise when directly comparing the costs of different road surfacings, and it can be misleading to do this. Meaningful economic comparisons can only be undertaken on the whole-of-life costs of the complete pavement structure or complete treatment approach, rather than just for the individual components. This ensures that the varying durability of different surfacings and supporting pavements is always adequately included.

In addition, while unit rates can be determined for most surfacing treatments, they are highly dependent on a number of project specific factors. The surfacing is designed in conjunction with the pavement structure and not all surfacing options are suitable or available for all situations.

Rigid (concrete) pavements are designed and constructed quite differently to flexible road pavements. The concrete surface is usually only the textured base slab, rather than a separate surfacing layer. Hence its unit cost can't be directly compared to a thinner non structural flexible surfacing.

Whole-of-life costing allows comparison of the total project costs, and considers the differing performance characteristics of the various rigid and flexible pavement alternatives under consideration.

3.0 Roadside barriers

3.1 Overview

Roadside barriers, located in the road corridor between the road and sensitive receivers, are able to provide reductions in traffic noise by interrupting the path of noise propagation from source to receiver. Barriers for mitigating road traffic noise can take a number of forms including concrete or masonry noise walls, and mounded earthworks.

The use of roadside noise barriers should be considered after road design measures have been assessed, and should be used in preference to property treatments where practical. Roadside barriers are preferable to property treatments as:

- a considerable reduction in road traffic noise levels is able to be achieved with appropriate barrier design
- noise mitigation is able to be provided to outdoor areas at residences
- visual screening of the road is provided for sensitive receivers which can improve community acceptance of the road project
- noise barriers can be incorporated into and enhance the aesthetic design of a road project.

In assessing the practicality of roadside barriers, it is important to consider factors such as the noise attenuation achieved, overall cost per property, maintenance and road safety/ access considerations.

Roadside noise barriers will not be feasible in all situations, particularly in rural areas where properties are typically more isolated and further from the road. They are also not suitable where properties adjacent to the road require access directly on to the road.

However, in areas where groups of sensitive receivers are located adjacent to a new or upgraded road, roadside barriers can provide an effective form of noise mitigation.

Gallipoli Underpass

Adelaide Crafers Highway

Southern Expressway

3.2 Minimum performance

For a noise barrier to be considered reasonable and practicable, it should desirably provide an average noise reduction of at least 5 dB(A) at shielded properties. If a noise reduction of less than 5 dB(A) is achieved, receivers shielded by the barrier are not likely to perceive a benefit. However, lower barriers may be effective as part of a combined noise mitigation program.

3.3 Preferred placement

The placement of barriers will depend on a number of factors including noise attenuation, urban design, road safety considerations and construction feasibility.

This section presents the acoustic theory related to the placement of noise barriers, which should be considered when assessing a proposed barrier design or an adjustment to a design.

3.3.1 Theory

When road traffic noise reaches a roadside barrier, different portions of the noise will be:

- *reflected:* noise that is reflected back towards the road, the amount of which will depend on the sound absorption properties of the barrier material
- *absorbed:* noise absorbed by the barrier material
- *transmitted:* noise that passes through the barrier material, dependent on the noise transmission loss provided by the material
- *diffracted:* noise that passes over the top or around the ends of the barrier.

A solid barrier will provide a shadow zone within which a noise reduction is achieved. The further a receiver is located within a shadow zone, the greater the noise reduction achieved at that receiver. This is due to increased reductions in the level of diffracted noise as the level of shadowing is increased.

The shadow zone, and therefore noise reduction, achieved by a barrier depends on its height, length and location. However, the noise transmission loss achieved through the barrier material and the sound absorption of the material also need to be considered, and are discussed further in Section 3.5.

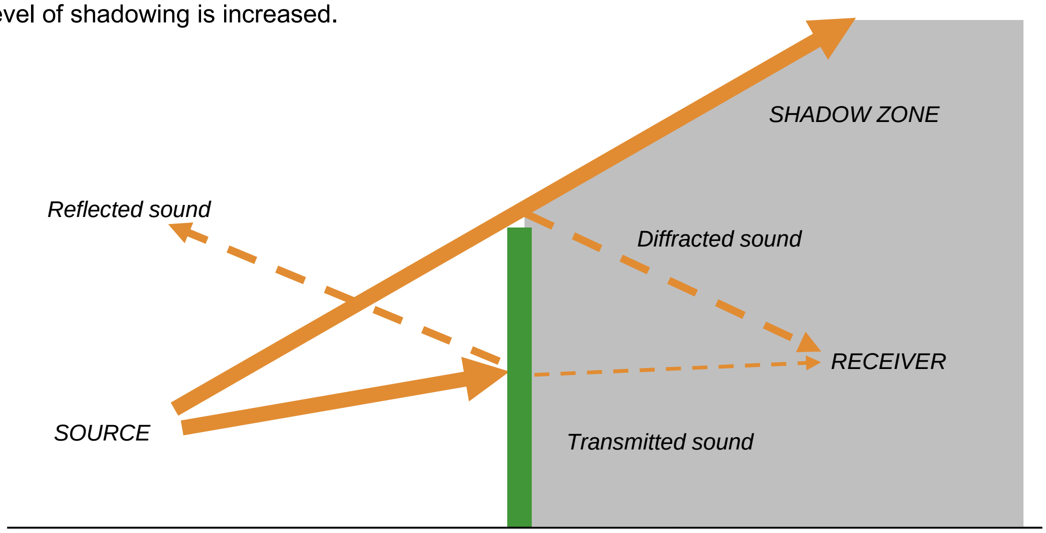
3.3.1.1 Height

Any roadside barrier must be high enough to break line-of-sight between the road noise sources and the receiver. Typically, the noise sources are car and truck engines, the road-tyre interface and, in some cases, truck exhausts.

Typical source heights above the road are:

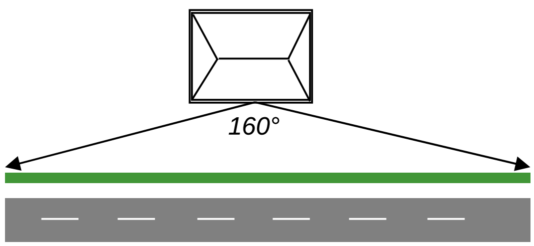
- 0.5 metres for light vehicle engines
- 1.5 metres for heavy vehicle engines
- 3.6 metres for heavy vehicle exhausts.

The higher a barrier is constructed, the more noise attenuation it will provide. A barrier that just breaks line-of-sight to the source will typically provide a noise reduction of about 5 dB(A).

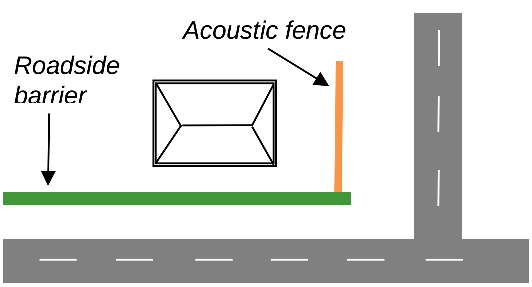


An overview of the interaction of sound with a barrier. The noise reduction will improve as a receiver moves further into the shadow zone.

Noise walls must at least break line-of-sight between the road and receiver.



The barrier should be long enough to provide at least 160° of protection for a receiver.



Where a roadside barrier needs to be left open for access reasons, a returned fence along the property boundary may be able to maintain the required noise reduction.

As the barrier height is increased the noise reduction will improve, although the additional noise reduction achieved for each fixed increase in height will typically decrease as the barrier height is raised beyond two metres. Acoustically designed, taller barriers should be able to achieve noise reductions of 10 to 15 dB(A) at sensitive receivers. Achieving reductions greater than this is not normally possible.

The barrier height may need to be adjusted depending on the height of the road relative to the receiver. If the road is higher than the receiver, such as on a bridge or viaduct, the roadside barrier height required to break line-of-sight may not be as high. If the road is lower than the receiver, such as houses on a hill overlooking a road, then the barrier height required to break line-of-sight will be higher. In this case it may be preferable to install fences at the receivers rather than roadside barriers.

3.3.1.2 Length

If roadside barriers are not of sufficient length, road traffic noise can diffract around the ends of the barrier and compromise the noise mitigation provided by the barrier. Acoustic design of barriers should take this into account to ensure that the barrier still meets the noise mitigation objectives.

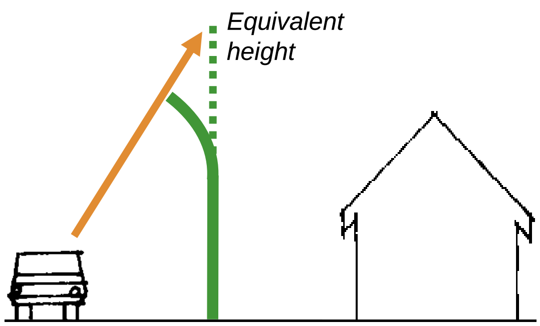
As a rule of thumb, the length of a roadside barrier should provide at least 160° of protection for a receiver.

If a barrier must be open to allow access for a particular local road, it may be possible to maintain the desired noise reduction by providing a returned fence on the property boundary of the end receiver. More information on acoustic fences installed at properties is provided in Section 4.2.

3.3.1.3 Location

The noise mitigation achieved by a barrier can be improved by locating it as close as possible to either the noise source or the receiver. For roadside barriers, this means that the noise mitigation can be maximised by locating it as close to the roadside as possible. However, this must not compromise road safety requirements.

The effectiveness of a roadside noise barrier is also improved if the receivers are relatively close to the road such as in an urban environment. In rural environments where a receiver may be a significant distance from the road, roadside barriers will not be as effective even if they are located as close as possible to the road edge.



A cantilevered barrier angled across the road can increase the noise mitigation achieved by a barrier.

Table 2: Reasonable barrier height limits

Barrier location	Height limit
Within road corridor	Up to 7m[1]
Property boundary Property access is from another road	Up to 4m[1],[2]
Property boundary Property access through barrier	Up to 2.4 with solid gates[3]

Note:

(1) Barriers that are greater than 3.5m in height must take into account factors such as the noise reduction benefit versus cost, practical construction limitations, visual amenity and overshadowing issues. Generally, these barriers should be set back from an adjacent property boundary taking into account the ability to maintain the space and the potential to reduce the impact of the barrier by using clear barrier material.

(2) Individual project circumstances may result in a project specific requirement to alter the height above 4m

(3) Fences with gates may be constructed to a height above 2.1 metres as long as the gate is designed so as not to degrade the acoustic performance of the fence and the functionality of the gate is acceptable (eg the gate is automated).

The effective location and height of a barrier can be improved by angling or curving a cantilevered barrier in towards a road. However, the impacts this may have on reflected noise, cost, clearance distances and shadowing need to be considered.

When designing earth mounds the highest point of the mound should be located as close to the road as possible. This is discussed in Section 3.8.

3.3.2 Reasonable barrier limits

The Department has prescribed a maximum reasonable height of seven metres for barriers that are located within the road corridor. This limit is based on the overall cost of construction, cost of increasing the height or length compared to the additional noise reduction achieved, practical limitations, visual amenity and community reaction.

It is important that a cost benefit analysis be carried out to demonstrate that the envisaged roadside noise barrier is reasonable (or otherwise) when compared to other treatments.

3.3.3 Responsibility

For noise barriers located in the road corridor or on Department-owned land, the Department is responsible for design, construction and ongoing maintenance. Barriers or fences on private land become the responsibility of the landowner once construction is complete.

3.4 Road safety

It is critical that the design of roadside barriers incorporates road safety requirements. The location of barriers will need to make allowances for roadside clearances, lines of sight and lighting which may affect the distance from the road at which the barrier can be installed.

Road design engineers should be consulted about the location of noise barriers as early in the process as possible.

3.4.1 Clearances

Any road will need a roadside clearance area (clear zone) that is kept free from obstructions, to allow vehicles space for recovery or emergency stopping. The clear zone will be specified for each carriageway based on the design speed, traffic volumes and batter slopes.

Generally, no noise barrier should be located in the clear zone. However, if deemed necessary, barriers in the clear zone must be protected by safety barriers designed in accordance with Departmental road design guidelines (K-Net #891637). Safety barriers should be a minimum distance of one metre from any roadside noise wall, measured from the back of the safety barrier or integrated into the noise wall.

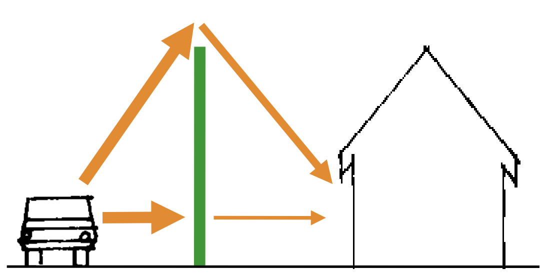
3.4.2 Emergency access

Where long stretches of barriers are needed for noise reduction purposes, it may be necessary to provide access for vehicles in an emergency. Access may be provided by overlapping barrier sections around a gap such that there is no reduction in the acoustic performance of the barrier (refer to Section 3.9.2).

3.4.3 Structural considerations

Noise barriers must be appropriately designed to accommodate factors such as wind loads, vehicle impacts and their own weight.

The European Committee for Standardisation have prepared technical standards for mechanical design and safety factors for noise barriers. The technical standards are referenced in the References and Further Reading section.



The noise transmitted through a barrier should be at least 10 dB(A) lower than that diffracted over the barrier so that the overall noise level is not affected. A higher R_w value for the barrier material will mean less noise is transmitted through.

3.4.4 Line of sight

Consideration needs to be given to the effect of roadside noise barriers on sight distances in the following situations:

- at-grade intersections
- roundabouts
- pedestrian crossings, particularly near horizontal curvature sections
- merging traffic.

It is also important that road signs are not obscured from the line of sight of the driver.

The roadside noise barrier location should be such that all Departmental road design requirements relating to sight distances are achieved. This should be determined early in the barrier design as decreasing barrier lengths or shifting barrier locations at a later stage may have an impact on the noise mitigation achieved by the roadside barriers and their feasibility.

3.4.5 Lighting

It is important to design the height and location of noise barriers such that they do not interfere with any overhead lighting design. Roadside noise barriers located in front of overhead lighting should not cast excessive shadows on the road or cause non-uniform illumination of the road that may affect road safety.

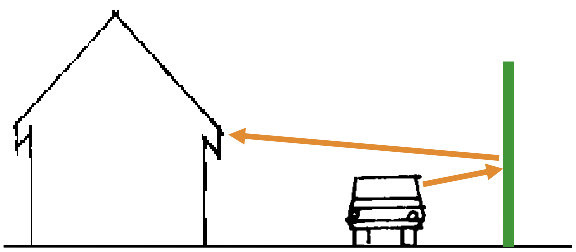
The roadside noise barrier and lighting designs should achieve the requirements of the Departmental lighting design guidelines.

3.4.6 Glare

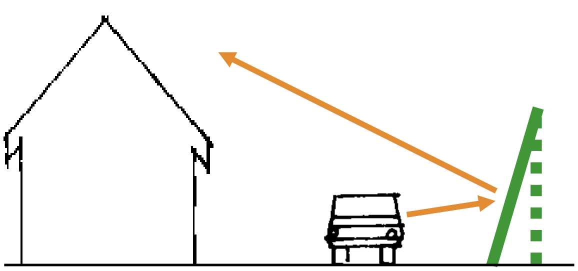
The reflection of light (glare) can be a potential safety issue for barriers constructed from reflective materials such as metal, glass and acrylic. Where this may be a concern, an assessment of solar glare should be undertaken.

It may be possible to reduce this problem by orientating barriers appropriately or reducing their transparency.

Gaps in barriers, such as in the timber fence shown above, will reduce the noise mitigation achieved.



Reflected noise can increase noise at receivers across from a noise barrier.



Reflected noise problems can be reduced by using barriers angled by at least 10°. However, this may reduce the effective height of the barrier slightly compared to the same barrier erected perpendicular to the ground.

3.5 Barrier design

3.5.1 Materials

There are many different materials that can be used to construct roadside noise barriers, and assist in achieving urban design objectives. In considering the noise mitigation effectiveness of a barrier material, the two material properties that are most critical are the transmission loss and sound absorption of the material.

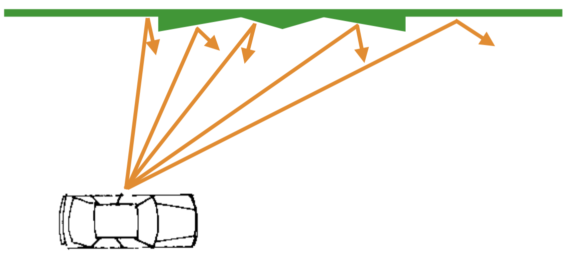
The transmission loss of a material is typically defined by either the weighted sound reduction index (R_w) or sound transmission class (STC), which are single number ratings of the ability of a material to block sound energy passing through it. A higher rating implies a greater noise reduction through the material.

However, care needs to be taken in assessing the material's transmission loss across lower frequencies of sound, which are prominent in road traffic noise, as this can vary considerably for materials with equivalent R_w or STC ratings. Two materials may have the same R_w rating but one could be significantly better at mitigating low frequency noise.

Any material should be selected such that noise transmitted through it does not increase the overall road traffic noise level at the receiver. In practice the road traffic noise level at the receiver transmitted through the wall should be at least 10 dB(A) lower than that diffracted over the wall. Normally, a material with a higher density will be more effective in reducing transmitted noise.

The barrier should be designed such that there are no gaps or cracks across its height and length. The presence of gaps and cracks can significantly impact the overall noise reduction achieved by a barrier design.

The sound absorption of a particular material is described by the single number noise reduction coefficient (NRC), with a higher NRC implying a greater sound absorption. It is important to consider the sound absorption properties as a highly reflective roadside noise barrier on one side of the road can cause reflected noise to impact receivers on the other side of the road. If reflective barriers exist on both sides of the road, reflected noise may build up between them causing unpleasant travelling environments and reducing the effectiveness of the barriers.



Horizontally angling barriers to create dispersive faces can randomly reflect noise, reducing the proportion of noise reflected in any one direction. This can reduce noise levels at an adjacent receiver or reduce the build up of reflected noise between parallel barriers.

Colorbond steel is often used for property fences and can be a cost effective roadside barrier at heights of up to 2.4 metres.

Double skin Colorbond with a 330mm cavity was used for noise walls up to 4.5m high on the Southern Expressway Duplication

Potential problems caused by reflective barriers can be reduced or avoided by:

- using a more absorptive barrier material
- angling barriers away from the road, either vertically or horizontally
- installing vertically irregular barriers on either side of the road.

More absorptive barrier materials may improve the noise reduction provided but they can also increase the barrier costs. The noise reduction benefit of an absorptive material should be considered in the context of any increased cost.

A barrier angled vertically at least 10° away from the road will perform similarly to a standard absorptive barrier. Angled barriers may reduce a reflected noise problem at a lower cost than using absorptive barrier materials. However, angling the barriers away will move them further from the road and decrease their effective height.

Angling barriers horizontally to create dispersive faces and having irregular height barriers on either side of the road can also reduce reflected noise. However, these methods are not typically as effective as vertically angling barriers.

3.5.1.1 Sheet steel (e.g. 'Colorbond')

Noise barriers constructed from sheet steel are commonly used as part of road projects due to their lower construction cost. Normally they are provided to individual properties as fences, but may also be used as roadside barriers in situations where a barrier of less than three metres in height is needed.

Sheet steel barriers are normally only acoustically effective to a height of 2.4 metres. Beyond this, noise transmitted through the barrier may start to contribute and reduce any additional reduction achieved by increasing the barrier height. However, thicker sheet steel, or two layers of sheet steel with an air gap in between, can be used to construct barriers higher than 2.4 metres that would provide the required noise reduction.

Precast concrete barriers, such as those at the Gallipoli Underpass, are effective noise barriers but are relatively costly.

3.5.1.2 Precast concrete barriers

Precast concrete barriers are often used for roadside noise barriers as they are effective up to and beyond the Department's reasonable height limits, are highly durable and not easily damaged. It is also possible to texture, pattern, colour and paint precast concrete to assist with the urban design objectives of a project.

The disadvantages of precast concrete barriers are the relatively high cost as well as the weight of the wall panels. Significant excavation is typically required for the footings of concrete barriers and, if a panel is damaged, the work required to replace it is considerable. While their durability helps to prevent damage, it also means that the walls are generally not deformable during an accident, increasing the risk of injury.

When texturing a concrete noise barrier, it is important to use bevelled edges in patterns so that pollutants will not settle on ledges. Heavy texturing will also be difficult to clean should the barrier be subject to graffiti.

Painted and textured finishes are easier to restore if subject to graffiti, although the quality of the substrate is important to consider during application of these finishes. Anti-graffiti coatings can be applied although they are relatively costly.

Precast concrete walls were constructed as part of the Gallipoli Underpass project. The walls were textured and painted in areas to complement the urban design objectives, and were treated with an anti-graffiti coating on the road side. The walls were also painted on the rear side facing the residences due to resident concerns about appearance.

Image: NSW Road Traffic Authority

Lightweight concrete panels can be used for visually effective barriers.

