NSW EPA

Rail Infrastructure Noise Guideline

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1 Introduction

Better transport is a key objective of the NSW Government. It includes improved public transport and increased movement of freight by rail. The growth of our rail transport network brings many benefits to the wider community. These include reduced fuel use and air pollution, lower greenhouse gas emissions, less road congestion and better safety. Rail transport is a vital component for achieving sustainable cities and preserving the environment.

Nevertheless, adverse effects on residents living alongside rail lines can occur from exposure to increased train movements, extended rail operating hours and development along transport routes that are not designed to mitigate noise and vibration. The extra noise may disturb sleep, causing stress and annoyance. It can also interfere with daily activities including talking, hearing and studying. These impacts need to be managed to protect the amenity and wellbeing of those local communities living near rail lines.

Rail operations can be inherently noisy. Relatively high noise levels may still occur even after all feasible and reasonable means of mitigating the noise have been applied. A suite of initiatives is needed to address existing rail noise, including limiting noise from rolling stock and providing avenues for relief for those acutely affected by rail noise. These initiatives are discussed in Appendix 1.

Better planning to achieve more liveable cities has resulted from the introduction of the *State environmental planning policy (infrastructure) 2007,* (the 'Infrastructure SEPP') and the supporting *Development near rail corridors and busy roads – interim guideline 2008*. One of the key objectives of this guideline is to ensure that adjacent development achieves an appropriate acoustic amenity by meeting internal noise criteria specified in the Infrastructure SEPP.

When new rail lines are being built, or existing lines redeveloped, attention needs to be paid to controlling noise. The *Rail infrastructure noise guideline* is designed to assist the ongoing expansion and upgrade of rail transport by ensuring that potential noise impacts associated with rail infrastructure projects are managed effectively.

1.1 Role of this guideline in managing noise and vibration from rail activities

The *Rail infrastructure noise guideline* replaces the *Interim guideline for the assessment of noise from rail infrastructure projects* (IGANRIP) (DECC 2007).

The purpose of this guideline is to ensure noise and vibration impacts associated with particular rail development projects are evaluated in a consistent and transparent manner. It applies to heavy and light rail infrastructure projects including the construction of new rail lines and upgrades to existing lines. It provides a procedure for the consideration of feasible and reasonable noise mitigation measures that form part of a noise impact assessment (NIA) that will be used by planning authorities to assess rail projects.
The *Environment Planning and Assessment Act 1979* (EP&A Act) specifies when an environmental impact assessment is required. The EP&A Act requires that proponents and planning authorities examine and take into account to the fullest extent all matters affecting the environment. This guideline provides a procedure to consider feasible and reasonable noise mitigation measures that form part of a noise and vibration assessment. This guideline only applies to rail infrastructure projects as defined in section 1.4.[1].

[1] See also technical note 8 to tables 1, 2 and 3 (page 11).

This guideline is one component of a number of rail noise initiatives being developed to manage the environmental impacts of noise and vibration from the NSW rail system. The other complementary initiatives aim to reduce noise and vibration impacts from *existing* rail operations, which have mostly grown over a long period of time. These include:

- a noise abatement program to address existing acute levels of heavy rail noise on a priority basis
- planning guidelines for new residential developments alongside rail lines
- national rolling stock standards to reduce noise and other emissions from these sources.

These are described at Appendix 1.

Effective management of rail noise requires the combined efforts of rail infrastructure owners, managers, developers, rail operators, freight owners, train manufacturers, regulatory and planning authorities, port facility operators, residential developers and the community.

1.2 Who is this guideline for?

This guideline is for rail infrastructure proponents (both private and public), consent/approval authorities, designers, engineers, contractors, and commercial and industrial developers involved with the design, approval, construction and development of heavy and light rail infrastructure projects in NSW or rail traffic-generating developments. It will help assess the potential noise and vibration impacts associated with the ongoing expansion and upgrade of the rail network in NSW.

Triggers for assessing rail traffic-generating developments are outlined in Appendix 2. These are non-rail land-use developments that will generate rail traffic on existing network lines through the nature of their operation; e.g. mines and extractive industries.

This guideline may also be a point of reference for planning or regulatory authorities assessing railway-related activities not subject to approval under the EP&A Act or licensing under the *Protection of the Environment Operations Act 1997* (POEO Act) such as:

- rail activities not requiring an environment protection licence
- heritage railway operations.

1.3 Guideline objectives

The purpose of this guideline is to specify noise and vibration trigger levels for assessing heavy and light rail infrastructure projects to protect the community from the adverse effects of noise and vibration from rail infrastructure projects.