3.5.1.3 Lightweight concrete panels

Autoclaved aerated lightweight concrete panels have been used to construct roadside noise barriers with some success in other states. They are effective barriers up to the Department's height limits, and are lower in both material cost and construction cost when compared to precast concrete barriers. Due to the lightweight nature of the panels, they can be relatively easily replaced when damaged and are deformable during traffic accidents.

The disadvantages associated with the use of lightweight concrete panels are that they are easily damaged.

With the appropriate design, visually appealing barriers can be constructed from lightweight concrete panels. While they are not able to be coloured using dyes, they can be coated with paint and a hard wearing finish to reduce the likelihood of damage to the panels.

Masonry and stone barriers, such as this one at Glen Osmond, can be visually appealing and acoustically effective. However, they are normally costly when compared to alternative materials.

3.5.1.4 Masonry and stone

Masonry barriers, typically consisting of bricks and blocks, are able to be used where a visually appealing design is required as they provide a range of texture and colour options.

Stone barriers are used less commonly but can be constructed where heritage areas require a sensitive barrier design. Both types of barrier are acoustically effective up to a considerable height.

The typical disadvantage associated with masonry and stone walls is the increased cost relative to other materials.

Gabions, barriers with loose stones held in a wire frame, can be used as a cheaper alternative to stone noise walls. However, due to their construction, gabions require a solid central section or panel so that noise transmission through the barrier does not render it ineffective. Gabions with a central earth section have been constructed as road traffic noise barriers in Victoria.

Images: Modular Wall Systems

Modular walls can be used as cost effective noise barriers similar in appearance to masonry barriers.

Image: Exel Composites

Composite barriers can be used as cost effective noise barriers up to certain heights.

3.5.1.5 Modular walls

Proprietary modular walls consisting of compressed fibre cement skins around foam cores can be used as road traffic noise barriers in certain situations.

Due to the relatively low construction and installation costs, modular walls can offer a cost effective solution. They are able to be designed and constructed to mimic the look of masonry barriers, and have easily replaceable panels if damaged.

However, care should be taken when installing a modular wall as a road traffic noise barrier to a height above approximately 3.5 metres as noise transmitted through the material may start to degrade the performance of the barrier. Sandwich panels such as modular walls typically have a weakness in the mid-frequency range due to panel resonance, and this will control the transmission loss of any barrier.

3.5.1.6 Composite noise barriers

Composite noise barriers, constructed of a composite material such as glass-reinforced plastic, can be effective road traffic noise barriers in certain situations.

As with modular walls, they have low construction and installation costs and are easily replaceable if damaged.

However, care must be taken to select a composite barrier with an appropriate transmission loss rating as some composite barriers are unlikely to be effective at heights over three metres.

Timber can be used to visually soften roadside barriers but care must be taken to avoid gaps between pieces of timber.

3.5.1.7 Timber

Timber noise barriers can be effectively used in some situations to soften the visual impact of roadside noise barriers. They are relatively cheap barriers, simple to construct and can be easily adapted and replaced on site.

Care needs to be taken in the selection of timber with consideration given to durability, need for treatment to avoid rot, and sustainability of the timber. Thicker, denser timber should also be used if the roadside barrier is to be constructed to a significant height to prevent noticeable noise transmission through the wall. Timber barriers should not be used in bushfire prone areas.

It is important to avoid gaps between timber pieces so that the noise mitigation is not compromised. There have been cases where timber fences installed on completed projects have had gaps between the timber slats, which reduced their effectiveness.

Plywood noise barriers are commonly used interstate and overseas, and can be treated to improve the durability of the barrier. Propriety plywood noise barrier products are available, and may be able to be used up to the Department's reasonable height limits in many cases.

Timber barrier sections may also be used in conjunction with other materials to provide more visually diverse options. Timber barriers interspersed with 'Colorbond' steel barrier sections were preferred by some Victoria Road residents as part of the Port River Expressway project.

Image: Eastlink

Transparent barriers at Eastlink (Victoria) and Goodwood reduce the overall visual impact and are also useful where views need to be retained.

Earth mound at Gawler

3.5.1.8 Transparent barriers

Transparent roadside noise barriers, constructed from glass or acrylic products, are relatively common in other Australian states where views need to be maintained, or to reduce the visual impact and overshadowing effects of opaque noise barriers. Although relatively expensive, transparent panels can provide a suitable noise barrier option for bridges.

The design of transparent noise barriers needs to consider the transmission loss achieved by the panel material, as lightweight panels are unlikely to be effective above about three metres. The design should prevent glare from sunlight and headlight reflections affecting drivers. Angling the barrier away from the road should also be considered as this will help rain clear traffic pollutants from the face, improving the long-term transparency.

Where transparent barriers may impact on the privacy of neighbouring residents, a frosted opaque finish could be investigated.

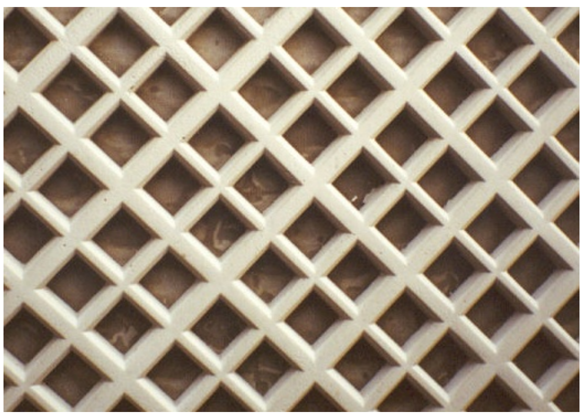
3.5.1.9 Earth mounds

Earth mounds can be effective road traffic noise barriers if the highest point of the mound can be located as close to the road as possible. They also provide opportunities for the reuse of excavated soil and screening planting. However, earth mounds typically require a large footprint if they are to achieve a significant height, and this limits their effectiveness where receivers are close to the road.

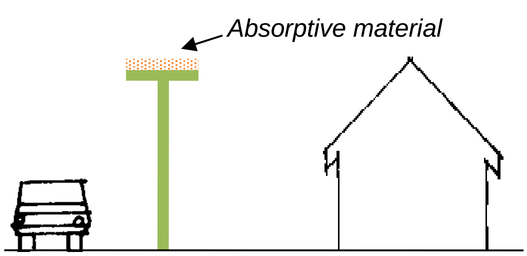
Earth mounds are discussed in more detail in Section 3.8.

Image: VicRoads

Solar panels can be incorporated into noise barriers, such as these ones installed as part of the Tullamarine-Calder interchange upgrade.



Texture of an absorptive barrier installed on the SE Freeway, Melbourne.



Absorptive materials may also be installed on the top of barriers, as shown, to provide improved noise reduction on both sides of the barrier.

3.5.1.10 Solar panels

As awareness of environmental sustainability has improved, a number of road projects in Europe have created road traffic noise barriers angled away from the road with solar panels on the roadside face. Solar panels have also been incorporated on the noise barriers as part of the recent Tullamarine-Calder interchange upgrade in Melbourne. While incorporating solar panels into noise walls currently has a considerable initial cost, they can help to achieve both future energy savings and project sustainability objectives.

Consideration must be given to locating any solar panels high enough on the noise barrier to prevent vandalism and damage. Typically, the panels would need to be at least two metres above ground height. The barriers should also be angled to provide greater solar exposure.

The feasibility of solar panels as barriers will need to be determined based on a project-specific cost benefit analysis that considers the energy provided over the life of the barrier against the cost of the current technology. Community and stakeholder views should also be considered.

3.5.1.11 Absorptive barrier materials

Absorptive roadside noise barriers may be considered where barriers are to be installed on both sides of the road and reflected noise poses a specific problem. Absorptive barriers consist of a solid barrier with an applied surface which is acoustically absorbent. Note that the absorptive material may only need to be installed near or at the top of the barrier.

Absorptive barrier materials normally cost more than standard reflective materials. Cheaper materials that have higher sound absorption than regular barrier materials are available but are not always visually appealing and rarely used.

Due to the reduced build up of reflected noise, absorptive barriers may be able to be installed to a lower height than reflective barriers. However, absorptive barriers are normally unnecessary or are not cost effective for the majority of road projects. Alternative methods of addressing reflected noise problems are discussed on page 17.

Table 3: Summary of barrier materials

Material	Benefits	Drawbacks
Sheet steel	• Relatively cheap • Easy to install	• Not normally effective above 2.4 metres high • Low visual appeal
Precast concrete	• Effective at most heights • Durable • Able to be textured or painted	• Costly • Difficult to install • Heavy and difficult to replace if damaged
Lightweight concrete panels	• Effective at most heights • Cheaper than precast concrete • Can be visually effective with appropriate design • Panels easy to replace	• Susceptible to damage • Installed examples have had low visual appeal • Colour can only be applied as a finish
Masonry	• Effective at most heights • Visually effective and can be textured and coloured	• Costly
Stone	• Effective at most heights • Visually effective in heritage areas	• High cost
Modular walls	• Can appear similar to masonry walls • Cost effective compared to masonry and concrete • Panels easy to replace	• Not effective above certain heights depending on material selection
Composite barriers	• Cost effective compared to masonry and concrete • Panels easy to replace	• Not effective above certain heights depending on material selection
Timber	• Cost effective compared to masonry and concrete • Can soften visual impact of barriers	• Need durable, treated timber • Care needed in barrier design • Not suitable in bushfire zones
Transparent (glass and acrylic)	• Can maintain views across and over the road • Soften visual impacts	• Expensive • Transmission loss, glare and privacy impacts need to be considered
Earth mounds	• Provide opportunity for landscaping and reuse of excavated soil	• Difficult to locate highest point near the road
Solar panels	• Assist in achieving sustainability goals • Improved community acceptance	• High cost • Initial cost versus long term benefit requires investigation
Absorptive barriers	• Reduce reflected noise • May be constructed to lower height than reflective walls in some situations	• High cost • Not cost effective in most situations

3.5.2 Cost and design life

The overall cost of a barrier will normally be a major factor in the selection of the material.

Table 3 provides an indication of the relative installation cost of a barrier material, but it is also important to consider the overall cost over the design life of a barrier. All barriers will deteriorate over time and this will significantly impact on cost if regular repair and replacement of the barrier is required.

In situations where a design life of 25 years or more is desired or where a particularly detrimental climate is expected, a more durable barrier material such as concrete should be considered. This can reduce the long term barrier cost by reducing the need for reconstruction.

It is also important to consider the acoustic life of a barrier. Timber barriers, for example, can rot to leave gaps and cracks through the barrier that will reduce the noise mitigation achieved. Such barriers may require regular maintenance even though the barrier itself is structurally sound. Generally, the acoustic life of a barrier should be at least equal to its design life.

3.5.3 Maintenance

Ongoing maintenance of roadside noise barriers will be required at times, to:

- remove graffiti
- repair or replace damaged barrier sections
- wash or paint sections of the barrier.

It is important to design a barrier that minimises the need for ongoing maintenance. This may include the selection of an appropriate barrier material, anti-graffiti treatment and appropriate texturing to deter graffiti and reduce the build up of pollutants.

It is also important to consider access for maintenance. During the design stage, suitable access arrangements should be established that ensure that maintenance personnel and plant can easily access the barrier when required, without needing to close traffic lanes or negotiate with property owners.

For barriers located on the property boundary, the department will need to obtain on-going permission from property owners to access their property for maintenance. For barriers located off the property boundary, the department may consider gifting the strip of land between the property boundary and the barrier to the adjoining property owner to avoid the safety and maintenance issues associated with long narrow strips of land). Ownership should be transferred to the property owner, but an easement retained to enable access by the department for maintenance[1]. Some residents may be concerned about consequential increases in rates, however the increase in property value (and hence rates) is unlikely to be significant.

The approach taken on previous projects (eg Gallipoli Underpass, Southern Expressway Duplication), whereby the Department retained ownership of the land but granted an easement in favour of the adjoining property owners for the use and enjoyment of the land, is no longer acceptable to the Lands Titles Office.

3.5.4 Vegetation

The installation of vegetation between the road and a sensitive receiver will not normally result in noticeable noise mitigation for traffic noise. Approximately 30 metres of dense vegetation are required to achieve a just perceptible reduction in road traffic noise of 3 dB(A).

However, it is important to consider the psychological effect of vegetation. While it may not reduce the actual road traffic noise level noticeably, vegetation that provides a visual screen from the road has been found to be effective in reducing residents' perception of road traffic noise. Conversely, where vegetation has been removed as part of a road project, complaints about increased road traffic noise have often been received.

This perceived benefit of vegetation should always be considered as part of the noise management and urban design strategies for road projects.

[1] *Gifted land should preferably be at least 900mm wide so as not to restrict the useability of the land (eg a gap of 900mm between a shed and the barrier may be utilised for storage of bins, installation of a modular rainwater tank etc).*

Vegetation adjacent to a road may not reduce noise levels but can block line of sight to the noise source.

The noise walls at the Gallipoli Underpass were textured and finished to complement the ANZAC theme.

Image: EastLink

Normally, barriers are more visually effective when they follow the horizontal alignment of the road.

3.6 Urban design

Roadside noise barriers can be used to great effect as part of the overall visual design of a project. The urban design of any barriers should complement the overall design of the road corridor.

As part of the Gallipoli Underpass project, for example, the noise walls were designed to blend in with the overall ANZAC theme of the project.

Barriers will be viewed in two ways, as people are travelling past them along the road and as fixed parts of the landscape, and it is important to consider the look of a barrier from both views.

Urban and landscape designers involved with a project should be consulted as early as possible in the design of any roadside noise barriers.

The noise walls on the Westlink M7 in Sydney are angled outwards to enhance the visual effect.

3.6.1 Barrier location

Typically, the most visually effective noise barrier is one that is parallel to the road. However, where certain features may need to be emphasised, a roadside barrier could be curved around them to good effect.

Sudden, sharp direction changes can be disconcerting to motorists so it is preferable to use curved barriers where they need to follow roads around bends and corners. It is also possible to use regular, small steps to curve barriers without noticeably impacting on the driving experience.

If there needs to be a sudden change in the barrier material or height, it may be worth considering separating and overlapping the different barrier sections to lessen the visual impact of the change.

Where a noise barrier ends, tapering could be used as a visual signal for motorists. Sometimes, however, it may be visually effective to make a bold end statement.

Image: Urban Superway

Image: EastLink

Transparent noise walls can be used to maintain views across the road and connect the road to its environment.

3.6.2 Barrier height

The top edge of a noise barrier is usually quite distinct against the background and should be considered carefully. Normally, the top edge of a barrier should follow the road surface when considered on a large scale.

In terms of visual impact, it is better to have the barrier height parallel to the road surface. Uneven changes or steps in height should be avoided as they can create a disruptive vision for motorists. If required, steps should be as small and regular as possible.

It is also important to have a barrier that appears effective to the casual observer. In some cases where the acoustically required barrier height changes along a road, it may be worth constructing the barrier at the maximum required height along the entire length. While this increases costs and the material required for the barrier, it can avoid complaints about adjacent properties receiving barriers of different heights and about the visual impact of the barrier.

It may also be worth considering angling barriers outwards as even a small change can enhance the experience for the motorist. Angled barriers tend to look more visually appealing than barriers constructed perpendicular to the ground. However, it should also be noted that angling a noise barrier can move the effective top of it away from the road and lessen the noise reduction provided.

3.6.3 Views

Barriers that block significant views from or across the road should be avoided.

On a bridge, or where a road opens up to a significant view of the surrounding area, transparent noise barriers should be considered. This can both improve the experience for motorists and connect the road to its environment.

Plantings along the front of a barrier will soften its impact.

Subtle colours should normally be used.

Simple, abstract patterns are preferable so as not to distract motorists.

3.6.4 Landscaping

Unless they form a key part of the visual design of a road, most noise barriers should be visually screened from motorists and residents. The best way to achieve this is generally with the planting of appropriate vegetation to soften the noise barrier. Local trees and plants will help to connect the barrier to its environment.

It is important to plant vegetation that will soften the impact of the barrier in both the short term and the long term. While tall trees behind the barrier will reduce its dominance, they will take time to grow and it is important that the barrier is not left bare in the meantime.

Generally, vegetation in front of a barrier should grow relatively quickly and be self-seeding. It is also important that vegetation be selected that minimises any watering and maintenance requirements.

New Jersey style barriers can assist in reducing road-tyre noise to some degree.

3.6.5 Appearance

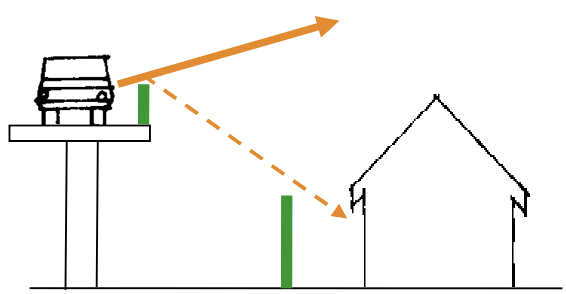
The colour, texture and patterning of a noise barrier are important parts of its visual design.

Subtle colours are normally best as they complement the road, as well as the natural or urban environment. The barrier should appear natural and in harmony with the surrounding landscape. Brighter colours can be used if part of the urban design of a project, but care should be taken so that they are not overused.

Texturing and patterning a wall can be visually effective and deter graffiti. It is important that patterns are repetitive and simple so that they do not overly distract passing motorists, particularly on high speed roads.

Horizontal patterning of a wall should also be considered as it can be effective in reducing the appearance of height.

New Jersey style barriers installed on the side of bridges can be effective due to the increased height of the barrier relative to the receiver.



In certain situations, New Jersey style barriers on the side of raised roads may provide a greater level of noise mitigation than property fences.

3.7 New Jersey style barriers

New Jersey style barriers are common features on road corridors and can often assist in providing small road traffic noise reductions.

The installation of solid New Jersey style barriers on the side of a road can reduce noise generated from the interaction between tyres and the road surface. However, the barriers are unlikely to be effective in reducing engine noise and noise from heavy vehicles due to their limited height. While this reduces their effectiveness as a barrier, small reductions provided by New Jersey style barriers may assist in either removing or reducing more expensive noise mitigation treatments that would otherwise be required.

They provide more noise attenuation when used on the edge of bridges or raised roads as the angle of view from road to receiver increases their effective height.

New Jersey style barriers provide better noise attenuation and safety than conventional steel guardrails, although at significantly increased cost. Where guardrails or safety fences are required, it may be appropriate to use New Jersey barriers instead for the additional noise attenuation.

Earth mounds can be designed to be noise barriers with low visual impact.

3.8 Earth mounds

Earth mounds, or bunds, represent effective traffic noise barriers in certain situations where enough space is available to construct a barrier of reasonable height. They can be designed to have a low visual impact and to reuse excavated soil as part of a road project. However, they normally require a significant amount of excavated soil if designed to a considerable height.

Earth mounds are generally suitable for outer suburban and rural projects where there is sufficient space and where a mound will complement the natural environment.

3.8.1 Gradient limitations

A significant constraint of earth mounds as noise barriers is that the highest point of the barrier is not able to be located immediately adjacent to the road as a slope is required to build up the height of the mound.

The slope of the mound facing the road should be as steep as possible, while meeting safety objectives, to move the effective barrier location closer to the road. The maximum desirable slope is typically 2:1 (H:V) but 3:1 (H:V) is preferable for maintenance reasons.

On the side facing the receivers, the slope has no impact on the noise mitigation and the mound can be sloped down more gradually to reduce any visual impact.

Note that the slope that can be attained for an earth mound will depend on the quality of material available. If only low-grade, highly organic material is available, then a gentler slope will be necessary to provide stability to the mound.

If a steeper slope is required, low walls may be able to be used to support the mound. Gabion walls can be used in conjunction with earth mounds to provide a steep slope on one face with a more gradual slope on the other side.

Where space is available, locating a barrier on top of an earth mound can increase its effective height.

While earth mounds may not require as much maintenance as traditional barriers, it is important to consider well-thought out plantings on the mound so that it does not look bare like the mound shown above.

3.8.2 Combined mound and barrier options

To increase their effective height, it is possible to install roadside barriers on top of an earth mound. For example, a three metre high barrier installed on the crest of a two metre high earth will have the same acoustic benefit as a five metre high barrier installed in the same location. Any of the barrier types outlined in Section 3.5.1 are able to be installed on top of an earth mound with appropriate design.

However, care should be taken when designing a combined mound and barrier that the barrier is not moved further away from the source to accommodate the mound footprint. If a barrier is moved away from the source to allow for the mound, the additional noise mitigation achieved by increasing the overall height may be negated.

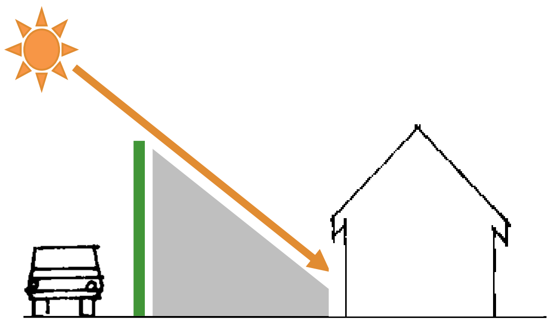
3.8.3 Vegetation and maintenance

Earth mounds provide the opportunity to plant vegetation along the sides and top of the barrier, lowering the visual impact of a barrier. To assist plants to establish root growth, the top 600 mm of surface material should not be compacted.