It is designed to streamline decision-making processes by providing consistent and transparent procedures for determining appropriate mitigation for rail infrastructure developments that have potential noise and vibration impacts. A key objective is to identify impacts from *additional* traffic on redeveloped rail lines, and to minimise noise exposure levels from new rail line developments or significant redevelopment of existing rail lines. The procedures outlined should be considered in a project's noise impact assessment process.

When government agencies review environmental assessments under the EP&A Act for rail projects or land-use developments generating additional rail traffic, they should assess these proposals against the requirements in this guideline.

1.4 Projects to which this guideline applies

This guideline applies to proposed rail infrastructure projects that would be assessed and determined under the EP&A Act or that are likely to be licensed under the POEO Act. It takes a rail project-based approach to the consideration of noise mitigation measures for areas impacted by rail infrastructure. It applies consistently to passenger and freight rail in urban, suburban and rural settings. The noise and vibration trigger levels presented in tables 1−4 (pages 9−14) indicate when noise mitigation measures should be considered. If the environmental impact assessment of a proposed rail project shows that the trigger levels are likely to be exceeded, the assessment is required to outline feasible and reasonable noise mitigation measures that could be implemented to ameliorate the predicted impacts. (Section 3.1 provides advice on applying the triggers.) This guideline should be used whenever there is potential for noise and vibration impacts from heavy and light rail infrastructure projects.

This guideline specifies noise and vibration trigger levels for:

- residential land affected by heavy rail projects, including new rail lines, redevelopments of existing lines and projects to bring disused rail lines back into service
- residential land affected by light rail developments
- sensitive land uses near heavy and light rail developments
- rail traffic-generating developments
- non-network rail lines that are on or exclusively servicing industrial sites[1].

Trigger levels for *new* heavy rail projects are more stringent than those for *redeveloped* heavy rail projects to reflect the greater opportunity to apply mitigation options during the planning and design stage. There is also evidence to suggest people react more to a newly introduced noise source than to a source that has been present for some time.

In some cases, a rail infrastructure project could result in some sections of new track and some redeveloped sections. The relevant trigger levels should be applied where this is the case.

1.4.1 Heavy rail projects

In NSW, heavy rail is considered to be rail infrastructure and its associated rolling stock which may be electrified or hauled by diesel locomotives that operates in dedicated rail corridors for either passenger and/or freight transportation. Heavy rail generally operates at higher speeds, has a higher carrying capacity than light rail and travels over longer distances[2]. Passenger rail services currently provided by CityRail and CountryLink (operated by RailCorp) and freight operations are heavy rail.

This guideline distinguishes between *new* or *redeveloped* rail lines as follows:

1.4.1.1 New rail line

A new heavy rail line development is one where a rail infrastructure project is to be developed on land that is not currently an operational rail corridor. The South West Rail Link is an example.

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[1] Non-network rail lines exclusively servicing industrial sites are dealt within in section 1.4.5

[2] If ‘metro’ or rapid transit (fast, frequent and high capacity) services were introduced in NSW, they would be considered heavy rail projects.

Typically this will involve a rail line being developed on land that has not previously had a rail line or on land where an existing rail line is to be substantially realigned[1] outside the existing rail corridor.

1.4.1.2 Redeveloped rail line

Redevelopment of a heavy rail line occurs where any rail infrastructure project is to be developed on land that:

- is located within an existing and operational rail corridor[2] where a rail line is or has been operational; or
- is immediately adjacent to an existing operational rail line which may result in widening of an existing rail corridor.

Typically this will be where works on an existing rail line are proposed that will *increase its capacity* to carry rail traffic or alter the track alignment through design or engineering changes. In practice this often means duplicating track within an existing rail corridor. The Kingsgrove to Revesby quadruplification project is an example.

A disused heavy rail line that is brought back into use should be assessed as a redevelopment under this guideline. This is because a line brought back into use will add to existing rail traffic noise where it is a feeder line rather than introduce a new noise source [3]. However, if the corridor has been substantially realigned, then the realigned section should be assessed as a new rail line.

For example, a rail duplication project could require a section of track to be constructed outside the current corridor because constructing that section within the corridor would bring it too close to existing residences. The section to be constructed outside the existing corridor could allow for a noise barrier to be built which would not have been possible had the line not been moved onto the new path. This section would be considered a 'realigned' section of the project and should be designed to meet the more stringent 'new' noise trigger levels even though it is part of a redevelopment project.

1.4.1.3 Other rail works

This guideline applies to all heavy rail infrastructure redevelopments including works such as crossovers, sidings, turnouts, loops, refuges, relief lines, straightening curves or the installation of track signalling devices. These should be assessed in accordance with the redeveloped rail line trigger levels.