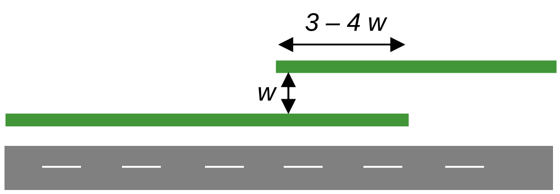
While adding a row of vegetation to the top of an earth mound will not noticeably reduce noise levels, it can assist in creating the perception of reduced road traffic noise by providing visual screening of passing vehicles. It will also improve privacy for residences near to the road.

Many of the maintenance issues associated with noise barriers will be avoided by the use of an earth mound. However, maintenance will still be required particularly of planted areas. During the design stage, it is important to consider access for maintenance personnel and equipment to planted areas of the mound. With appropriate design, maintenance should be able to be carried out without needing to shut down lanes of traffic.

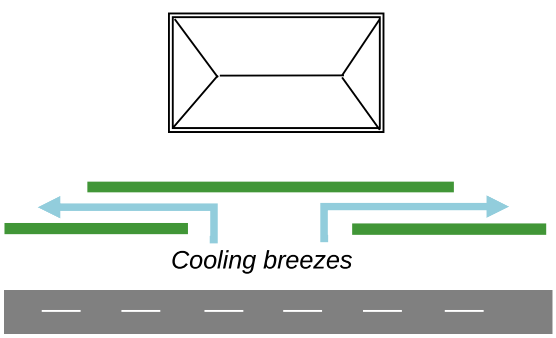
The material and slope of the mound should also be considered during the design stage, to minimise run-off and erosion.



It is important that noise barriers do not block sunlight to house windows, particularly during winter.



Access paths can be provided by overlapping barrier sections. As a rough guide, the overlapping section should be 3 to 4 times longer than the gap.



Overlapping barrier sections can create paths for natural breezes to circulate air.

The gaps should be designed so as not to reduce the acoustic performance of the barrier, or contravene Crime Prevention through Urban Design (CPTED) principles.

3.9 Public considerations

While roadside noise barriers may be readily accepted for their noise mitigation benefits, it is also important to consider other impacts they can have on the community. These include shadowing, access, air circulation, privacy and security, graffiti, and effects on fauna movements.

The local Council should be consulted on the proposed barrier location and design.

3.9.1 Shadowing

Noise barriers that are sited next to sensitive receivers can have significant shadowing impacts, particularly if the northern or eastern façade of a residence is located immediately adjacent to the barrier. In these situations, it is important to locate noise barriers such that the winter sun will still be able to penetrate any windows along the façades.

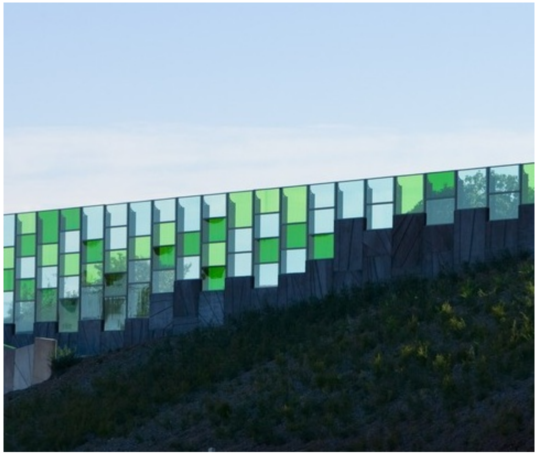
Where shadowing impacts from a noise barrier mean that an area may have excessive shade coverage during winter, the potential impacts should be discussed with the property owner. It may be preferable to reduce the height of the barrier and provide additional property noise mitigation treatments to compensate for the reduced noise mitigation.

3.9.2 Gaps for access and air circulation

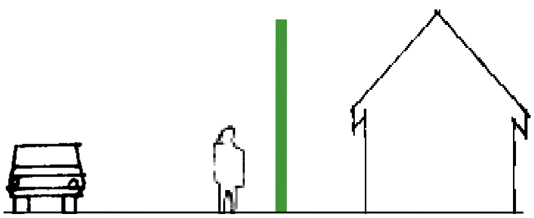
Where long stretches of noise barriers are planned, it may be necessary to provide access points for emergency vehicles as well as for public and maintenance reasons.

Gaps in the barrier may also be desirable to allow natural breezes to circulate around adjacent properties.

Overlapping barrier sections can be used to provide access/ air circulation. However, the overlap length typically needs to be three to four times longer than the gap to maintain the acoustic performance of the barrier. When considering the use of overlapping barriers, designers need to have regard to the principles of Crime Prevention through Urban Design (refer to Section 3.9.4).



Noise barriers that have both transparent and opaque panels can provide privacy as well as light.



Having barriers and pedestrian paths visible to passing motorists will increase the perception of security for both residents and pedestrians.

Plain noise barriers with a high degree of public exposure can become targets for graffiti.

3.9.3 Privacy

Solid roadside noise barriers can have the additional benefit of improving privacy for residents adjacent to the road, both visually and by discouraging trespass. This is particularly beneficial where residents are newly exposed to the road and may be concerned about being clearly visible to passing traffic.

In cases where a transparent noise wall is desired for natural lighting, a frosted opaque finish or similar may effectively provide both light and privacy. Alternatively, the lower half of the barrier could be opaque with the top being transparent and providing the necessary light.

3.9.4 Security and Crime Prevention

Security is an important consideration in any roadside noise barrier design. It is important that noise barriers be designed such that there are no hiding spots for potential attackers, especially adjacent to pedestrian and cycle paths. The use of transparent noise barrier materials can increase security but may not be desirable where residents require privacy.

Where opaque noise barrier materials are to be used, it is generally preferable to place pedestrian paths on the road side of the barrier to improve security for pedestrians and deter people attempting to trespass on properties behind the barrier. Lighting designs should also attempt to minimise shadowed areas around the barriers adjacent to pedestrian paths. There are several resources available to assist in applying the principles of Crime Prevention through Environmental Design[2].

3.9.5 Graffiti

Deterring graffiti on barriers can be a significant problem particularly where there is a long stretch of wall with a high degree of public exposure.

Graffiti can be reduced through the application of anti-graffiti treatments and ongoing maintenance but this can be a costly approach.

Alternative approaches could include applying a texture or pattern to the wall, having climbing vegetation on it or screening it from public exposure through plantings in front of it. It may also be effective to have local street artists apply pre-designed and approved works to the wall.

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[2] Planning Institute of Australia (2009), Safety and Surveillance Fact Sheet, http://www.healthyplaces.org.au/site/safety_and_surveillance.php

3.9.6 Fauna movements

Many road projects will cross movement corridors for native fauna, particularly in rural areas and around waterways. Roadside noise barriers can potentially obstruct these movement corridors but also present an opportunity to direct fauna to designated, safe road crossing points. Where fauna movement corridors have been identified, measures should be integrated into the noise barrier design to direct fauna movement and allow crossing where necessary.

The typical approach used to allow fauna movements where noise barriers may impede them is the design of fauna underpasses at specific locations, such as waterways passing under the road, with the noise barrier sitting on top and adjacent to the roadside. The roadside noise barrier, in conjunction with any necessary wildlife fencing, prevents fauna from crossing the road and serves to direct them to the underpass. Where the passage is being designed for climbing animals, such as possums, it may also be possible to design a vegetated bridge pathway over the noise barrier(s) and above the road.

Both of these approaches have the additional advantage that fauna will not move directly across the path of traffic, reducing native fauna losses and increasing road safety.

Consideration of native fauna also needs to be taken when using transparent noise barriers, as many birds in flight have been found to collide with them. Transparent noise barriers may need to be intensively patterned to reduce the chances of this occurring.

4.0 Property treatments

4.1 Overview

In many situations, roadside barriers will not be able to achieve the noise mitigation requirements for a project and/or will not be feasible. This will commonly occur where there are multi-level properties adjacent to the road or in rural areas where properties are isolated and the length of barrier required to mitigate the road traffic noise will not be cost effective.

In these cases, noise mitigation treatments should be installed at each affected sensitive receiver to achieve compliance with the noise criteria.

Property treatments for noise mitigation will consist of a combination of:

- acoustic fences installed on one or more property boundaries
- architectural treatments installed on the property to reduce road traffic noise ingress into sensitive internal areas.

It is always preferable to install acoustic fences on property boundaries, rather than architectural treatments, as these provide protection for both indoor and outdoor areas of a property.

However, for multi-level properties, and properties where a fence will not achieve the noise mitigation requirements, architectural property treatments represent the most reasonable and effective form of noise mitigation. In some cases, a property owner may also prefer architectural treatments to fences.

Where fences are not able to achieve the noise mitigation requirements for a property, architectural treatments should be installed in accordance with the treatment packages specified in the RTNG. Property treatments are only applicable to properties classified as sensitive receivers under the RTNG.

The following sections outline general property treatments for residential properties. However, similar treatments may also be suitable for other land uses such as schools, caravan parks and nursing homes if deemed appropriate.

Acoustic fence on a property boundary

Acoustically treated window

An external view of an acoustically treated air vent. Vents such as this can be used to provide acoustically treated air paths that allow windows to be closed at night time.

4.2 Reasonableness

Property treatments should be provided at receivers requiring road traffic noise mitigation, where:

- all reasonable and practicable road design measures have been applied
- roadside barriers have not been deemed to be reasonable and/or practicable.

In cases where roadside barriers have been constructed and predicted noise levels still exceed the relevant criteria, property treatments should only be provided where the predicted exceedance with the roadside barriers is greater than 2 dB(A). If the exceedance is less than 2 dB(A), it is not considered reasonable to provide property treatments as:

- a significant level of noise mitigation will already be provided via the roadside noise barrier
- the required property treatments will not provide a noticeable noise reduction benefit.

4.3 Treatment options

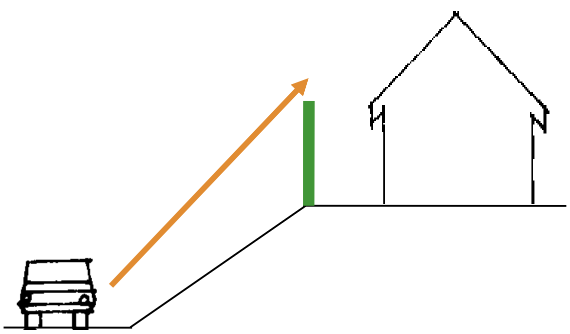
This section discusses methods of assessing, selecting and installing appropriate property treatments to achieve compliance with the RTNG and maximise the noise mitigation achieved.

Included is information on:

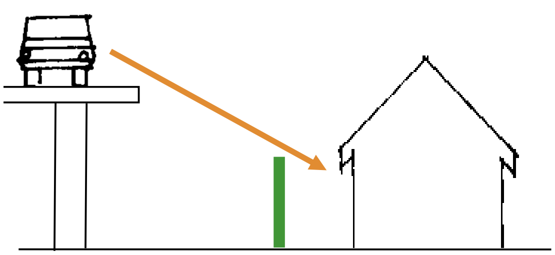
- acoustic fences installed at properties
- window treatments
- door treatments
- wall treatments
- ceiling treatments
- the provision of alternative ventilation.

Generally, the treatments provided to any residence will include a combination of the above depending on the amount by which noise levels are predicted to exceed the criteria and the effectiveness of each treatment.

Acoustic fences can provide effective noise mitigation from road traffic, but should break line-of-sight to the road noise sources as a minimum.



The effectiveness of a property fence will be increased if the road is depressed relative to the receiver.



The effectiveness of a property fence will be decreased if the road is elevated. In this case, a New Jersey style barrier or roadside barrier would provide more effective noise mitigation.

4.3.1 Acoustic fences

Acoustic fences installed at the property boundary of sensitive receivers are often effective noise mitigation measures that provide reductions of both external and internal road traffic noise levels. Because of this, they are normally preferable to other property treatments.

Acoustic fences may also be used in conjunction with architectural treatments to achieve the overall required noise reduction.

Much of the theory and considerations relating to acoustic fences is similar to that presented for roadside barriers in Section 3.0. This section provides additional advice specifically relating to the installation of fences at properties.

4.3.1.1 Height

As for roadside barriers, any fence installed on a property boundary must be high enough to break line-of-sight between the road noise sources and the receiver.

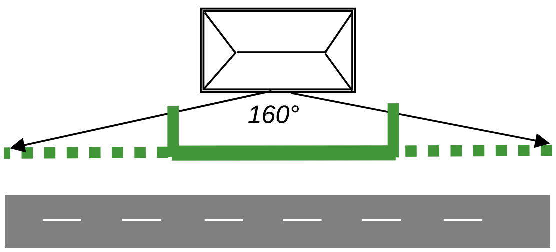
Where traffic mainly consists of light vehicles, a fence that breaks line-of-sight to the road-tyre interface may be sufficient. However, near a freight route, a higher fence may be needed to mitigate noise from truck exhausts.

A fence that just breaks line-of-sight will typically provide a noise reduction of approximately 5 dB(A). A fence providing less than a 5 dB(A) noise reduction would not normally be considered cost effective noise mitigation, unless architectural treatments had already been deemed not to be cost effective.

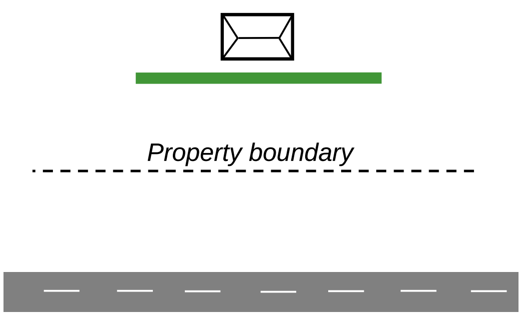
Fences installed at the property boundary are most effective when the road is depressed relative to the receiver, such as in a cutting, as the effective barrier height is increased.

In situations where the road is raised relative to a receiver, property boundary fences may not be as effective, as they would normally need to be of substantial height just to break line-of-sight. In these cases, roadside noise barriers and architectural property treatments are more effective forms of noise mitigation.

Fences with gates are not normally constructed any higher than 2.1 metres.



Returns can be used to shorten the required fence length.



Where a property boundary is located midway between the road and the dwelling, a fence may be more effective located closer to the dwelling.

The Department's reasonable barrier height limits for fences installed at a property boundary, as outlined in Table 2 and the RTNG, are:

- 2.1 metres where access to the property is through the fence
- 3.5 metres where access to the property is not through the fence.

Gates in a fence reduce the noise reduction achieved and it is not normally practical to increase the height beyond 2.1 metres unless the gates are carefully designed. This would involve careful treatment of gaps to maintain overall acoustic performance and automating the gates so that the functionality is acceptable.

4.3.1.2 Length

As for roadside barriers, a property fence should provide at least 160° of protection for receivers from a straight section of road. This is in order to prevent noise diffracting around the edges of the barrier reducing its effectiveness.

For acoustic fences, this can be achieved by either constructing a long, straight fence or by returning the fence sides around the edges of the property.

The overall length of a fence and the associated cost should be considered against the cost of the architectural treatments that would be provided in lieu of the fence. In some cases, it may be more cost effective to provide architectural treatments rather than a lengthy acoustic fence.

4.3.1.3 Location

Acoustic fences are usually placed on the property boundary as this is the most convenient location for the resident. In situations where the boundary is close to the dwelling and/or close to the road, this will normally also provide effective mitigation of road traffic noise.

However, if the boundary is located a significant distance from both the dwelling and the road, then it may be necessary to locate the fence closer to the dwelling to improve the noise mitigation provided.

The closer the fence is to the road or receiver, the more noise mitigation it will provide.

Sheet steel fences are commonly used for acoustic fences less than 2.4 metres high, due to their relatively low cost.

As part of the upgrade of Portrush Road, some property owners contributed towards the enhancement of their fence beyond the standard design.

It is important that fences, particularly timber fences, are designed such that there are no gaps or cracks.

4.3.1.4 Material

Any of the materials described in Section 3.5.1 would also be able to be constructed as an acoustic fence at a property boundary, should it be deemed reasonable to do so. Reference should be made to Section 3.5.1 to determine the benefits and drawbacks of each considered material.

On most projects, to restrict costs to a reasonable level, the Department will offer to provide property owners with a sheet steel (e.g. 'Colorbond') fence if an acoustic fence is required to mitigate road traffic noise levels.

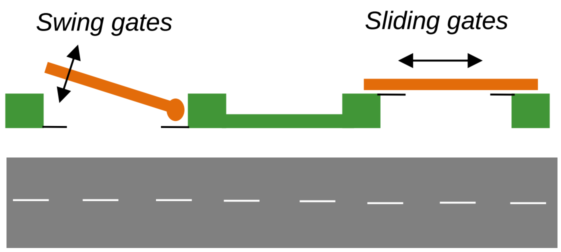
However, as the acoustic performance of sheet steel fences may start to degrade at heights above 2.4 metres, an alternative barrier material should be selected where a higher barrier that provides the necessary traffic noise reduction is required. If a different barrier material is necessary to achieve the noise mitigation goals, then the most reasonable material that meets the acoustic requirements should be selected and approved by the Project Manager and Senior Environmental Management Officer (SEMO).

A more expensive fence material may also be offered to property owners where:

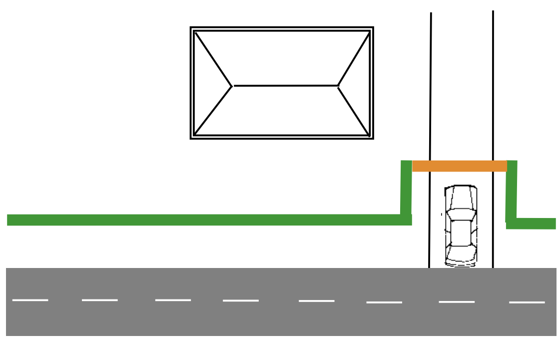
- a fence exists with a reasonable level of investment (replacement of like-for-like will be offered if the fence material is acoustically acceptable)
- the proposed fence material would reduce the property value

Property owners may also choose to have the fence constructed from a different material, so long as it meets the acoustic requirements. In this case, any additional cost (above the cost of the fence offered by the Department) will have to be borne by the property owner.

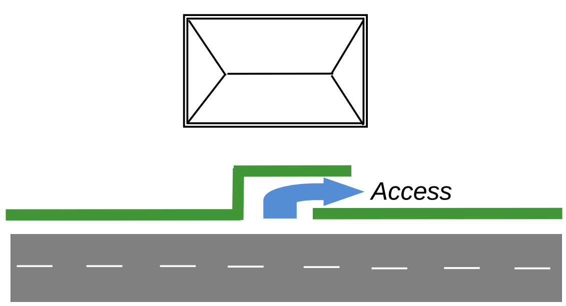
In selecting a material for a fence at a property, it is important to select a material and fence design that has no gaps or cracks across its height and length. The presence of gaps and cracks can significantly impact the overall noise reduction achieved by a fence design.



Sliding gates should be overlapped at the ends where possible, and solid metal plates provided at the ends of swing gates to cover gaps.



A driveway gate should be designed to provide enough space for a vehicle to stop in front of it without affecting traffic on a busy road.



Acoustically designed gates may be avoided if overlapping barrier sections can be constructed.

Where fences are being provided at the front of properties, it may be worth offering fences with an improved visual impact to owners. For example, on some recent projects, property owners have been offered timber fences, or combined timber and ‘Colorbond’ fences, to improve the aesthetic design.

However, care needs to be taken that timber fences are constructed with no gaps between the timber pieces. This could be achieved by overlapping timber sections.

4.3.1.5 Gates

In many cases, acoustic fences installed along a property boundary will require gates to provide access for cars or pedestrians.

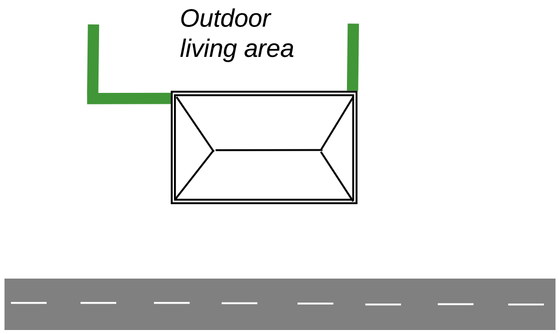
Gates should be constructed to the same height as the fence and from a material with an acoustic transmission loss equivalent to that of the barrier material. Normally, gates are made from ‘Colorbond’ or timber to match the boundary fence construction.

It is important that the gate introduces no significant gaps that will reduce the effectiveness of the fence. This can normally be achieved by overlapping the ends of the gate where possible and/or providing solid metal plates at the ends of the gates to cover gaps at the sides of the gate.

The Department prescribes a reasonable height limit of 2.1 metres for fences containing gates. With careful design, gates can be constructed to heights above 2.1 metres without reducing the acoustic performance of the fence. However, this will increase the weight of the gate and it may need to be automated for functionality reasons.

In the case of gates providing access to a property driveway immediately next to a heavily trafficked, free-flowing road, it is important to include enough space in the design for a vehicle to stop before the gate without impacting on traffic using the road. This could be achieved by setting the gate back from the line of the fence.

In some situations it may be possible to avoid the use of a gate by having an opening protected by an offset and overlapping fence section.



Fences protecting outdoor areas located on the opposite side of the dwelling to the road may be able to use shielding provided by the dwelling to increase their effective area.

'Colorbond' fence at a property on South Road with a return protecting noise ingress from the side.

Masonry fence on Portrush Road with a recess to allow a vehicle to enter the driveway.

4.3.1.6 Acoustic fences for outdoor living areas

For properties where the required noise mitigation is not able to be achieved through road design measures, roadside barriers and acoustic fences, the Department will offer property treatment packages in accordance with the RTNG. As part of these packages, properties may be offered a fence to protect an outdoor entertaining or living area of no more than 50 m^2.

Fences offered as part of the treatment packages range from 2.1 to 2.7 metres high and should be designed in consultation with the residence to provide noise mitigation for an outdoor area that may be used for outdoor dining, living and/or entertaining.

The design of fences protecting outdoor areas should follow the same acoustic principles discussed earlier, although with the aim of mitigating road traffic noise in the outdoor area rather than at the property itself. The fence would normally be constructed from 'Colorbond' or equivalent sheet steel unless an alternative material is considered appropriate by the Project Manager and SEMO.

Depending on the location of the outdoor area, it may be possible to combine the fence with the side of a dwelling to protect a greater area at a lower cost. This could be done, for example, where an outdoor living area is on the opposite side of the house from the road and the fence is used to provide mitigation of road noise from around the sides of the house.

It is important to consider how these fences may impact on a property during design and features such as pedestrian gates may need to be included.

4.3.1.7 Responsibility

The responsibility for the installation of an acoustic fence as part of a noise mitigation program is borne by the Department.

In some cases the property owner may wish to arrange installation of the fence themselves and responsibility for this would pass to them. The owner will need to provide evidence that the fence would still meet the acoustic requirements. The Department will cover the cost up to the cost of the fence that was originally offered. Any additional cost will be the responsibility of the property owner.

The Department will verify completion of the works, after which responsibility for the maintenance of the acoustic fence will pass to the property owner.

Due to their size and lightweight nature, windows are one of the major noise transmission paths into a room.

Secondary and double glazing systems are two possible noise mitigation treatments that can produce significant noise reductions if properly installed.

4.3.2 Windows

When considering architectural property treatments for dwellings, one of the first features that will need to be treated are any windows in façades that require noise mitigation treatments.

Depending on the treatment package for the property, architectural treatments for windows may include one or more of:

- window seals for the existing window
- replacing the existing glazing with thicker glazing
- replacing the existing window with a new double glazed window
- providing a secondary window at an air gap from the existing window.

4.3.2.1 Window seals

Where an operable window exists, any cracks around the perimeter will enable sound to enter a building and reduce the acoustic effectiveness of the window. Providing acoustic seals around the perimeter of a window is an effective method of reducing noise flanking around the window edge.

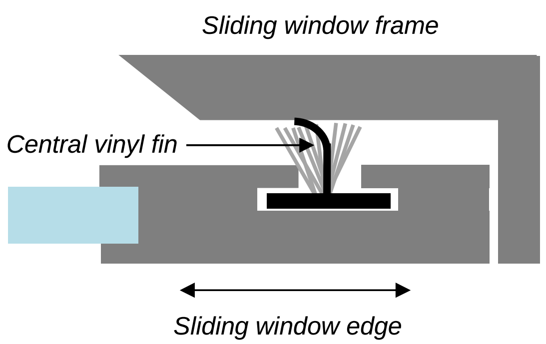
Acoustic window seals should always be properly adjusted to provide a tight seal when the window is shut. Rubber seals, or seals made from an equivalent solid material, are normally the best as brush seals will not effectively seal the gaps around the window and are not cost effective for noise mitigation purposes.

While rubber seals are not readily available for sliding windows, it is possible to fit brush seals with a vinyl fin down the middle which will provide better noise mitigation than traditional brush seals.

When property treatments are being provided, window seals should be installed, if practical, to:

- any existing windows where no secondary window is being provided
- new secondary or upgraded windows.

Seals may also be fitted to existing windows where a new secondary window is being installed. However, if seals cannot be easily fitted to the existing window then the effect on the overall noise reduction is unlikely to be significant as long as the new window is fitted with acoustic seals.



Typical operation of a vinyl fin seal for sliding windows and sliding, glazed doors. It is important that the vinyl fin contacts the window frame.

Jalousie or single-hung windows, such as those shown above, are difficult to effectively seal and should be avoided, where possible.

4.3.2.2 Sealing existing windows

Where existing windows are to be provided with seals, the ease with which it can be achieved will depend on the window type. Typically, awning or casement type windows can be fitted with acoustic rubber compression seals around the perimeter without too much difficulty. However, single-hung, double-hung and jalousie windows are normally not able to be provided with seals that will provide any noticeable noise reduction.

For existing sliding windows in aluminium frames, vinyl fin seals should be provided if it is possible to fit them into the grooves in the window. In many cases with existing windows, this will not be possible and there is no practical option for fitting acoustic seals.

In all cases, it will be necessary to install and adjust the seals so that the window and frame both contact the seals when closed. The tighter a seal is, the better the noise reduction that will be achieved. However, it is also important that the seal is not too thick to prevent the window from being able to be closed properly.

For existing windows that are not able to be fitted with acoustic seals, an alternative approach may be to provide secondary glazing to the window. Proprietary secondary glazing products are available at relatively low costs that can provide an airtight seal and considerable noise reduction across a window, without the need to modify the existing window. More information is provided in the secondary windows section of this chapter.

When sealing any type of windows, it is also necessary to seal any gaps and cracks around the frame using a flexible caulking compound.

The seals should be installed and adjusted so they fit tightly between the window and frame when the window is closed.

Awning and casement window styles are better for single glazed windows as a positive compression seal can be obtained around the perimeter.

Image: Titane Pty Ltd

The double glazed window system shown has a relatively small air gap which may need to be increased for road traffic noise.

4.3.2.3 Upgrading existing windows

For architectural treatments at some properties, it will be necessary to upgrade the window to accommodate either 6 mm or 10 mm thick glazing. The thicker glazing will be more effective at reducing lower frequency road traffic noise due to its weight.

In many cases the installation of the heavier glass will necessitate the replacement of the window framing, as standard residential frames are not able to bear the additional weight, particularly where 10 mm thick glazing is used. When replacing the window framing to accommodate thicker glass, the frame should be well sealed to the building structure. The frame material does not have a significant influence on the noise reduction achieved by the window but it should be strong enough to hold the weight of the glass. Generally, the new frame material should match the material of the existing frame as much as possible.

While the like-for-like replacement of an existing window is preferable if the frames need to be replaced, it is always better to install a new awning window where a single-hung, double-hung or jalousie window exists unless the window style has a heritage-listing or particular significance. This is due to the poor sealing achieved around single-hung, double-hung and jalousie window types. Awning windows fitted with rubber compression seals to achieve a good seal around the perimeter typically achieve the greatest noise reduction. However, a horizontal sliding window could also be installed provided it is designed to accommodate vinyl fin seals.

4.3.2.4 Installing double glazed windows

For those properties most affected by road traffic noise from a project, the RTNG specifies the installation of a new double glazed window system consisting of a 6 mm thick pane and a 10 mm thick pane separated by an air gap of at least 75 mm. This new window completely replaces the existing window. Equivalent double glazing constructions could also be installed as discussed in the sections following this.

Double glazed windows consist of two panes of glass separated by an air gap, installed in a single, sealed metal or timber frame. The noise reduction through the window is controlled by both the thickness of the glass and the width of the air gap. The use of thicker glazing and of a wider air gap will increase the noise reduction achieved.

In order to provide better reduction of road traffic noise, it is important to maximise the air gap as far as practicable to better reduce low frequency noise. Air gaps of 50 mm or less do not normally provide effective mitigation of road traffic noise and should be avoided.

The thickness of the glazing in the double glazed system is also important in mitigating traffic noise, and the thickness of each pane should be at least 6 mm. Note that any thickness of glass will be acoustically weak at particular sound frequencies due to the properties of the material. In order to improve the reduction offered by the double glazing, it is better to have two panes of different thickness such that the weaknesses do not coincide at a single frequency.

As new double glazed windows will contain both panes of glass in the same window frame, it is critical that good quality, well adjusted window seals are provided around the perimeter. Otherwise, noise will enter around the cracks in the frame and no discernible benefit may be obtained by installing the double glazed window. For this reason, awning or casement windows achieving a tight compression seal around the perimeter are preferable.

Where the two glass panes are located in the same sealed window frame, it will also be necessary to either fill the cavity between the panes with an inert gas, such as argon, or with moisture absorbing desiccant to minimise fogging and condensation in the space.

An alternative installation for a double glazed window system is to install the two panes in individual frames. For example, an awning window could be installed on the outside face with a sliding window on the internal face.

While it can be costly, this option provides a better seal around the window as both frames can be fitted with acoustic seals. It also means that the cavity can be easily ventilated and there is no need for it to be filled with an inert gas or moisture absorbing desiccant.

A proprietary acrylic secondary glazing system installed on the internal side of an existing window.

4.3.2.5 Providing new secondary windows

Instead of providing upgraded or double glazed windows, it may be more cost effective to retrofit a new secondary window at an air gap from the existing window in certain situations. This will effectively provide a double glazed window without the need to replace the existing window. However, care should be taken to ensure that the proposed secondary window treatment will achieve an equivalent noise reduction to the original treatment.

As part of the property treatments installed during the Gallipoli Underpass project, for example, sliding windows containing 6 mm thick glazing were installed on the interior side of existing windows at the maximum possible air gap.

The two most critical components of any secondary glazing installation are the air gap achieved from the existing window, and the thickness of the new glazing. Any proposed treatment should be compared to the original required treatment, as detailed in the following section. As a rule of thumb, a minimum 75 mm wide air gap should be achieved with any secondary window designed to effectively mitigate road noise.

As discussed previously, the secondary window should always be provided with acoustic seals. Where a secondary window is installed on the interior of an existing window, a sliding window will generally be most suitable and it should be designed to accommodate vinyl fin seals. If a secondary window is installed on the outside of the existing window, an awning or casement window achieving a positive compression seal would be best.

Where possible, the existing window should also be fitted with acoustic seals. However, if this is not practical, the noise difference would not be expected to be significant as long as the new secondary window is well designed.

Secondary windows can be difficult to install and it is best to engage an experienced glazier with experience in the installation of secondary glazing, preferably for noise reduction purposes.

An alternative secondary glazing option is an acrylic secondary glazing system. Proprietary systems are available where acrylic secondary glazing is installed as panels on a custom-built magnetic frame. These systems are relatively cost effective and provide an airtight seal around the secondary window. The panels can be removed with relative ease or designed to be sliding, which allows the window to be opened and ventilates the cavity.

Due to the relatively low cost of such a system, it may also be an effective method of sealing an existing window that is not able to be easily fitted with appropriate seals.

However, as the glazing in these proprietary systems is acrylic, which is less dense than glass, the secondary glazing must be at least 8 to 10 mm thick. Acrylic secondary glazing is unlikely to be effective for properties significantly affected by road traffic noise, i.e. those receiving RTNG Treatment Package 4.

Secondary windows can be useful for treating homes under a heritage order as the outside appearance of the windows will not change.

4.3.2.6 Noise reductions from different window systems

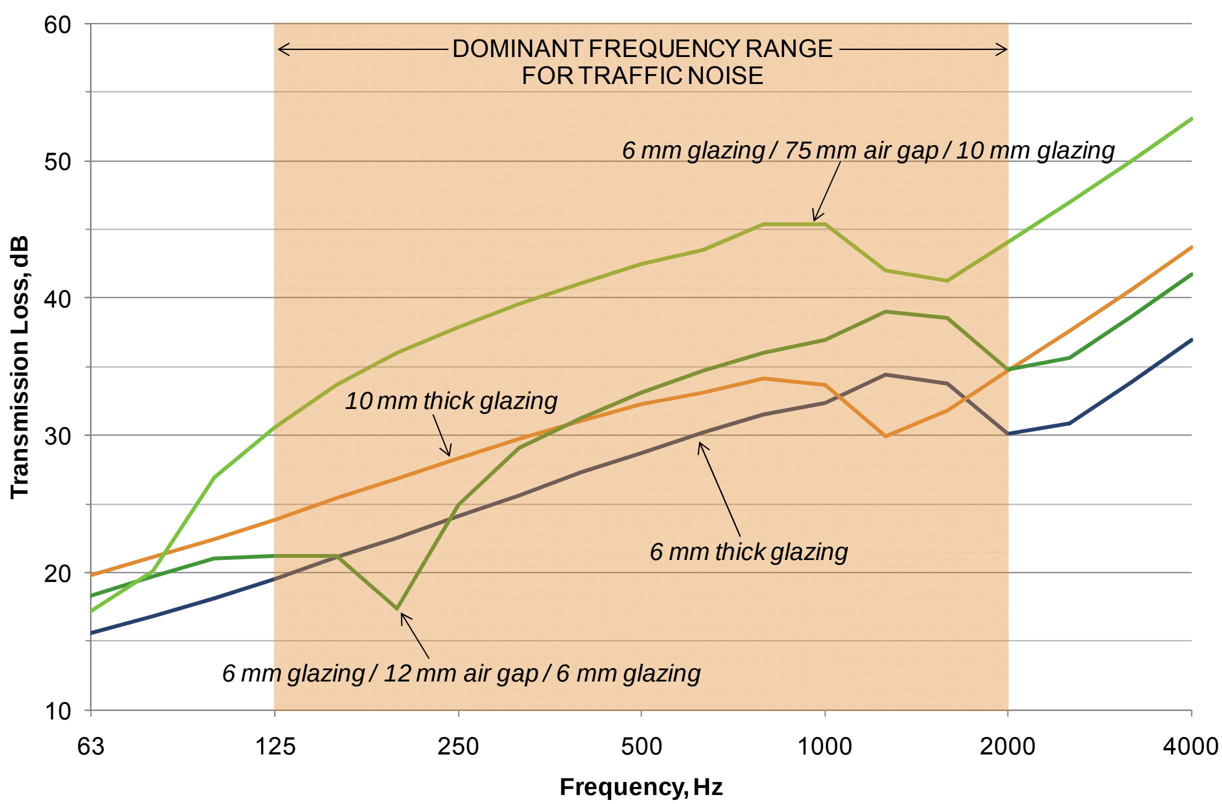
Table 4 on the following page details approximate noise reductions achieved in a typical room with different windows, relative to a sealed window with 3 mm thick glazing.

The noise reductions have been predicted based on a residence adjacent to a high speed road, with significant heavy vehicle traffic.

Table 4 can be used to assess the benefits obtained by the use of different window systems, and to choose equivalent systems that may be more practicable when treating a property.

The figure below also demonstrates the relative performance of different glazing systems across the typical traffic noise frequency range. Note that the approximate noise reductions presented on this figure only consider noise transmitted directly through the glazing and do not account for noise transmitted around the perimeter of the window.

Note that when investigating residences significantly affected by road traffic noise, it may be preferable to engage an acoustic consultant to assess the treatments to determine the most effective treatment package.



Approximate transmission loss achieved by different glazing systems across the dominant frequency range for traffic noise.

Table 4: Approximate internal road traffic noise reductions with different window systems

Window configuration[1]	Approximate overall internal noise reduction relative to sealed window with 3 mm thick glass, dB(A)	
4 mm sealed glazing	+ 2	Single glazing systems
5 mm sealed glazing	+ 4	
Operable window with 6 mm thick glazing	+ 6	
Operable window with 10 mm thick glazing	+ 9	
3 mm + 6 mm glazing at 50 mm air gap	+ 7	Retrofitted secondary glazing systems
4 mm + 6 mm glazing at 50 mm air gap	+ 8	
5 mm + 6 mm glazing at 50 mm air gap	+ 9	
3 mm + 10 mm glazing at 50 mm air gap	+ 10	
4 mm + 10 mm glazing at 50 mm air gap	+ 11	
5 mm + 10 mm glazing at 50 mm air gap	+ 12	
8 mm + 6 mm glazing at 50 mm air gap	+ 9	Double glazing systems
8 mm + 6 mm glazing at 100 mm air gap	+ 12	
10 mm + 6 mm glazing at 50 mm air gap	+ 14	
10 mm + 6 mm glazing at 100 mm air gap	+ 17	
10 mm + 8 mm glazing at 50 mm air gap	+ 14	
10 mm + 8 mm glazing at 100 mm air gap	+ 17	

Note:

(1) All operable window systems assumed to be awning/casement windows with acoustic seals around the perimeter.

4.3.2.7 Other considerations

Decorative and heritage-listed windows

The appearance of decorative windows, such as those containing patterned glass, may be adversely affected by the installation of window treatments. Secondary glazing treatments are often able to be installed without any physical alteration to an existing decorative window, but these treatments should be discussed with the property owner if they will alter the internal or external appearance of the window.

If patterned glass is able to be replaced with thicker glass of the same appearance, than this may be considered as the appropriate treatment should the cost be reasonable. Note that 6 or 10 mm thick patterned glass will normally have equivalent acoustic performance to standard float glass of the same thickness.

If it is not reasonable to undertake the required acoustic treatments without affecting an existing decorative window, then the property owner should be consulted and given a choice between retaining the window and receiving the treatment.

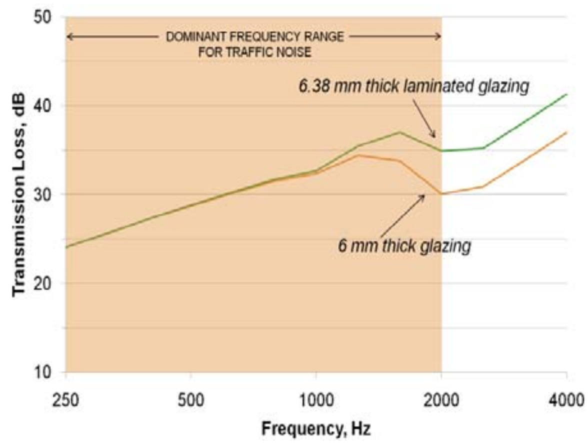
For heritage-listed properties, the outward appearance of the windows will often form part of the heritage order. In these cases, secondary glazing treatments should be considered as they may be able to meet the acoustic requirements without altering the exterior appearance.

Laminated glass

A commonly used type of glazing for thermal and acoustic reasons, laminated glass is glass with a polyvinyl butyral (PVB) interlayer sandwiched between two panes of glass. For example, 6.38 mm thick laminated glass consists of two panes of 3 mm thick glass sandwiched around the PVB interlayer.

Laminated glass provides better higher frequency noise reduction than regular glass but has little or no additional benefit when low frequency noise is the main problem. For this reason, laminated glass is not typically necessary for road traffic noise mitigation treatments unless higher frequency noise events may be a problem.

On a transport infrastructure project this could include such noise events as car horns, car doors opening and closing, and pedestrians passing by a residence.



Laminated glass provides improved noise reduction when compared to float glass, but only at frequencies above 1 kHz.

Air-conditioners

Window-mounted air conditioners need to be removed from any façade being treated for road traffic noise as they represent an acoustic weakness and will often prevent a window from closing properly.

Where a window-mounted air conditioner is being removed as part of a treatment package, an equivalent system may be provided for the room if required and considered reasonable. This can be achieved by either:

- providing split-system air conditioning to the room as well as an alternative ventilation system for the rest of the property as outlined in Section 4.3.6, or
- providing ducted reverse cycle air conditioning for the property.

Note that ducted reverse cycle systems should not generally be provided due to the high initial and on-going costs.

Solid and glazed doors in external building façades represent an acoustic weakness and may require treatment.

Image: Raven Pty Ltd

Example of an acoustic seal installed on the foot of a door.

Rubber door seals around the perimeter of a door frame.

4.3.3 Doors

Other key features of a property that will need to be treated as part of any treatment package are external doors in any building façade predicted to be above the noise criteria.

Depending on the treatment package required for a property, treatments to external doors may include one or more of the following:

- providing acoustic seals to the door
- replacing hollow core doors with solid core doors
- upgrading glazed doors to incorporate thicker glass or secondary glazing

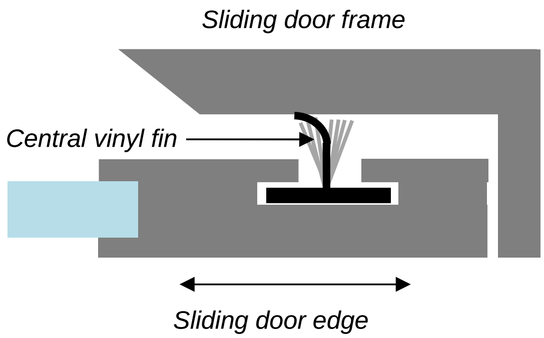
4.3.3.1 Door seals

As for windows, any cracks around the perimeter of a door will enable sound to enter the building and reduce its acoustic effectiveness. It is important to provide acoustic seals around the perimeter of any external doors in affected façades.