1.4.2 Light rail projects

Light rail refers to a passenger transport system that generally operates at a lower capacity and on a localised, shorter network compared to heavy rail, does not use locomotives to haul the carriages and may operate on shared roadways with other road vehicles. Sydney's Light Rail is an example.

All proposals for light rail projects, whether they are new developments in greenfield areas or redevelopments in existing rail corridors, are to be evaluated against the same trigger levels.

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[1] 'Substantially realigned' means the track is moved sufficiently to allow new noise mitigation options to be considered that would not have been feasible if the track had not been moved.

[2] An 'operational rail corridor' is a rail corridor on which rolling stock is operating.

[3] A disused heavy rail line may be brought back into use where no other rail lines are in operation. The trigger levels for a redeveloped rail line would still apply (unless the corridor is substantially realigned) because the opportunity to apply mitigation options through land-use planning is unlikely to be available. See also section 1.5, paragraph (c).

This guideline applies to all light rail development including works such as crossovers, sidings, turnouts, loops, refuges, relief lines, straightening curves or the installation of track signalling devices.

1.4.3 Residential and non-residential noise receivers

This guideline recognises that in some cases there may be land uses that are particularly sensitive to noise where more stringent triggers are appropriate. In addition to residential land, specific triggers have been set for schools, hospitals, places of worship and recreational areas so the characteristic activities for each of these land uses will not be unduly disturbed.

When identifying land uses and noise receivers, both existing and planned development should be considered.

1.4.3.1 Planned development

Planned development is approved development, including staged development that identifies building locations.

In such cases, noise impacts on existing land uses must be identified and assessed. When assessing the noise impacts on planned development near a rail corridor, a range of matters should be considered, including but not limited to:

- the type of consent or approval
- the existing noise environment, including existing rail-noise sources and whether the rail development under assessment is for a new or redeveloped rail line
- the proposed future character and land-use objectives for the area, e.g. an area may be identified for future urban growth
- whether the planned development has contemplated or assessed existing or future rail-noise sources.

For example, a proponent of a rail infrastructure project should assess noise impacts on future residences near the rail corridor (that are not yet built) in accordance with this guideline if it was unreasonable for the developer or the consent authority of that housing to have considered rail noise impacts. This would be because the rail project was not expected or proposed at the time the development consent was given for the housing.

1.4.3.2 Planned rail corridors

Where planned rail infrastructure projects (and/or corridors) have been approved, it is reasonable for a developer and consent authority to consider such approved projects in accordance with the requirements of the Infrastructure SEPP.

1.4.3.3 Existing rail corridors

In the case of existing rail corridors, the Infrastructure SEPP refers to the *Development near rail corridors and busy roads – interim guideline* which must be taken into account where development is proposed in, or adjacent to, specific railway corridors. The guideline relates to SEPP rail clauses 85, 86 and 87. For certain development near rail corridors, the Infrastructure SEPP also requires agreement from the rail authority and identifies specific matters it must take into account before deciding whether to give approval.

1.4.4 Rail traffic-generating developments

Some industries, such as mining and extractive industries, may generate additional rail traffic that can increase the noise from a network significantly. When reviewing environmental assessments for such land-use developments, government agencies should consider the potential noise from rail traffic-generating developments against the requirements detailed in Appendix 2.

1.4.5 Non-network rail lines on or exclusively servicing industrial sites

Non-network rail lines exclusively servicing one or more industrial sites, such as a spur line connecting a mine to a network line, are not common but are likely to be proposed more often in future. Because they are somewhat unique, they should be assessed as described in Appendix 3.

1.5 Excluded from this guideline

This guideline *does not* apply to:

a. The mitigation of noise from existing rail lines where no rail infrastructure projects are proposed (rail noise abatement programs are being developed to provide relief for those acutely affected by rail noise).

b. Development to which clause 87 of the Infrastructure SEPP applies. Examples include development for the purpose of a dwelling house, church, hospital, school or childcare centre on land that is in or immediately adjacent to a rail corridor that the consent authority considers is likely to be adversely affected by rail noise and vibration.

c. Routine maintenance of the railway system, including bringing back into use a rail line temporarily closed through damage (due to landslide, flooding etc) − the *Interim construction noise guideline* (DECC 2009) applies.

d. Projects involving maintenance facilities for rolling stock (including stabling yards and shunting operations), which should be assessed in accordance with the NSW *Industrial noise policy* (EPA 2000).

e. Noise from the construction of a rail project as construction is of a temporary nature and is addressed under the *Interim construction noise guideline* (DECC 2009).

f. Activities exempted from 'railway systems activities' under Schedule 1 of the POEO Act[1] which refers to rail activities taking place at fixed locations (stationary noise sources) that are covered by the *Industrial noise policy* (EPA 2000).

g. Occupational noise and vibration, which are regulated by WorkCover NSW under the *Work Health and Safety Act 2011*.