For hinged doors, tight rubber seals, or seals made from an equivalent solid material, should be installed around the head, jamb and foot of the door. Appropriate seals should be selected based on their performance and simplicity of use. Long-life seals that require little or no maintenance are preferable. Brush seals will have little or no acoustic benefit if used on hinged doors.

For sliding doors, rubber seals are not readily available and it is best to use vinyl fin seals which provide better noise mitigation than brush seals. It is often difficult to fit vinyl fin seals to existing sliding doors and in these cases acoustic door seals may not be able to be reasonably provided. However, for any new sliding doors being installed, the frame should be designed to incorporate a vinyl fin seal.

To obtain maximum acoustic performance from door seals, it is important to ensure that they are properly adjusted. The seals should make tight contact with the frame of the door when closed, although it is important that the seals are not so tight that the door cannot be closed properly.



Vinyl fin seals for sliding doors are identical to those for sliding windows. It is important for the vinyl fin to contact the frame when closed.

Vinyl fin seals should be fitted such that the vinyl fin makes contact with the frame when the door is closed, as discussed in Section 4.3.2.

When providing seals to an existing door, it is also important to seal gaps and cracks around the frame using a flexible caulking compound.

Any undercut external doors, or doors including an air grille or pet door, will need to be replaced as this will significantly reduce the noise reduction achieved across the door. Alternative options for pet doors that will not affect the noise mitigation treatments may need to be investigated with the property owner.

Mail slots contained in treated doors will need to be permanently sealed shut.

4.3.3.2 Installing a solid core door

Where existing external doors are of a hollow core construction, they will generally need to be replaced with a solid core door which contains a solid material between the two door skins to increase acoustic performance. If the door is well fitted with perimeter seals, there will normally be a marked increase in the noise reduction achieved.

When installing a solid core door for acoustic reasons, the door should be at least 38 mm thick to provide higher noise reduction at lower frequencies. Installing a door made of a denser material will improve the lower frequency noise reduction. Good quality acoustic seals should be installed around the head, jamb and foot of the doors.

A typical specification for a solid core door is:

- a 38 mm thick solid core door
- rubber compression seals to three sides of the frame
- drop-down seal (or acoustic equivalent) to the foot of the door.

To improve the noise reduction across a solid core door, a thicker door could be used. In the majority of situations, a solid core door of 45 mm thickness or less should suffice.

If a 45 mm solid core door is not sufficient to achieve the desired noise reduction, it may be necessary to install an acoustic proprietary door designed to achieve a specific transmission loss. Any proprietary door selection should be reviewed by an acoustic engineer. Acoustic proprietary doors are costly and would not be necessary for the majority of road traffic noise mitigation treatments.

Note that solid core doors should not be undercut. All gaps and cracks around the door frame should be sealed using a flexible caulking compound.

4.3.3.3 Upgrading glazed doors

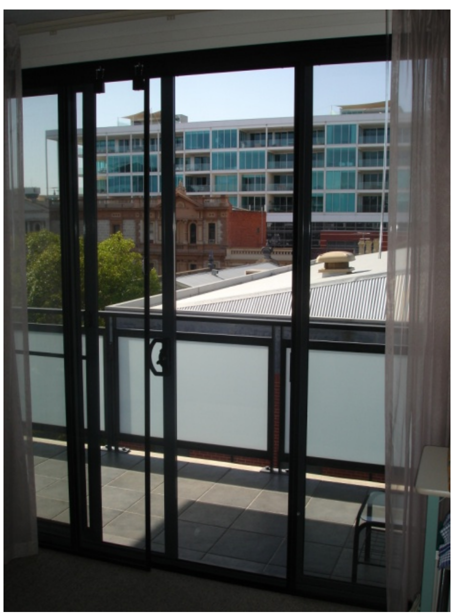
External glazed doors serving an outdoor area or balcony are relatively common and can represent a major noise transmission path into a property. To acoustically treat these doors it will be necessary to upgrade the glazing to at least 6 mm thick. The thicker glazing will result in increased noise reduction, and can be effective in reducing low frequency noise.

In some cases, the use of thicker glazing will mean that the framing of the glazed door needs to be replaced with a construction that can bear the additional weight. Many standard frames are able to hold 6 mm thick glass but if glazing thicker than 6 mm is necessary, custom-made frames will usually need to be installed.

When upgrading the glazing in a door, it is important that the door is also fitted with acoustic seals. This is relatively straightforward for hinged doors but some sliding doors may not be able to fit the required vinyl fin seals into their frame.

If a new sliding door frame is being constructed as part of the treatments for a property, it should be designed to accommodate a vinyl fin seal on both sides of the head, both sides of the leading edge door jamb and the trailing edge of the sliding door such that an airtight seal is achieved with the window closed.

Secondary acrylic glazing installed on magnetic frames on the inside of an existing sliding door.



While secondary glazing will mean that two doors need to be opened, it can be a cost effective treatment that does not impact on the appearance of the existing door.

In most cases, replacement of an existing door should be like-for-like, e.g. replacing a sliding door with an upgraded sliding door of the same style. However, if a choice is available in the door style, it is always acoustically preferable to install hinged doors fitted with acoustic seals around the head, jamb and foot of the door.

4.3.3.4 Double and secondary glazing

Glazed doors may also be upgraded to include double or secondary glazing, where these treatments represent cost effective, acoustically equivalent treatments.

To assess whether a double glazing or secondary glazing treatment is acoustically equivalent to a single glazed door, refer to the noise reduction table for different glazing systems in Section 4.3.2.

Double glazed doors

Doors incorporating double glazing are similar to double glazed windows as they comprise two panes of glass in a single frame, separated by an air gap. The noise reduction through the double glazing is improved by using thicker glazing and by increasing the width of the air gap.

As a rule of thumb, the air gap between the two panes of glass in a double glazed door should be at least 75 mm to provide effective reduction of road traffic noise. This often makes double glazed doors costly and difficult to install as the frame needs to be relatively large.

As they are installed in a single frame, the sealing achieved around a double glazed door becomes critical as poor sealing can significantly reduce any benefit obtained by using the double glazing. Hinged doors fitted with acoustic seals around the head, jamb and foot are best, although a well-constructed sliding door fitted with vinyl fin seals will also be acceptable. It is important that the seals are properly adjusted.

Secondary glazed doors

Secondary glazing, or retrofitted double glazing, involves installing a secondary glazed door at an air gap from the existing door, in a separate frame. Effectively this means that users have to open two doors, and some property owners may not prefer secondary glazed doors. However, they can also be cost effective treatments, as they leave the existing door as is, and are able to achieve a considerable noise reduction.

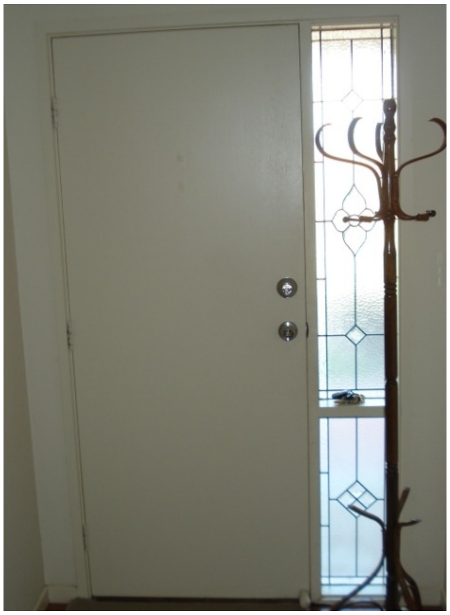
The performance of a secondary glazed door depends on the thickness of the new and existing glazing and the air gap between the two panes of glass. A secondary glazed door for road traffic noise mitigation should contain 6 mm thick glazing and be installed at a minimum air gap of 75 mm from the existing door.

Typically, secondary glazed doors would be comprised of two sliding doors. However, it may also be possible to have a hinged door on the outside, with a sliding door on the internal side.

Any retrofitted secondary door should be designed to incorporate acoustic seals as outlined in the previous sections. As long as the secondary door is installed with properly adjusted seals, then it will not be necessary to fit the existing door with acoustic seals as the noise reduction achieved is unlikely to be significantly affected.

In some cases, acrylic secondary glazing may also be able to be installed as a noise mitigation treatment for glazed doors. Proprietary secondary glazing systems for doors are available and they provide a system where acrylic secondary glazing panels are installed on the internal side of a glazed door. The panels can be slid open once removed from the magnetic frames. This can be a cost effective treatment that also provides an airtight seal around the door due to the magnetic frames.

As it has a lower density than standard glass, any acrylic glazing should be at least 8 to 10 mm thick. Acrylic glazing for doors is unlikely to be suitable for those properties most affected by road traffic noise, i.e. those that are receiving RTNG Treatment Package 4.



Sidelights adjacent to treated doors may also require treatment depending on the thickness of the glass and the necessary treatment package.

Doors with decorative glass panels in and around them can be difficult to provide acoustic treatments for. If the glazing cannot be replaced with thicker glazing, secondary glazing treatments could be considered.

4.3.3.5 Other considerations

Sidelights

Sidelights may require similar treatment to windows. Treatments may include upgrading the thickness of the sidelight glazing or the provision of secondary glazing. Normally, a maximum of 6 mm thick glass should be provided for sidelights due to the relatively small area.

If secondary glazing is being provided to a sidelight, proprietary acrylic secondary glazing may be the most effective treatment as it allows the air cavity to be ventilated and will not affect the external look of a decorative sidelight.

Decorative and heritage-listed doors

The appearance of some decoratively glazed or timber doors can be adversely affected by mitigation treatments. The appearance of any treated doors should be maintained as much as possible. Patterned glass should be replaced with glass of the required thickness and identical patterning if possible. Note that for small areas of decorative glazing, treatments may not be needed where the noise transmission through the decorative glazing is not significant.

If it is not reasonable to undertake the treatments without affecting a decorative door then the property owner should be consulted and given a choice between maintaining the door and undertaking the treatments.

Difficulties may arise if the doors are part of a heritage order on a property. If the heritage order means the doors cannot be replaced and a secondary door cannot be provided, then treatments to the door may not be possible.

Fire-rated doors

In some situations, there may be a requirement for a treated door to achieve a specific fire-rating. Reference should be made to the Building Code of Australia (BCA) to determine whether this is necessary for a specific property.

Fire-ratings will impose restrictions on the door material and the seals provided to the door. Generally, a fire-rated door will meet the requirements of the RTNG treatment packages.

External walls may need to be treated where there are lightweight constructions and openings such as wall-mounted air conditioners.

Damage to external walls that could reduce the noise reduction achieved across a facade should be repaired with mastic or with additional wall materials.

4.3.4 Walls

Most external property walls are constructed from heavy, solid materials and provide significantly higher noise reduction than other building façade elements such as windows and doors. Masonry, brickwork, blockwork and well-designed studwork walls will not normally need to be provided with mitigation treatments for road traffic noise.

However, for properties where damage to the walls has occurred or the walls are of a particularly lightweight construction, acoustic treatments to the walls may need to be considered. Treatments may also be required where air vents and wall-mounted air conditioners exist.

4.3.4.1 Repair of existing walls

In some cases, cracks and gaps in an existing property wall may exist that allow the passage of sound from the outside in. These can significantly reduce the effectiveness of any acoustic treatments to other building elements.

Small gaps and cracks in walls, including gaps around any penetrations in a wall, should be sealed airtight with suitable mastic. The depth of mastic should fill the entire gap, if possible. Note that superficial cracks in masonry, brickwork and blockwork walls that do not penetrate completely through the wall may not need to be treated. However, cracks or damage to plasterboard linings of lightweight walls should be repaired.

Any large gaps in walls that are not able to be adequately treated with mastic should be repaired with the same material as the wall. For example, damaged plasterboard sheeting should be replaced with new plasterboard sheeting.

Where gaps and holes in external walls mean that the room is not habitable prior to any treatments being carried out, the Department will not provide acoustic treatment to the rooms unless the property owner improves the condition of the walls so that the room is deemed habitable.

Habitable spaces with lightweight external walls may need wall treatments if they are significantly affected by a transport infrastructure project.

Transportable buildings should not be provided with property treatments beyond package 2, due to the cost and extent of the works. Roadside barriers or acoustic fences should be considered instead.

4.3.4.2 Lightweight walls

Lightweight external walls of habitable rooms may need to be treated for properties most affected by road traffic noise, i.e. those eligible for RTNG Treatment Package 4. Lightweight walls requiring treatment could consist of weatherboard walls, studwork walls with a single layer of plasterboard on either side or walls made of sheet metal around a habitable space.

Treatment of these lightweight walls would typically involve both:

- installing an additional layer of plasterboard or sheet metal on a new set of studs completely separated from the existing wall by at least 20 mm
- glass-fibre, polyester or rockwool insulation, with a minimum density of 14 kg/m^3, in the cavity between the new and existing wall layers.

A discontinuous wall construction such as this reduces air-borne and structure-borne noise and can considerably increase the noise reduction achieved across lightweight walls. The noise reduction through the wall can be further increased by having a larger cavity between the new and existing walls, or by installing additional layers of material on the new studwork.

Note that the above treatment is an example of a typical lightweight wall upgrade only and the actual treatments will depend on the noise reduction desired, the existing wall construction and consultation with the property owner. Any treatments to a lightweight wall as part of a road traffic noise mitigation package should be specified by an acoustic engineer, to ensure that the treatments will be effective.

If a space with lightweight walls is not deemed habitable by the Department in its current condition, no treatments should be carried out.

Additionally, under the RTNG, transportable buildings or properties with lightweight external walls around the entire building should not be provided with property treatments beyond RTNG Treatment Package 2. This is due to the extent and cost of works necessary to effectively treat these buildings. Barriers should be considered to mitigate traffic noise for these properties.

Air vents in a façade requiring property treatment will need to be removed, replaced or acoustically treated.

Wall-mounted air conditioners will need to be replaced with an equivalent system in a treated façade.

4.3.4.3 Other considerations

Air vents

Air vents installed in external walls can represent an acoustic weakness if untreated.

Depending on the alternative ventilation system being installed at a property, existing air vents in a façade exposed to road traffic noise above the criteria should be either:

- replaced with a vent that provides attenuation of traffic noise
- acoustically treated
- removed and the resulting gap in the wall repaired with appropriate material.

For information on ventilation systems and the requirements for treating air vents refer to Section 4.3.6.

If existing air vents are to be removed and filled in, it must be ensured that the room does not contain a connection for a flue-less gas space heater. If a connection exists, the space will require permanent ventilation openings and the air vents will either need to be retained (and acoustically treated) or alternative permanent ventilation openings provided.

Air conditioners

Wall-mounted air conditioners provide only a thin barrier between the inside and outside of a property and will need to be removed from any façade that is being treated for road traffic noise.

Where a wall-mounted air conditioner is being removed as part of a treatment package, an equivalent system may be provided for the room if required. This can be achieved by either:

- providing split-system air conditioning to the room as well as an alternative ventilation system for other habitable spaces as outlined in Section 4.3.6, or
- providing ducted reverse cycle air conditioning for the property.

Note that ducted reverse cycle systems would not generally be provided due to the high initial and on-going costs.

Plasterboard ceilings are common in residential homes and provide a reasonable noise reduction. However, an additional layer of plasterboard may need to be installed for significantly affected properties.

In some situations, acoustically open ceilings such as this one may need replacement or the addition of a solid plasterboard layer on the upper face.

4.3.5 Ceilings

While it is unlikely to be necessary for the majority of properties treated as part of a project, upgrades to the ceiling may be required for those properties most affected by road traffic noise and receiving RTNG Treatment Package 4.

Upgrades to a roof-ceiling construction may also be necessary where the existing construction is particularly lightweight.

Upgrades to a ceiling will normally have a considerable cost associated with them, particularly in older properties where ceiling wiring may need to be reinstalled in accordance with building regulations.

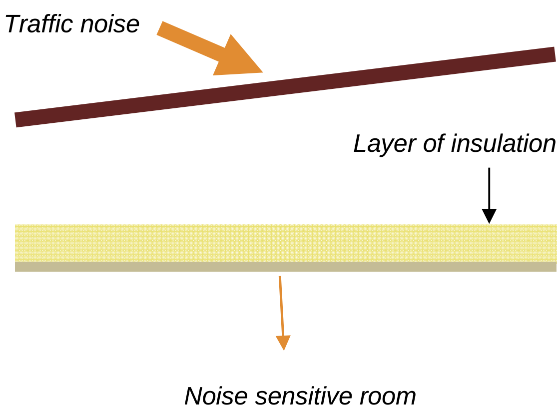
4.3.5.1 Adding additional ceiling layers

For properties receiving RTNG Treatment Package 4, and for areas where an existing ceiling construction may be too lightweight, the performance of the ceiling can be increased by adding an additional layer of 13 mm thick fire-rated plasterboard directly underneath the existing ceiling. The additional layer of plasterboard can normally be direct fixed to the existing ceiling will increase the mass and thickness of the system, improving the noise reduction through it.

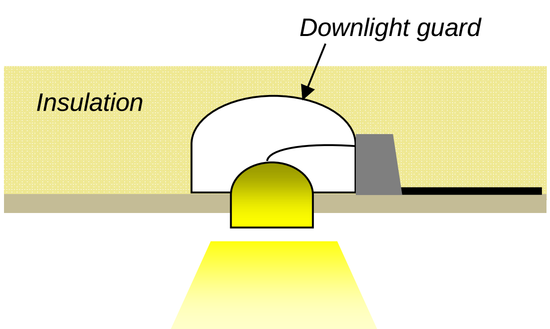
When adding an additional layer of plasterboard to the ceiling, it is important to consider whether the ceiling support system, typically joists or furring channels, will be able to bear the additional weight. If not, then the ceiling support system may also need to be upgraded by reinstalling joists and furring channels, increasing the treatment cost considerably.

Where a ceiling may be particularly lightweight, such as an acoustically open ceiling, 13 mm thick fire-rated plasterboard tiles may be able to be glued to the back of the existing ceiling tiles.

Additional ceiling layers can also interfere with lights, air conditioning grilles, ceiling fans and decorative features such as cornices that form part of the existing ceiling. These features will need to be removed and re-fixed to accommodate the new plasterboard layer.



Laying thick, heavy density insulation above a ceiling space can considerably improve the noise reduction provided by the overall roof-ceiling construction. This is mainly achieved through the absorption of reverberated noise within the ceiling space.



Downlights can pose a fire hazard when covered with insulation. Proprietary products can provide electrically safe covers for downlights that allow insulation to cover the back of the light and improve the noise reduction through the ceiling.

4.3.5.2 Ceiling insulation

The insulation above a ceiling also plays a role in reducing the level of noise transmitted through it. For properties receiving RTNG Treatment Package 4, insulation should be laid across the entire ceiling area if it is not already present.

The thicker the insulation, the greater the noise reduction achieved. Minimum 100 mm thick insulation should be installed to mitigate road traffic noise.

The other property affecting the performance of ceiling insulation is its density and fibrous insulation materials such as glass-fibre, polyester batts and rockwool should have a minimum density of 14 kg/m^3.

It should be noted that ceiling insulation can represent a fire hazard when installed around downlights. This hazard can be reduced by providing a suitable clearance for insulation around any downlights, in accordance with AS/NZS 3000, but this will reduce the noise transmission loss through the ceiling. A better solution is to install a proprietary product on the back of each downlight to provide an effective noise and fire resistant barrier that also allows insulation to be extended around downlights.

4.3.5.3 Chimneys

As most chimneys are directly open to the outdoors, they will need to be treated for those dwellings that require RTNG Treatment Packages 3 or 4.

If a chimney is functional, a metal damper can be installed on the top of the chimney to reduce noise ingress when it is not in use. The damper is opened when the chimney is to be used. If a chimney is not functional and the fireplace is simply decorative, it may be possible to seal off the chimney completely.

Any existing dampers for chimneys should be checked to ensure they are operating effectively, and resealed if necessary.

4.3.6 Ventilation

The provision of alternative ventilation to treated rooms forms an important part of architectural property treatments as it allows residents to close their windows and doors whilst still having access to fresh air. If alternative ventilation is not provided, residents may need to open their windows to allow fresh air in, reducing the effectiveness of any noise mitigation treatments.

Alternative ventilation will need to be provided to rooms where architectural treatment packages are being applied to all façades with an operable window. If a room has a façade with an operable window that does not need to be treated for road traffic noise, then alternative ventilation will not normally need to be provided as the resident may open the window to ventilate the room without affecting the noise mitigation treatments.

Three typical alternative ventilation methods are presented in this Manual:

1. Roof space ventilators combined with ceiling relief vents.
2. Ducted reverse cycle air conditioning.
3. Evaporative cooling.

While methods other than those presented may be considered, they will need to be assessed against the requirements of the Building Code of Australia (BCA).