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[1] 'Railway systems activities' exempted under Schedule 1 of the POEO Act are activities in a railway workshop; railway fuel depot; railway station building or freight depot. Also exempted are activities such as: refuelling of rolling stock; repair, maintenance or upgrading of track away from the track site; loading or unloading of freight onto rolling stock; and the operation of signalling, communication or train control systems.

2 Noise and vibration trigger levels

This guideline addresses *rail* noise and vibration, including:

- airborne noise that is heard at or within noise-sensitive premises
- ground-borne noise generated inside a building by ground-borne vibration from a vehicle passing by on rail
- vibration in buildings that affects amenity.

Airborne noise from rail pass-bys is generated by a combination of noise from the propulsion of the rolling stock (usually diesel or electric locomotives) and from its interaction with the track. This type of noise generally comes from the operation of a surface rail line and reaches a receiver primarily through the air.

Ground-borne noise or regenerated noise in buildings is typically noted at receiver locations where the level of ground-borne noise is likely to be greater than airborne noise (e.g. in buildings above rail tunnels where the airborne noise is masked by the tunnel).

Vibrations in buildings associated with movements on a rail network can cause disturbance and complaint in a similar fashion to noise. Assessment of vibration is dealt with by a separate guideline, as outlined in section 2.6.

A comparison of airborne noise levels for rail operations in other jurisdictions in Australia and overseas is presented in Appendix 4.

2.1 Trigger levels used in this guideline

Operational rail noise can have a significant effect on noise-sensitive receivers near a rail line. This guideline specifies noise and vibration trigger levels. If these are likely to be exceeded by the proposed rail development, mitigation measures need to be considered to reduce the predicted noise levels. See section 3.1 for advice on applying the triggers. The noise and vibration triggers in this guideline apply to existing noise-sensitive receivers and future sensitive receivers associated with planned developments.

2.2 Noise descriptors used in this guideline

All the noise trigger levels in this guideline differentiate between noise impacts during the day and at night. A more stringent noise trigger is applied for night-time. It is widely accepted that noise is generally more disturbing at night because more noise-sensitive activities occur at that time (e.g. listening activities and sleep). Also, most residents are at home and noise is more intrusive due to lower background levels at night.

To evaluate predicted rail noise, triggers are provided for both L_{Aeq} (the level of average noise energy over the day or night period which includes maximum noise events from individual train pass-by events) and L_{Amax} which, for the purposes of this guideline, is the maximum noise level not exceeded by 95 per cent of individual train pass-by events. Applying the L_{Amax} descriptor for residential land uses recognises that rail noise events are not adequately described for all scenarios by using only the L_{Aeq} descriptor. See Appendix 5 for more information.

For non-residential noise-sensitive land uses, only L_{Aeq} is applied, as the focus is on speech interference and providing adequate acoustic protection to conduct the activities associated with those land uses.

2.3 Airborne noise trigger levels for heavy rail

Trigger levels in this guideline that apply to heavy rail projects relate to:

- the absolute level of rail noise associated with all rail transportation services, and
- the increase in the predicted rail noise due to the proposed rail infrastructure project in the case of redevelopments.

If the noise impact assessment undertaken for the infrastructure proposal indicates that the trigger levels in this guideline are likely to be exceeded, a detailed study must be made to evaluate the predicted noise and vibration levels. The predicted levels should then be compared to the noise and vibration trigger levels identified in this guideline. It is then necessary to consider feasible and reasonable mitigation measures. If the triggers are not exceeded, mitigation considerations are not required under this guideline. However, assessment obligations under the EP&A Act remain unaffected.

For heavy rail projects, trigger levels are given for a *new* rail line development and for *redevelopment* of existing lines. In the case of a *new* railway, an assessment of noise impacts and mitigation measures must be considered where the predicted noise level is likely to exceed the trigger levels. An assessment of noise impacts and mitigation measures for a *redeveloped* line must be considered when an increase in rail noise is predicted to occur (for either L_{Aeq} or L_{Amax}) by the number of decibels specified in table 1 (page 9) *and* when the predicted level exceeds the trigger values in table 1 for residential receivers or in table 3 (page 10) for non-residential receivers. The trigger levels for an increase in the L_{Aeq} and L_{Amax} are set at levels where the increase in rail noise is likely to be perceptible (see Appendix 5).