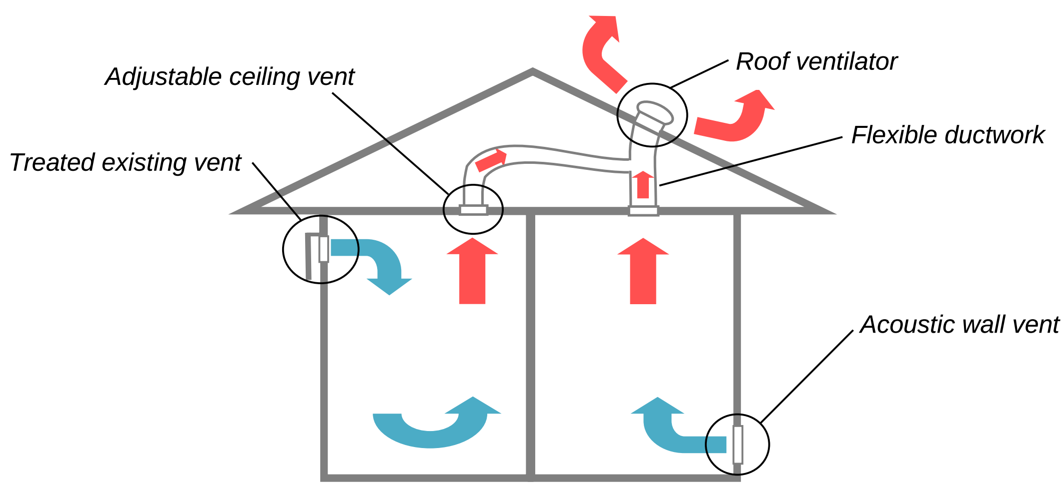
It is important to note that ventilation treatments may not need to be installed at all properties. Those that have existing fresh air ventilation systems serving rooms that require noise mitigation may not need ventilation treatments if they can already close their windows and be provided with fresh air.

For example, properties with existing ducted reverse cycle air conditioning systems serving rooms requiring noise mitigation treatments will not require a new fresh air ventilation system.

4.3.6.1 Building Code of Australia requirements

Any alternative ventilation provided to rooms will need to comply with the requirements of the BCA and Australian Standard (AS) 1668.2. AS 1668.2 is referenced by the BCA and requires that any ventilation system is designed to provide bedrooms and living rooms with a minimum air flow rate of 10 L/s for each person in the room, i.e. 30 L/s for a typical living room and 20 L/s for a two-person bedroom.

The BCA also requires that all habitable rooms in houses and apartments must be provided with ventilation openings for both air movement and ventilation. This can generally be met in



Roof space ventilators ducted to ceiling vents remove air from the rooms, drawing fresh air in through acoustically treated wall vents. This system can be reversed to force fresh air into the rooms.

residential properties by leaving exterior windows and doors as operable. Note that no exterior window or door should be sealed permanently shut as part of any house treatment package without alternative ventilation openings being provided for the room in accordance with the BCA.

For educational institutions being treated as part of a noise mitigation plan, greater consideration will need to be given to meeting BCA requirements for minimum air flow rates and ventilation openings due to the greater number of occupants in the building. If an educational institution is to be provided with architectural treatments, a suitably qualified building services engineer should be engaged to assess ventilation requirements.

Solution 1 – roof space ventilators with ceiling relief vents

A variety of roof space ventilation products exist on the domestic market. These range from conventional 'whirly bird' turbine roof ventilators, which provide natural ventilation, to motorized fan units that can be manually or thermostatically controlled to operate when required.

Image: CSR Edmonds

Roof space ventilators were widely used to provide ventilation to residences as part of the Northern Expressway project.

These products are commonly used in new and existing homes, to extract hot, humid air from the roof space. In such installations, under-eave vents are typically provided to allow flow of fresh air, commonly referred to as 'make-up air', from outside to the roof space, which is negatively pressurized by the roof ventilators.

In addition to providing roof space ventilation, these products can also be used to provide ventilation to habitable rooms directly below the roof space. To do this, ceiling mounted air vents are required to allow the transfer of air from the occupied areas through to the roof ventilators. Closable ceiling registers are available which allow the user to regulate the air flow through the occupied areas by closing the register when ventilation is not required or heat loss needs to be limited.

Flexible ducting and splitters should be installed between the ceiling relief vents and the roof ventilators to prevent air flow leakage in the roof.

This alternative solution can have slightly higher energy demands but allows for a filter box to be installed in-line with the fan to filter the air intake. It may also have lower costs in certain situations.

The advantages of both versions of this system include:

- low electricity consumption
- low on-going maintenance costs
- relatively low installation costs
- flexible – can be easily tailored to suit a variety of different house plans
- low noise levels.

Disadvantages include:

- no active heating or cooling
- normally impractical to filter the make-up air unless system is reversed to positively pressurize the rooms.

Image: Silenceair

'Silenceair' acoustic wall vent installed in a double-brick wall. Proprietary vents such as these provide passive ventilation along with some noise control.

Image: Acoustica

Powered ventilators are also available commercially and provide filtered, fresh air and a substantial noise reduction. However, they require a relatively low ongoing energy use.

Ventilation openings

As noted previously, the roof ventilation solution requires ventilation openings in rooms for make-up air from the outside. For rooms or areas that must have external doors and windows closed for acoustic reasons, this may be achieved by:

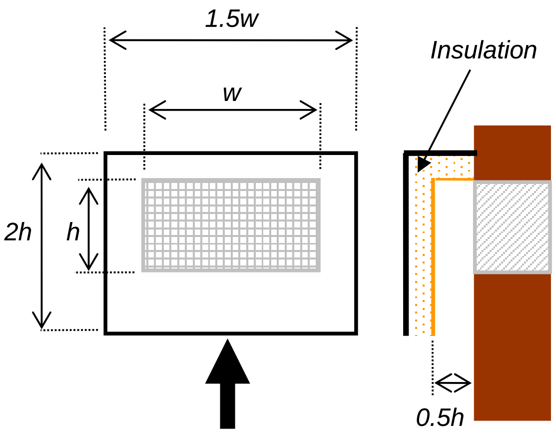
- providing proprietary acoustic wall vents
- providing powered ventilators
- acoustically treating existing air vents.

Acoustic wall vents, such as the 'Silenceair' products, are passive ventilators that allow air in or out whilst providing some noise control. In many situations, they can be installed in existing walls to provide fresh air. In typical residences, two vents would serve a two-person bedroom and three vents a living room.

However, acoustic wall vents are not able to be easily fitted into all wall constructions such as masonry walls, and can be costly to retrofit in some situations. Future product developments may overcome these problems.

Powered ventilators are mechanical ventilators installed on the interior of a wall and connected to the outside via a wall duct. They provide both air filtration and noise reduction, and offer relatively low energy use. Proprietary powered ventilators are available, such as the 'Aeropac' ventilators distributed in Australia by 'Acoustica', and can normally be installed for lower cost than equivalent acoustic wall vents.

'Aeropac' ventilators typically work in any standard wall construction and a single ventilator per room will suffice in most residential applications. For other powered ventilator models, the air flow provided by the ventilator should be checked against the air flow requirements for the room to determine the number of units required.



Minimum dimensions for a galvanised sheet steel hood covering an existing wall vent.

Acoustically treating wall vents, such as this one near the Gallipoli Underpass, is an effective yet unsightly treatment option.

Due to the slightly increased energy use associated with the powered ventilators, they can represent a less environmentally-friendly and more costly solution in some circumstances. The carbon filters in the current 'Aeropac' models normally need to be changed every 14 to 16 months, although at minimal cost. As they are not contained within the wall, powered ventilators may also be considered a somewhat more unsightly solution than acoustic wall vents by some property owners.

Another solution is to acoustically treat existing air vents by providing an external hood constructed of galvanised sheet steel and lined internally with minimum 25 mm thick, 14 kg/m^3 acoustic insulation. This can provide the necessary noise reduction through the vent and does not require work internally at the property.

While acoustically effective, the cost of this solution should be considered against the cost of installing passive or powered ventilators. The external hood for the vent is also not aesthetically pleasing.

Solution 2 – ducted reverse cycle air conditioning

Reverse cycle, split ducted air conditioning systems are readily available for domestic homes. Systems incorporating modern, inverter driven units are relatively quiet and energy efficient nowadays.

The systems supply conditioned outdoor air to rooms through supply ceiling registers, with a return air grille and path provided in each room.

The disadvantage of ducted reverse cycle air conditioning is that the installation cost and ongoing energy use are significantly higher than other solutions. In the majority of situations the cost associated with this solution is not reasonable and it should only normally be considered in extraordinary circumstances. For example, it may be considered where elderly residents require a high degree of comfort or where an existing reverse cycle system needs to be replaced.

Benefits of a reverse cycle air conditioning system include:

- good control of internal temperature with an appropriately designed system
- provides both heating and cooling
- flexible to different house designs.

Disadvantages include:

- highest energy consumption
- highest initial and ongoing costs.

Solution 3 – evaporative cooling

As an alternative to reverse cycle air conditioning systems, it is also possible to install evaporative cooling systems in certain situations.

Evaporative cooling systems work well in dry climates and require less ongoing energy than reverse cycle systems. The installation and maintenance costs are also typically lower due to the relative simplicity of the system.

One disadvantage of evaporative systems is that they require breeze paths through a room to work effectively. While this can normally be provided via an open window, this will not be possible where noise is a problem. To allow effective operation of the system it will be necessary to provide alternative air relief paths (e.g. through the ceiling), increasing the installation costs.

The conditioning provided by evaporative air conditioning systems is not normally as effective as that provided by reverse cycle systems and it is not possible to heat the air in winter. However, cool air can be provided and an evaporative system may represent an appropriate medium between a roof ventilator system and a reverse cycle system in some situations.

The advantages of an evaporative cooling system for ventilation are:

- reasonable control of internal temperature with an appropriately designed system
- flexible to different house designs
- considerably lower installation and ongoing costs than reverse cycle systems
- lower energy consumption than reverse cycle systems.

Disadvantages include:

- higher energy consumption than Solution 1
- higher cost than Solution 1 (in most cases)
- conditioning of space not as effective as reverse cycle systems and no heating of the space provided
- requires additional relief air paths.

4.3.6.2 Summary of ventilation treatments

Due to its low ongoing energy use, the roof space ventilator system is the preferred ventilation system for residences and has been put into place on many properties as part of the Northern Expressway project.

However, in some situations, ducted reverse cycle air conditioning systems or evaporative cooling systems are preferable. These include situations where:

- the construction of the residence, or a heritage order placed on it, make it impractical to install the roof space ventilator system
- an existing air conditioning system is being removed or made redundant
- residents may be subjected to extreme temperature conditions or are particularly sensitive to changes in the ambient temperature, such as elderly residents.

4.3.6.3 Responsibility

The Department will be responsible for the installation of the ventilation system.

The Department will verify completion of the works, after which responsibility for the maintenance and ongoing costs of the system will pass to the property owner.

4.4 Limitations

Property treatments can be effective noise mitigation measures in many situations but do have limitations associated with them. These will need to be addressed if property treatments are required as part of a project.

Architectural treatments to properties will only provide noise mitigation to internal areas of buildings, with outdoor areas still subject to higher noise levels. In order to reduce this problem, local fences providing protection to outdoor areas of properties should be installed as part of a house treatment package.

Installing property treatments at private properties will also involve a significant amount of consultation in order to arrange inspection of properties, discuss treatments with owners and to arrange for legal documents to be signed and treatments to be installed. This will increase the amount of time required to finalise noise mitigation treatments as part of a project. Comparatively, the consultation required in implementing road design measures and roadside noise barriers is typically much less.

Community perception of the effectiveness of property treatments relatively to other noise mitigation treatments may also be a limitation.

Glenelg Tram Extension

Rail Revitalisation Project

Seaford Rail Extension (concept)

5.0 Rail noise mitigation

5.1 Overview

Potential noise impacts from new and upgraded rail infrastructure projects the Department undertakes must also be considered and a practical noise management strategy developed.

This section provides an overview of rail noise mitigation to assist in reducing the noise impact associated with increased rail transport.

As for road noise, rail noise may be addressed through a combination of rail design measures, rail corridor barriers and property treatments. However, the complexities of rail noise relative to road noise mean that a specific understanding of rail noise mitigation is important.

This section includes:

- an overview of rail noise principles
- rail design measures
- noise barriers in the rail corridor
- property treatments.

5.2 Rail noise principles

Noise from rail vehicle pass-bys is generated by two main sources:

- engine noise generated by the diesel or electric locomotive or the multiple unit
- rollingstock noise generated by the interaction of the wheels and the rails.

The relative contribution of each component will depend on the rail system and rail vehicle.

For freight rail systems, the contributions due to the diesel locomotive and the rollingstock will normally be significant and will both require consideration. However, for electric passenger rail systems, the engine noise generated by the multiple units are normally considerably less than that generated by the rollingstock.

Another significant noise source from rail systems is the noise from safety warning horns. Although these are considered safety measures and are not subject to assessment under most noise guidelines, warning horns can be a source of complaints adjacent to a rail line. This aspect of rail noise should be addressed during the design stage of most rail infrastructure projects.

5.2.1.1 Rail noise transmission methods

Unlike road traffic noise, where air-borne noise is the primary concern, rail noise can impact on sensitive receivers through two different transmission methods:

- (air-borne) noise transmitted to receivers through the air
- ground-borne noise transmitted to a residence or other sensitive building as ground-borne vibration and reradiated as noise inside the building.

Of these methods, noise transmitted through the air is normally the most significant. In most cases, ground-borne noise will only be a concern where rail passes through or underneath a sensitive development.

5.2.1.2 Rail noise metrics

The noise adjacent to rail lines is different to the noise adjacent to major roads, in that it is made up of relatively infrequent loud events in contrast to the more constant noise generated by large traffic flows.

In order to address this, the noise generated by rail movements is quantified using two different noise metrics:

- L_{eq} – the equivalent noise level over an appropriate time period, contributed to by all pass-bys during that period
- L_{max} – the maximum noise level during a time period, generated by a single pass-by event.

In comparison, the majority of road traffic noise assessments only address L_{eq} noise levels.

It is important to recognise that both of these metrics need to be assessed for rail infrastructure projects as they can both contribute to annoyance. It may be necessary to implement different mitigation measures to address each of these noise metrics.

5.2.1.3 Rail noise policy

In South Australia, rail noise policy is governed by the EPA. The EPA released the *Draft Guidelines for the Assessment of Noise from Rail Operations* for public consultation in June 2010. These guidelines provide a formal method for the assessment of rail noise, as well as the assessment of ground-borne noise and vibration.

Freight rail corridors should be located away from residential areas where possible, with non-sensitive commercial and industrial areas preferable.

Locating the rail corridor in the middle of an existing road corridor can lessen the overall noise impact.

5.3 Rail infrastructure design

As for road noise, rail design measures are normally the most effective way of mitigating rail noise impacts.

Rail design measures that may be implemented to reduce rail noise are:

- appropriate route selection
- quieter rail vehicle selection
- adjustments to vertical and horizontal alignments
- reducing the track speed
- track design measures
- relocation of associated rail facilities
- maintenance programs.

5.3.1 Route selection

During the route selection phase of any new and upgraded rail projects, an initial noise impact assessment should be undertaken to determine the relative noise impacts of different alignment options.

The route selection phase noise impact assessment would broadly assess the impact of the nominated alignment options and would include an indication of the likely noise mitigation treatments necessary for each option. The noise impact of the different options should be included as a criterion in the eventual selection of the preferred alignment.

During the route selection phase, the major rail design factor affecting noise at sensitive receivers is the horizontal alignment. To minimise the noise impact of rail infrastructure, it is generally preferable to select the route option that is the furthest distance away from large groups of sensitive receivers.

However, depending on the relative noise mitigation cost it may be preferable to select an option that requires a relatively small amount of treatment to a large number of receivers, rather than providing significant noise treatments to a few receivers.

In most cases it will also be beneficial to locate a rail alignment in the middle of an existing arterial road corridor where possible, in order to mask the rail noise with more constant traffic noise.

Tramlines generate significantly less noise than other rail transit systems.

There is no significant difference in noise levels between electric and diesel passenger rail vehicles.

Freight trains are the loudest rail vehicles and freight routes should avoid noise sensitive areas.

5.3.2 Rail vehicle selection

For the majority of rail infrastructure projects it is unlikely that there will be an option to select alternative rail vehicle types. However, in the early planning stages of new passenger rail line developments, a choice between different types of rail vehicles may be possible.

Diesel-driven passenger rail vehicles, or diesel multiple units, are typically the loudest passenger vehicles as they generate noise from both the diesel engine and from the wheel-rail interface.

Electric multiple units produce less engine noise than diesel-driven vehicles but the difference in overall noise levels between the two systems is not as significant as commonly thought. Most of the noise from passenger rail systems is generated by interactions between the wheels and the rails which is a feature of both diesel and electric multiple units. In reality, electric passenger rail systems normally only generate marginally lower L_{eq} noise levels than equivalent diesel-driven vehicles and generate similar L_{max} noise levels.

Trams are the quietest passenger rail system. The L_{eq} noise level generated by a tram pass-by in Adelaide has been measured to be 10 to 15 dB(A) quieter than that produced by the existing diesel trains. Light rail systems can be used to significantly reduce the noise impact of rail developments as long as they are able to provide the necessary service and capacity.

Freight trains are the loudest rail systems, due to the noise from the diesel locomotives and the overall length of the rollingstock which can exceed one kilometre. Depending on the frequency of pass-bys on a freight rail line, the overall L_{eq} level may not differ greatly from a high frequency passenger line but the L_{max} is likely to be considerably higher.

Rail overpasses will result in increased noise levels relative to underpasses.

Rail tunnels can be an effective, if costly, means of reducing air-borne noise issues but may introduce ground-borne noise issues if located under sensitive areas.

5.3.3 Vertical and horizontal alignment

As with roads, minor changes to vertical and horizontal rail alignments may be able to be made during the concept and detailed design phases of a project in order to reduce noise impacts on small groups of receivers. This will normally be more easily achieved in rural areas where more space is available but small changes may be able to be achieved in urban environments to reduce or eliminate the need for other noise mitigation measures.

It is important to note that rail alignments are normally less flexible than road alignments due to restrictions on the gradients and curve radii that rail vehicles are subjected to. However, potential alignment alterations should still be considered where noise may be a problem.

Doubling the horizontal distance between the nearest section of a rail line and a sensitive receiver can achieve reductions in L_{eq} rail noise levels of up to 3 dB(A) and reductions in L_{max} rail noise levels of up to 6 dB(A). However, care should be taken to ensure that adjustments to horizontal alignments do not introduce sharper curves into the line that may produce wheel squeal during pass-bys. Refer to Section 5.3.4 for more information on wheel squeal.

Changes to the vertical alignment can also affect noise levels at sensitive receivers. For example, increasing the height of the rail relative to the receiver will increase noise levels as less ground absorption occurs along the transmission path.

Conversely, a decrease in the height of a rail line relative to a receiver can be beneficial for rail noise due to increased shielding of the noise source, especially where the rail line may be in a cutting which will provide natural noise barriers on either side. The increased noise mitigation will need to be considered against the additional cost and effort required to reduce the rail height but may represent a cost effective measure in certain situations.

Placing the rail alignment in an underground tunnel will remove most air-borne noise issues but may generate ground-borne noise issues for any receivers above the alignment. This is discussed in more detail in Section 5.3.5.

5.3.4 Reducing the track speed

As the speed of a rail line increases, the pass-by noise level will also normally increase due to greater engine noise and greater noise associated with the wheel-rail interface. For example, increasing the speed of a train from 100 km/h to 120 km/h would be expected to result in an increase in L_{eq} noise levels of approximately 2.5 dB(A), and L_{max} noise levels of approximately 4 dB(A).

Therefore, it is possible to reduce rail noise by reducing the design speed of a track. However, the acoustic benefit of this would need to be considered against the reduction in service due to the lower train speeds. In the majority of cases, the relatively small decrease in noise levels will not be worth the restriction in vehicle speed.

5.3.5 Track design measures

Track design measures are a critical part of the noise management process of any rail infrastructure process. Track design measures to reduce noise include:

- track construction measures
- reducing track curvature
- removing level crossings
- relocating turnouts and diamond crossings
- track isolation measures.

5.3.5.1 Track construction

In order to reduce noise from rail operations, it is preferable to construct the rail line out of continuous welded rail rather than jointed rail.

Rail vehicles generate additional noise when travelling over joints in a rail line, typically about 3 dB(A). Although this increase may not appear significant, the character of the noise created on jointed rail is often found to be considerably more annoying than that created on continuous welded rail. Jointed rail also normally results in a reduced ride quality.

5.3.5.2 Reducing track curvature

Two of the most common annoying noises that can occur near rail lines are flanging noise and wheel squeal.

Flanging noise is the sharp, sometimes tonal, noise created when the wheel flange contacts the rail as it moves around a curve. Wheel squeal is the high-pitched, tonal noise generated by the interaction between the wheel and the rail on curves where the wheel cannot pass freely through. Wheel squeal, particularly, is a significant source of complaints near the freight rail lines in the Adelaide Hills region.

Wheel squeal and flanging noise are not completely understood but the track curvature is a significant influence that contributes to the likelihood of these annoying characteristics being present in pass-by noise.

For freight rail lines, wheel squeal and flanging noise become more likely when the radius of curvature of a section of track is less than 600 metres, with increasing severity of squeal likely as the radius is decreased beyond 300 metres.

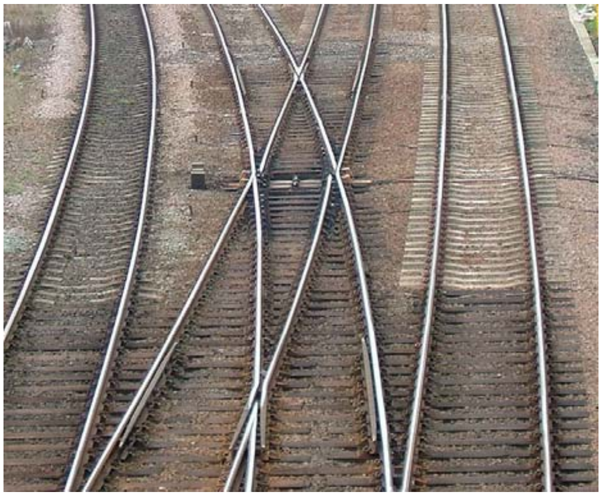
For passenger and light rail lines, wheel squeal may become a possibility where the radius of curvature is less than 150 to 250 metres.

5.3.5.3 Removing level crossings

Level crossings for railway lines over roads are typically undesirable as they slow traffic, can reduce track safety and can generate additional noise. This additional noise may arise from:

- warning horn use during a pass-by
- level crossing bells on boom gates
- a track embedded in the road surface.

The most effective way to reduce noise from level crossings is to remove the crossing altogether by closing the roads or separating the road/rail grade. However, these measures can be costly and are unlikely to be practical for smaller scale projects.



Turnouts and diamond crossings generate additional noise due to the impact of the wheels across the junction.

Where a rail track is directly fixed to a concrete base, vibration that generates radiated noise may be a problem. Isolated rail clips, such as these on the Glenelg Tram Overpass, help to reduce the vibration transmitted to the concrete slab.

5.3.5.4 Relocating turnouts and diamond crossings

Turnouts that enable rail cars to switch from one track to another at a junction can generate additional noise during a pass-by due to the impact of the wheels across the junction. Diamond crossings that allow two tracks to pass each other also generate additional impact noise.

There is an approximate increase in L_{eq} noise levels of 6 dB(A) across the turnout section of the track, roughly equivalent to a 3 dB(A) increase in the L_{eq} noise level at 15 metres from the track. For diamond crossings, the increase in L_{eq} noise across the crossing section of track is approximately 10 dB(A).

To avoid and reduce noise impacts from turnouts and diamond crossings, they should be located away from sensitive receivers wherever possible. Swingnose crossings, which provide more movement in the junction, can also be used at turnouts to reduce noise levels but require additional signalling and are relatively costly.

5.3.5.5 Track isolation measures

Track isolation measures may be used to reduce the level of vibration generated by a rail pass-by. In certain situations where the vibration generates noise, this will also help reduce rail noise impacts. This could include radiated noise from elevated rail structures or ground-borne noise from tunnels beneath sensitive receivers.

One of the simplest forms of track isolation is to place the rail on ballast which will absorb some of the generated vibration. Where ballast depth cannot be made sufficient, such as on a ballast trough bridge, an absorptive ballast mat can be used to increase the noise reduction provided.

For rail that is directly fixed to concrete, the use of isolated rail clips to reduce the vibration radiated from the rail to the ground can be an effective mitigation measure. Isolated rail clips were used to reduce structure-borne noise issues on the Glenelg Tram Overpass.

An alternative, although costly, solution in critical situations is to install a floating track slab. Commonly used in tunnels near or under vibration sensitive areas, the track slab rests on isolated support pads to reduce vibration transmission.

New railway stations may introduce additional noise impacts for nearby sensitive receivers.

Rail car stabling and maintenance depots can generate significant noise levels, and should be located in non-sensitive areas wherever possible.

5.3.6 Rail facilities

It is important to recognise that rail infrastructure projects will often incorporate the construction of associated facilities that can also generate significant noise. These may include any or all of:

- rail stations
- rail car stabling yards and maintenance depots
- bus interchanges
- park and ride facilities.

Noise levels generated by these facilities will need to comply with the requirements of the *Environment Protection (Noise) Policy 2007*.

5.3.6.1 Rail stations

Rail stations on passenger rail lines generate additional noise to a continuous line as rail vehicles brake on arrival, accelerate on departure and may also use warning horns as a safety measure when leaving.

Stations also introduce potential noise issues from public address systems and waiting passengers that can cause annoyance for nearby residents.

A typical station design should aim to:

- locate stations as far as practical from sensitive receivers (whilst maintaining accessibility)
- locate passenger waiting areas away from sensitive receivers
- direct public address systems away from sensitive receivers and operate them at the minimum practicable level.

5.3.6.2 Stabling yards and depots

Stabling yards and maintenance depots for rail vehicles can be a significant source of environmental noise emissions.

Noise from stabling yards can include idling vehicles, rail car shunting and warning horns. Maintenance operations, commissioning of rail vehicles and train wash facilities will also need to be considered.

Locating a stabling yard and depot as far away from sensitive receivers as possible is important. Additional mitigation measures that could be adopted include:

- enclosing noisy equipment in sheds
- operational restrictions such as requiring rail cars to be powered down when stabled and warning horns not to be used on site
- noise barriers shielding sensitive receivers.

5.3.6.3 Bus interchanges

Passenger rail developments will sometimes incorporate a bus interchange facility to link two different public transport systems. Bus interchanges may generate noise from bus movements around the facility, and may also introduce significant bus movements on to local roads serving the facility.

In order to minimise the impact of bus interchange facilities it is important to locate the movements within the facility as far as practicable from sensitive receivers. Bus access routes should also be located away from residential roads where possible.

5.3.6.4 Park and ride facilities

Park and ride facilities are another common feature of passenger rail infrastructure projects that can generate additional noise impacts. Noise generated by a park and ride facility will include:

- noise from low-speed vehicle movements
- acceleration and brake noise
- noise from the opening and closing of vehicle doors
- people noise.

The most effective method of reducing noise from park and ride facilities is to locate the car park and any entry/exit points as far as practicable from sensitive receivers. The design of the car park should also aim to discourage acceleration and braking next to residences.

5.3.7 Maintenance programs

An important feature of any NMP for rail infrastructure projects is ongoing maintenance of both the track and the rollingstock. Poorly maintained track and rollingstock can significantly increase both L_{eq} and L_{max} noise levels from vehicle pass-bys, introducing potential noise issues even where none may have existed previously.

Although maintenance may not be the responsibility of the Department once the rail infrastructure is constructed, it is important that it is recognised as a key noise mitigation measure for any project.

Where a section of track is identified as being a potential source of noise-related issues, ongoing maintenance should be programmed to:

- undertake regular wheel truing of rollingstock
- regularly grind the rail track to remove defects and obtain desirable rail head profiles if necessary
- provide friction modification of the rail and/or rollingstock if necessary.

These measures can substantially reduce rail noise, with studies reporting a 5 to 10 dB(A) difference in L_{eq} noise levels between those lines with a well implemented wheel truing and rail grinding program and those lines without.

Friction modification of the rail and/or rollingstock can also be an effective means of reducing particular noise issues such as wheel squeal. Application of a friction modifier to the rail in certain areas may be able to establish a coefficient of friction that reduces the contact between the wheel and rail causing the squeal but that still allows normal braking and traction.

Friction modifiers can be applied by hand but friction modification systems can also be set up on the track to continuously treat problem areas of the line.

A one metre high concrete barrier on the Glenelg Tram Overpass provided the necessary noise reduction due to the low height of the wheel-rail interface and the raised height of the noise source relative to the receivers.

Noise barriers for freight rail lines need to be designed to mitigate both wheel-rail noise and noise from the higher diesel locomotive.

5.4 Barriers in the rail corridor

As with roadside barriers, noise barriers installed in the rail corridor can be an effective noise mitigation measure if designed and installed appropriately.

Many of the design and construction principles and considerations regarding barriers in the rail corridor are identical to those covered in Section 3.0. This section addresses those issues particular to rail barriers.

Reference should be made to the roadside barrier section for additional information on:

- preferred barrier placement
- appropriate barrier design and materials
- urban design principles
- public considerations.

5.4.1 Barrier height and location

As for road traffic barriers, rail corridor barriers will provide a higher degree of noise mitigation when located as close as possible to the rail line. They will also perform better when the receivers are close to the rail corridor and the barrier, as would commonly occur in suburban areas.

The required barrier height will depend on a number of factors. As with roadside barriers, a barrier in the rail corridor should at least break line-of-sight to the noise source but this will depend on the type of rail line.

For electric rail, the majority of noise is generated at the wheel-rail interface and a relatively short barrier could provide a noticeable noise reduction, particularly if installed on the side of a rail bridge. For the Glenelg Tram Overpass, a one metre high concrete barrier was installed on the side of the overpass in a similar fashion to a New Jersey style barrier.

However, for diesel freight rail systems, the engine also produces significant noise and a significantly higher barrier may be required. Diesel locomotives emit noise at a height of three to four metres above ground, and an effective barrier will typically need to be at least three metres high.

5.4.2 Safety

Maintaining rail safety is an important consideration in the design and implementation of noise barriers in the rail corridor.

Barriers should be located to maintain sight lines, particularly for the visibility of signals, at level crossings and at stations where barriers should generally be avoided. It is also important that barriers not affect any necessary track lighting. Signal lighting distances may be up to several hundred metres.

5.5 Property treatments

Property treatments for rail noise mitigation should be addressed in a similar manner to those for road noise, outlined in Section 4.0.

Generally, noise mitigation treatments for road noise installed at a residence will provide an equivalent reduction for rail noise. However, there may be some differences in certain situations where the height of the rail noise source is significant or where the frequency of the rail noise is particularly different to that of road traffic noise.

Where noise from a diesel locomotive is a significant component of the overall rail noise level, an acoustic fence at the property is unlikely to provide a noticeable noise reduction due to the increased height of the noise source.

Noise from a diesel locomotive is also likely to have a significant low frequency component and it is important that any architectural treatments be designed to address this. Low frequency noise can be a particular problem where diesel locomotives are idling.

In order to address low frequency noise, it may be necessary to provide thicker single glazing in a new window rather than double or secondary glazing at a standard air gap. Alternatively, the air gap in the double or secondary glazing may need to be increased beyond 100 mm to provide the necessary noise reduction.

Alterations to standard property treatment packages may also need to be made where noise from a rail line is particularly tonal, such as in areas where wheel squeal is a problem. It is important that any treatments in these areas are designed to provide improved noise reductions at the particular frequency of the noise.

Government of South Australia
Department of Planning, Transport and Infrastructure

6.0 Consultation with property owners and the community

6.1 Overview

Engaging effectively with affected property owners and the wider community is a critical part of any noise mitigation treatment program. The community should be pre-emptively engaged to discuss:

- the noise management process, including the assessment of the noise impact of a project and measures being taken to mitigate the impact
- noise mitigation requirements for their properties and the reasons for any treatments being offered to them
- their input regarding noise mitigation treatments for their property.

Effective community consultation will significantly benefit the noise management process by:

- identifying potential problems as early as possible
- obtaining input from the community on preferred noise mitigation treatments
- raising community awareness of project options considered, noise impacts and treatments.

6.2 Consultation process

Community consultation relating to noise management issues will need to be undertaken with a wide range of people including those receiving mitigation treatments at their property and those who may be wondering why they are not receiving mitigation treatments.

The most intensive consultation will normally need to be undertaken with the owners of properties receiving mitigation treatments as they will be required to decide on treatments and sign legal agreements allowing works to be carried out. The property treatment negotiation process is discussed in Section 0.

Apart from negotiations with owners receiving property treatments, community consultation regarding noise may include any, or all, of the following:

- noise fact sheets
- community open days
- discussions with individual members of the community

6.2.1 Noise fact sheets

Noise fact sheets for road and rail projects are useful tools that should be provided to the community as early as possible in a project.

A noise fact sheet should broadly outline:

- basic principles of road traffic noise and its impact on humans
- the noise assessment process
- noise mitigation measures that have been considered
- the reasons for adopting or discounting particular mitigation measures (if applicable)
- contact details for residents to request further information.

It is important that the fact sheet also emphasises positive impacts of the project, such as the realignment of a busy road further away from noise sensitive locations.

Fact sheets should be made available on the project website, at community open days and at any face-to-face meetings with members of the community.

An example of a typical project fact sheet is included in Appendix B.

6.2.2 Community open days

Community open days can be effective ways to engage the community, especially those with whom direct contact may not have been possible previously.

It is important that trained personnel and adequate information are both readily available. Where a project may have a significant noise impact, it may be beneficial to establish a noise-specific information booth staffed by an acoustic engineer who has had involvement with the project.

Open days which provide information on noise-related issues should be held as early as possible in the project in order to:

- engage the community's concerns upfront
- determine what issues community members are most concerned about
- obtain input from the community on managing noise impacts with sufficient time to implement any changes to the noise management process.

6.2.3 Discussions with individual members of the community

It is likely that members of the community will be in contact to ask why they are not receiving mitigation treatments or why they are not receiving a greater level of treatment.

For people who are worried that their property is not receiving specific mitigation treatments, it should be emphasised that this is because the noise impact of the project is expected to comply with the relevant criteria. Any noise barriers or design measures that are contributing to noise mitigation at the residence should also be highlighted.

Another common complaint for projects where the level of noise mitigation treatment varies along the route is that one property may appear to be receiving a greater level of treatment to others nearby. In these cases the basic principles of the noise mitigation process should be reiterated, that noise mitigation is provided to reduce the noise impact to the extent required in accordance with the RTNG. If one property is scheduled to receive more treatment than another it will be because it is more significantly impacted by the project.

Note that the RTNG also specify that neighbouring receivers at a similar distance from the road or rail line should be treated as a group. Each of the receivers should then be provided with the same noise mitigation measures, reducing complaints about inequitable treatments.

During discussions with members of the community who are querying the proposed noise mitigation treatments, it can often be helpful to present to them the predicted noise levels before and after a project opens. These can be presented as either simple numbers on a page or as a noise contour map overlaid on an aerial photograph of the property.

Where property owners have valid concerns about the functionality or visual impact of mitigation treatments proposed for their property these concerns should be addressed as quickly as possible and alternative noise mitigation measures considered in consultation with the acoustic engineer.

6.2.4 Property treatment negotiation

Noise mitigation treatments installed at properties will necessitate consultation with property owners as the treatments are discussed and the required legal agreements signed.

Property treatment negotiation will typically involve:

- initial contact with property owners to arrange an inspection of the property
- an inspection of the property by an acoustic engineer and an initial discussion with the owner regarding the treatments
- finalisation of treatment measures in consultation with the property owner
- installation of the treatments
- ongoing consultation with the property owner.

A flow chart of the property treatment process used on the Torrens Road to River Torrens Project is provided in Appendix C, and may be used or adapted by other project teams. Examples and templates for letters and legal documents relating to implementation of façade treatment packages are provided in knet #10513911.

6.2.5 Start-up meeting

Prior to contacting property owners, an initial start-up meeting should be held with relevant members of the project team. This would generally include the Project Manager, community engagement officer, the environmental officer or person coordinating property treatments, acoustic engineer(s), and an architect.

The aims of the meeting should be to provide overviews of:

- the noise assessment process
- the Noise Mitigation Plan outlining which properties exceed the noise criteria and require noise mitigation and what type of noise mitigation will be provided.
- basic principles of noise control and the aims of the property treatments
- the consultation process.

It may also be useful to discuss appropriate responses to common queries. Common questions from property owners can include:

- Can I receive money instead of the property treatments?
- Can I change the treatments offered to me?
- Can I select my own building contractors?

- Why am I not being provided with a greater level of treatment?
- Why are property treatments being provided instead of noise walls?

It is important that property owners receive consistent messages and responses to queries throughout the negotiation process. A start-up meeting will help in ensuring that project team members understand the aims of the property treatment process and are able to respond to common questions raised by property owners.

6.2.6 Initial contact with property owners

After properties that require noise mitigation treatments are identified during the acoustic assessment, contact should be made with the owner of each property. The owner will need to be advised that the property has been identified as possibly requiring noise treatments to mitigate the expected impact of the project.

The owner should be asked to contact the Department to arrange a time for a property inspection and discussion with a consultation team member and an acoustic engineer. At properties where architectural treatments are likely, it should be made clear that the acoustic engineer may need to enter any room of the property to identify the exact required architectural treatments.

It is important that any initial contact does not reference specific treatments such as double glazing treatments or window upgrades as the treatments for the property at this stage have not been defined.

A letter containing contact details for the relevant Departmental staff member is normally the most appropriate form of initial contact. If no response is received from an initial letter, then a follow-up letter and/or phone call may be required. In some cases, a door-knock approach may be considered appropriate.

If no response is received and all reasonable efforts have been made to contact a property owner, then a waiver agreement should be sent to the owner as outlined in Section 6.3.

6.2.7 Initial property inspection

A large amount of information needs to be collected during the property inspection. It is important that the inspection process is well planned and efficient, with all team members having a clear understanding of their role, what information they need to collect, and how to record this information. Ensuring that all the right people are involved in the initial inspection will avoid having to carry out multiple inspections. Having pre-prepared templates or an app to facilitate information collection will also ensure the property owner is not inconvenienced any longer than necessary.

The initial property inspection should involve an acoustic engineer, an architect[3], environment officer or person coordinating the property treatments and a community consultation team member. Depending on the property owner, other attendees may also be necessary. For example, an interpreter may be required for property owners who may not have a sufficient understanding of English.

The role of the acoustic engineer and architect will be to inspect rooms on the properties that may require treatment and identify existing constructions. While the inspection is being carried out, the community consultation team member and/or person coordinating property treatments should describe the noise assessment process to the property owner.

The property owner should be made aware of the possible outcomes of the property inspection, ie:

- it may be determined that they are either eligible for treatments, in which case a recommended package of treatments will be produced for their property to meet the noise reduction requirements.
- it may be determined that no property treatments are required, ie noise levels at their property are expected to meet the criteria in the Road Traffic Noise Guidelines without the need for architectural treatments.

The owner should be advised that they will be contacted in the near future to confirm the outcome of the inspection and discuss the proposed treatments if applicable (see Section 6.2.9 for more detail).

6.2.8 Scope of works

Based on the inspection and discussion, the acoustic engineer should produce a draft scope of works,

[3] *It may not be necessary for an architect to attend property inspections if the acoustic engineer knows what to measure and photograph and has the ability to create basic floor plans (eg using an app). Properties requiring more complex solutions, eg heritage properties, will likely require an architect's input.*

detailing what treatments are required at the property, and the required standard.

This should be refined by the architect, who will ensure it is suitable for requesting tenders from building contractors. It is important that the architectural scope of works be reviewed again by the acoustic engineer prior to going to tender, to ensure the proposed treatments will deliver the required noise reduction.

The draft scope of works should be submitted, along with a cost estimate, to the Project Manager for review prior to seeking the agreement of the property owners.

Streamlining inspections and property treatments on Torrens to Torrens project

The Torrens to Torrens Project team streamlined the property inspection and treatment selection process by using *Podio's* cloud-based project-management platform to organise inspections, create floor plans, record and store data/ photographs and automatically generate property inspection reports and treatment scopes.

They further streamlined the process by working with an architect to generate standard building specifications for all of the treatments. The treatment scopes and specifications provided enough detail for building contractors to quote on, without the need for a second property inspection (builders had access to the property inspection reports and photos if further detail was required).

6.2.9 Agreeing on scope of works

Before eligible property owners are sent the scope of works for their review and signature, a meeting should be arranged with a Departmental representative to discuss the various treatments. This may be done one-on-one or, where there are large numbers of properties involved, group meetings may be more efficient.

Information sessions are best held *after* the property inspection, once it has been established which properties are eligible for noise treatments. Holding an information session before eligibility is established increases stakeholder expectations and is not productive for property owners whose property is ultimately deemed ineligible for treatment.

During the discussion, property owners should be made aware of exactly what treatments are being offered and the anticipated benefits of them. Any functional implications of the treatments should also be highlighted. For example, an explanation of the use of any new ventilation system will need to be provided.

In many cases, the property owner may be able to be given choices on their preferred noise treatments during the discussion. These choices could involve reasonably significant decisions such as whether they would rather have an acoustic fence or architectural treatments, or smaller decisions such as whether to replace an existing window with one with thicker glazing or to install a secondary window and leave the existing window in place.

However, care should always be taken to be clear when a choice of treatments is not available to a property owner. For example, the cost of an acoustic fence may be significantly higher than the cost of architectural treatments (or vice versa) and therefore is not an option for a property.

The property owner may express a wish to contribute to alternative treatments that would cost more than the package being offered by the Department. This is acceptable as long as the treatments will not noticeably reduce the noise mitigation achieved by the original treatments outlined in the acoustic scope of works. This could involve the owner contributing to the installation of reverse-cycle air conditioning for instance, rather than the ventilation treatments being offered as part of the treatment packages. If this is the case, then the property owner should be informed that the additional cost as a result of the change will need to be borne by them.

In certain situations, it may be beneficial to include either an acoustic engineer or architect in these discussions. Their role would be to provide specialist advice on any questions raised by the property owner and to discuss the practicalities of treatments such as functionality and appearance.

Once the final treatments are agreed with the property owners, they will be required to sign a Deed of Consent and Agreement as outlined in Section 6.33

6.2.10 Installation of treatments

Once the Deed of Consent and Agreement has been signed and returned, the treatment works should be put to tender to building contractors based on the scope of works and specifications.

During the installation of the treatments, property owners should be advised of the visit of contractors with ample notice and should be provided with a contact number if they have concerns with the contractors' works at any time. Owners should also be assured that the contractors are required to leave the site in equal or better condition than when work commenced.

Based on the advice of a building contractor during the tender or installation phase, it may be necessary to alter the treatment works due to unforeseen complications and costs associated with the proposed works. It is important that the property owner be consulted regarding any changes to the treatments. Any proposed alterations to treatments should also be reviewed by the acoustic engineer.

Where the property owner has opted for a different (more expensive) treatment to the one being offered, they may wish to engage an alternative contractor. This is acceptable, provided a waiver is signed releasing the department of its responsibility to provide noise mitigation. The property owner should be informed that the department will only reimburse costs up to the value of the treatments offered, upon receipt of proof that the treatments installed achieve the required noise reduction (eg receipts for acoustically rated products).

6.2.11 Verification

The building supervisor should inspect all properties to ensure that works have been completed to a satisfactory standard. The acoustic engineer should accompany the building supervisor for at least the first 25% of inspections to ensure the treatments have been installed correctly to achieve to necessary noise reduction. The acoustic engineer should be able to coach the building supervisor on what to look for, so that the remaining properties can be inspected by the building supervisor alone.

Property owners who have engaged their own contractors to install alternative/ more expensive treatments will have been required to sign a waiver releasing the department of its responsibility to provide mitigation, and as such, no inspection is required.

If the property owner is seeking reimbursement to the value of the treatments originally offered, they will need to provide receipts and proof demonstrating that the treatments achieve the necessary noise reduction.

6.2.12 Frequently asked Questions

Property owners may raise issues or concerns before or after completion of the noise treatments.

Q: Can I request an alternative treatment?

A: The offered treatments have been deemed the most reasonable and practicable form of mitigation in accordance with Departmental guidelines and the Environment Protection Act. Property owners may opt for a different treatment, provided it will deliver equivalent noise reduction, however, if the alternative treatment is more expensive and/or extensive, the property owner will be required to fund the difference. The property owner can engage their own contractor to do the work, then request a reimbursement from the department. The department will only reimburse up to the value of the treatments offered, and only if the property owner provides evidence that the treatments achieve the required noise reduction.

Q: I don't want the proposed treatments. Can I receive financial compensation instead?

A: Under no circumstances will the department provide monetary compensation in lieu of the required noise mitigation treatments. In cases where property owners indicate that they do not wish to receive any noise mitigation treatments to their property, a legal agreement needs to be signed that waives their right to receive noise mitigation treatments from the Department as part of that particular project (see Appendix D).

Q: I can still hear traffic noise. The treatments haven't worked.

A: the treatments are designed to minimise the noise impact of the project and achieve the target noise criteria, which are based on World Heath Organisation and EPA advice. They are not designed to eliminate road traffic noise.

6.3 Legal agreements

When installing noise mitigation treatments at properties, a signed legal agreement will be required from the property owner granting the Department and its contractors permission to carry out the necessary works at the premises. This document is normally termed a Deed of Consent and Agreement.

When organising a Deed of Consent and Agreement for a project, it is important that:

- the proposed treatments are clearly stated in the Deed or in an attached plan or scope
- the Deed is written in plain English and/or clearly explains any legal jargon

- the Deed resolves all necessary legal issues as required for the project.

When proposing a noise barrier on a property, a plan showing the location of the barrier and a description of the height and barrier material should generally be attached to the Deed. For architectural treatments, an attached scope of works is generally appropriate.

Deeds that are not easily understandable may create confusion. This can increase the time and cost required to implement mitigation treatments as well as create negative perceptions of the treatments for property owners.

In cases where property owners indicate that they do not wish to receive any noise mitigation treatments to their property, a legal agreement will need to be signed that waives their right to receive noise mitigation treatments from the Department as part of that particular project.

If property owners do not respond to approaches from the Department to arrange a property inspection and to discuss property treatments, a waiver agreement should be sent to the property owner if all reasonable efforts to contact them have already been made. A covering letter should outline that treatments can still be provided if the owner contacts the Department but that if no contact is made within a fixed period then the matter will be considered closed.

Examples of a typical Deed of Consent and Agreement and a typical waiver agreement are included in Appendix D.

Australian Building Codes Board, *Building Code of Australia.*

Austroads (2003) AP-G63 03 *Guide to the Selection of Road Surfacings.*

Austroads (2005) APR277/05 *Modelling, Measuring and Mitigating Road Traffic Noise*.

Department for Transport, Energy and Infrastructure (2007) *Road Traffic Noise Guidelines*.

Department of Planning and Local Government (2004) *The South Australian Urban Design Charter*.

Environment Protection Authority (1993) *Environment Protection Act*.

Environment Protection Authority (2007) *Environment Protection (Noise) Policy 2007*.

Environment Protection Authority (2010) *Draft Guidelines for the Assessment of Noise from Rail Operations*.

European Committee for Standardisation (2003) *CEN/TS 1794-1 Road Traffic Noise Reducing Devices, Non-Acoustic Performance, Mechanical Performance and Stability Requirements*.

European Committee for Standardisation (2003) *CEN/TS 1794-2 Road Traffic Noise Reducing Devices, Non-Acoustic Performance, General Safety and Environmental Requirements*.

Kotzen, B. and English, C. (2009) *Environmental Noise Barriers: A Guide to Their Acoustic and Visual Design*, 2nd Edition.

NSW Road Traffic Authority (2001) *Environmental Noise Management Manual*.

NSW Road Traffic Authority (2006) *Noise Wall Design Guideline*.

New Zealand Transport Agency (2010) *Draft Noise Barriers Design Guide*.

Queensland Department of Main Roads (2007) *Road Traffic Noise Management: Code of Practice*.

Standards Australia (1989) AS 3671 *Acoustics – Road traffic noise intrusion – Building siting and construction.*

Standards Australia (2000) AS/NZS 2107 *Acoustics – Recommended design sound levels and reverberation times for building interiors.*

Standards Australia (2002) AS 1668.2 *The use of ventilation and airconditioning in buildings – Ventilation design for indoor air contaminant control*.

Standards Australia (2007) AS/NZS 3000 *Electrical installations (Australian / New Zealand wiring rules).*

US Department of Transportation Federal Highway Administration (2010) *Highway Traffic Noise: Analysis and Abatement Guidance*.

VicRoads (2003) *A Guide to the Reduction of Traffic Noise*.

Appendix A – Noise mitigation checklist for road projects

- ☐ **Road traffic noise guidelines** – Do the *Road Traffic Noise Guidelines* apply to the project? What are the target noise levels?
- ☐ **Noise modelling** – Undertake a road traffic noise assessment to understand the existing conditions and future effects.
- ☐ **Road design measures** – Have reasonable road design measures been incorporated into the project? Consider adjustments to the vertical and horizontal alignments, low noise pavement surfaces, gradient variations, speed limit reductions, New Jersey barriers, etc..
- ☐ **Noise Mitigation Plan** - Determine the most practical combination of noise mitigation treatment measures, including road surface treatments, roadside noise barriers, property treatments (including a noise barrier at the property) or a combination of these.
- ☐ **Reasonable and practicable test** – Undertake a reasonable and practicable test to further refine the Noise Mitigation Plan. Consider visual impacts, community acceptance, engineering/design complexities and cost/benefit analysis.
- ☐ **Landowner consultation** - Consult with landowner(s) on general treatments options.
- ☐ **Property mitigation measures** – Determine detailed property mitigation measures and carry out property inspections and report on appropriate treatments.
- ☐ **Departmental approval** - Seek Project Director and SEMO approval of the proposed noise mitigation measures prior to seeking agreement with the landowner.
- ☐ **Agreement with landowner** - Seek agreement from the landowner on the proposed noise mitigation treatment measures.
- ☐ **Seek tenders** - Seek tenders for the implementation of the noise mitigation measures.
- ☐ **Commission works** - Commission and verify works in accordance with Departmental requirements.
- ☐ **Completion certificate** - Completion of Works Certificate must be signed when the works are finished.
- ☐ **Noise database** – Record treatment measures in the Noise database, including property address, description of treatment measures and date treatment measures were provided.
- ☐ **Project records** - Details of the treatment measures are to be filed within the project records for future reference.

Appendix B – Noise fact sheet example

XX PROJECT Noise Related Questions and Answers

I had noise treatments installed as part of the project, but I don't like them.
Treatments were installed after a lengthy consultation and tailored specifically to the existing constructions in your home. These treatments were installed after a signed deed of consent had been received from you, agreeing to the treatments that have been constructed.

My noise treatments don't work / I can hear traffic noise.
Noise treatments have been designed by an acoustic engineer in order to achieve a reasonable level of amenity. This does not mean that you will not be able to hear noise from the XX Project. The treatments are designed to achieve a level of amenity that will be acceptable to the majority of people. Noise levels from the road have been modelled based on the final 3-dimensional design and surrounding terrain. All buildings have been modelled to determine external noise levels at your property. The treatments have been tailored to your property to achieve a reasonable level of amenity.

I can't sleep.
It is anticipated that following opening of the project, a number of extra commuters will use the road to try it out. It may also take some time for your body to adjust to the additional noise being present in the environment. Generally, following the opening of a new noise source like the XX Project, it may take some residents some time to adjust to the new noise at night time so that their sleeping patterns are not affected. The noise treatments have been installed in order to give residents a suitable level of amenity so that sleep is not affected.

My neighbour got noise treatment, why didn't I?
All properties within 500 metres of the XX Project have been assessed against the *Road Traffic Noise Guidelines*, which is the South Australian document used to determine who qualifies for noise treatments and what level of treatments they should be provided. If you have not been contacted by the Department in regards to noise treatments, then noise levels at your property are deemed acceptable. Where you are exposed to an existing road traffic noise source, such as the Gawler Bypass, the project may actually be producing a decrease in noise levels relative to those levels before construction commenced.

Will the Department compensate me for energy use?
The Department will not compensate anyone for energy usage related to usage of the installed noise treatments. Noise treatments have been designed to achieve sustainable design, and low energy options have been used wherever possible. Use of ventilation systems that consume electricity is at your own discretion; they are an option provided to residents to be used to maintain a reasonable level of air quality in each residence.

Will there be more noise treatments?
No, there will not be any more noise treatments. Unless you are already in consultation with the Department regarding noise treatments, there will be no further treatments offered.

How do we know the noise modelling is correct?
The noise model will be validated after construction is completed to ensure that the predictions that noise treatments were based on are within an acceptable tolerance. This will be carried out once the road is operating under normal conditions.

Why did my neighbour have different treatments installed?
Each property has been assessed independently to ensure that their treatments are effective. Different house and window constructions mean that treatments are not uniform. Where a property might have been exposed to more noise before the XX Project was constructed, the impact of the project may have been less than at nearby houses, so treatments may not be uniform.

Why were walls like those at Gallipoli Underpass not built here?
A key urban design goal of the XX Project was to maintain the open vistas. Construction of roadside barriers would have resulted in these views being significantly impacted. Roadside noise barriers are also most effective

where roads and houses are very close. Due to the relatively large distances (compared to urban roads) between properties and the XX Project, roadside noise barriers were not a viable option for noise treatment.

Why is my fence is Colorbond, and not walls like those on Portrush Road?
A like for like process was followed on the Portrush Road project, and where there was an existing brick or masonry fence, this was upgraded by the department. Some residents on Portrush Road opted to pay the difference between a Colorbond fence and a brick or masonry fence.

Can I open my windows?
There is no requirement for you to use the noise treatments that have been installed. They are provided so that you have the facility to achieve a reasonable level of internal amenity. It may be that some residents prefer to have their windows and doors open during the day to allow fresh air to ventilate the house, and then close the windows and use the alternative fresh air systems to sleep at night.

Will trucks cause vibration in my home?
No houses are expected to experience felt vibrations from operation of the XX Project.

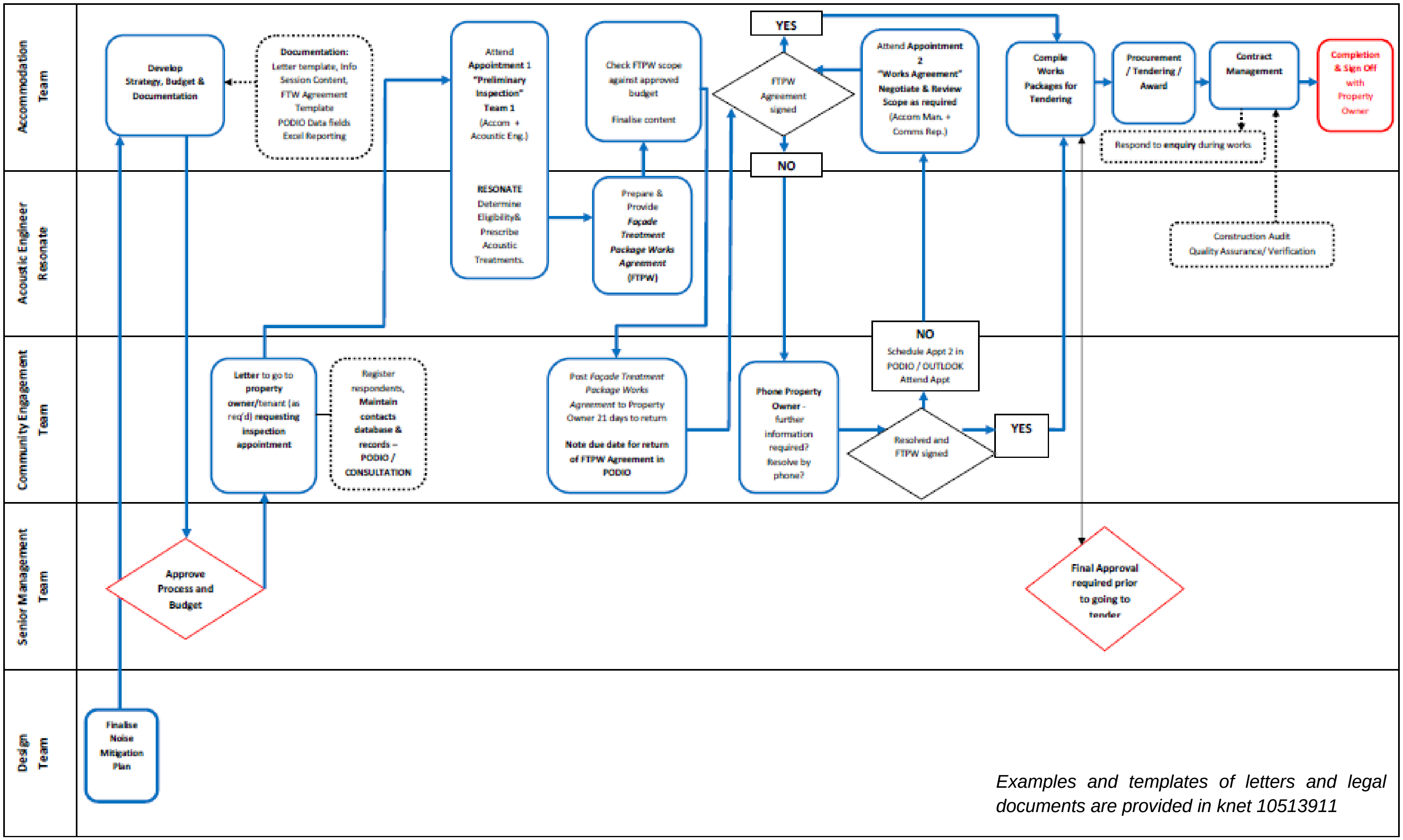
I am a business owner, will I receive noise treatment?
No, noise treatments are limited to residential properties only.

I have a complaint, who do I call?
Contact the XX Project contact line phone…

My noise treatment workmanship is poor.
Please contact the Department to arrange an inspection of the noise treatments.

Why didn't you plant trees to reduce the noise level? / Can trees reduce the noise levels?
Trees do not provide an effective way of reducing noise levels. In order to achieve a noticeable reduction of noise levels, 50 to 100 metres of thick dense forest is required. Individual trees do not provide any reduction, but can provide an effective visual barrier. In addition, noise caused by movement of trees in the wind can act to mask noise levels from traffic.

Appendix C: Example property treatment negotiation and installation flow chart



Examples and templates of letters and legal documents are provided in knet 10513911

(Return to *Insert name and address of contract manager* in the enclosed pre-paid envelope)

DEED OF CONSENT AND AGREEMENT

THIS DEED is made the …………… day of ……………..….

BETWEEN:

COMMISSIONER OF HIGHWAYS OF Roma Mitchell House, North Terrace, Adelaide, South Australia 5000 (“**the Commissioner**”)

AND
Insert property owner name (“**the Owner**”)

RECITALS:

A. The Owner(s) is/are the registered proprietors in fee simple of the premises more particularly described in Certificate of Title described as *Insert property address* (here and after called “**the premises**”).

B. The Commissioner proposes to carry out certain works in the vicinity of the premises.

C. Subject to the provisions of this Deed, the Commissioner has agreed to carry out certain noise amelioration works (“**the works**”) in the vicinity of the premises, being the works specified in the scope of works document attached.

D. Access to the premises may be required for the purposes of any of the following:

   Insert basic description of possible works

NOW THIS DEED WITNESSES AS FOLLOWS:

1. The Owner grants the Commissioner and his officers, contractors, servants and agents permission to enter onto the premises to carry out the works and to occupy the premises for the purposes of undertaking the works if required.

2. The Owner will do all things reasonably necessary to facilitate the carrying out of the works on the premises.

3. From the date that the parties sign this agreement liability of the owner and Commissioner shall be as follows:

   If in connection with the works, there is any loss of life, personal injury or damage to property (including contamination and erosion) resulting from the works which has been contributed to by the Commissioner’s wilful, negligent act or omission and this includes the Commissioner’s servants, agents, workers and other persons authorised by him in connection with the works, then the owner will not be responsible for any claims made or arising from the works. If however, such loss of life, personal injury or damage to property (including contamination and erosion) is caused by the owner then the owner will indemnify and release the Commissioner and the Crown in Right of the State of South Australia (South Australian Government) from all claims whatsoever.

The preceding paragraph means that if the Commissioner or anyone working for him commits a wilful, negligent act or omission then no claim can be made against the owner, however if the Commissioner does not commit a wilful, negligent act or omission then the owner will be responsible for all claims. This is called an indemnity and would only be referred to in the event that a claim is made during the period that the works were undertaken.

4. The *Owner* will be responsible for all maintenance, cleaning and repairs to the fence after installation.

EXECUTED BY THE PARTIES AS A DEED

SIGNED for and on behalf of the COMMISSIONER OF HIGHWAYS by a duly authorised delegate:

……………………………………………………

[Print Name:]

in the presence of:

……………………………………………………

Witness

[Print Name:]

SIGNED by *Insert Property Owner Name* (‘the owner”)

……………………………………………………

[Print Name:]

in the presence of:

……………………………………………………

Witness

[Print Name:]

Government of South Australia
Department of Planning, Transport and Infrastructure

XX PROJECT: NOISE REDUCTION TO RESIDENCE

Our Reference: *Insert file reference*

Insert date

Insert property address

Dear *Insert property owner name*,

In early 2013, members of the XX Project team contacted you to discuss noise reduction treatments for your property at *Insert property address*. I am advised by the team that you have not made contact with representatives of this office or returned any information sent on numerous occasions. This leads me to believe you do not want any noise reduction treatment.

If you choose not to receive any treatment please sign the enclosed Agreement confirming your decision and return it in the reply-paid envelope.

If you have a change of mind and would like to pursue noise reduction treatment please contact Ms XX to advise of your decision and to discuss your options.

However, if we do not hear from you within two weeks of dispatch of this letter, the department will consider the matter closed.

In the future you may choose to install noise reduction treatment at your own expense; however, the department will not be liable for any future cost or maintenance associated with subsequent noise reduction treatment for your property.

In the meantime, should you have any questions regarding this matter please contact Ms XX, Environmental Manager, on 8343 0000.

Yours sincerely,

Project Director

Government of South Australia
Department of Planning, Transport and Infrastructure

(Return to *Insert name and address of contract manager* in the enclosed pre-paid envelope)

XX PROJECT: AGREEMENT TO REFUSE NOISE REDUCTION TREATMENT TO RESIDENCE

THIS AGREEMENT is made the ………..….. day of ……………..……..

I, ………………………….., the registered proprietor in fee simple of the premises more particularly described in certificate of Title described as *Insert property address*, hereby advise that I choose not to receive any noise reduction treatment to my property.

I accept that should I choose in the future to install noise reduction treatment this will be at my own expense and the Department for Planning,Transport and Infrastructure will not be liable for any future cost or maintenance associated with subsequent noise reduction treatment for my property.

SIGNED by

…………………………	…………………………	_ _ / _ _ / _ _ _ _
PRINT NAME	SIGNATURE	DATE

WITNESSED by

…………………………	…………………………	_ _ / _ _ / _ _ _ _
PRINT NAME	SIGNATURE	DATE