As mentioned (section 1.4), the trigger levels are more stringent for new heavy rail projects than for redevelopments. The reason is that it is possible to apply a greater range of noise prevention and mitigation options during the planning stages for new rail projects in greenfields or on land that has not previously had a rail line than for projects in existing rail corridors. There is evidence to suggest that people's reactions to a newly introduced noise source are considerably greater than reactions to a source that has been present for some time (see Appendix 5.3).

Separate triggers are provided for day and night periods, with a more stringent trigger applied for night. This reflects the need to protect the community from rail-noise related sleep disturbance at night and encourages a greater volume of rail movements to take place during daytime. The 15-hour daytime period is defined from 7 am to 10 pm and the 9-hour night-time period is from 10 pm to 7 am.

2.4 Airborne noise trigger levels for light rail

If the noise impact assessment undertaken for a light rail infrastructure proposal indicates that the trigger levels in this guideline for light rail are likely to be exceeded, a detailed study must be made to evaluate the predicted noise and vibration levels. The predicted levels should then be compared to the light rail trigger levels in tables 2 and 3 (pages 9−10) and consideration given to whether feasible and reasonable mitigation measures need to be explored.

The levels for residential receivers take into account that existing roadways can be converted into light rail corridors. The trigger values for residential receivers in table 2 (page 9) are divided into day- and night-time periods. Triggers for non-residential receivers of noise from light rail are provided in table 3 (page 10). Ground-borne noise trigger levels are provided in table 4 (page 14) and vibration trigger levels are referenced at section 2.6.

Compared to the triggers for heavy rail developments, noise triggers for light rail are more stringent (see tables 1 and 2 on page 9). This is because modern light rail has many features to minimise noise and vibration. Light rail is generally quieter than heavy rail because the vehicles are shorter in length and diesel locomotives are not used to haul carriages. Appendix 9 provides additional information on noise triggers for light rail.

Table 1 Airborne *heavy* rail noise trigger levels for residential land uses

Type of development	Noise trigger levels dB(A) (External)[1, 2]	
	Day (7 am–10 pm)	**Night (10 pm–7 am)**
New rail line development[3]	Predicted rail noise levels exceed:	
	60 $L_{Aeq(15h)}$ OR 80 L_{AFmax}	55 $L_{Aeq(9h)}$ OR 80 L_{AFmax}
Redevelopment of existing rail line[4]	Development increases existing $L_{Aeq(period)}$[5] rail noise levels by 2 dB or more, or existing L_{Amax} rail noise levels by 3 dB or more ***and*** predicted rail noise levels exceed:	
	65 $L_{Aeq(15h)}$ OR 85 L_{AFmax}	60 $L_{Aeq(9h)}$ OR 85 L_{AFmax}

[1] See technical notes to tables 1, 2 and 3 on page 10
[2] These numbers represent external levels of noise that trigger the need for an assessment of potential noise mitigation measures to reduce noise levels from a rail infrastructure project
[3] See section 1.4.1.1 for definition of new rail line
[4] See section 1.4.1.2 for definition of redeveloped rail line
[5] $L_{Aeq(period)}$ means $L_{Aeq(15h)}$ for the day-time period and $L_{Aeq(9h)}$ for the night-time period

Table 2 Airborne *light rail* noise triggers for residential land uses

Type of development	Noise trigger levels dB(A) (External)[1, 2]	
	Day (7 am–10 pm)	**Night (10 pm–7 am)**
All light rail line developments[3]	60 $L_{Aeq(15h)}$ AND 80 L_{AFmax}	50 $L_{Aeq(9h)}$ AND 80 L_{AFmax}

[1] See technical notes to tables 1, 2 and 3 on page 10.
[2] These numbers represent external levels of noise that trigger the need for an assessment of potential noise mitigation measures to reduce noise levels from a rail infrastructure project.
[3] See section 1.4.2 for definition of light rail.

Table 3 Airborne rail noise trigger levels applicable to heavy and light rail developments for sensitive land uses other than residential

Other sensitive land uses	Noise trigger levels dB(A) (when in use) [1]	
	New rail line development	**Redevelopment of existing rail line**
	Resulting rail noise levels exceed:	Development increases existing rail noise levels by 2 dB(A) or more in L_{Aeq} for that period ***and*** resulting rail noise levels exceed:
Schools, educational institutions and child care centres	40 $L_{Aeq(1h)}$ internal	45 $L_{Aeq(1h)}$ internal
Places of worship	40 $L_{Aeq(1h)}$ internal	45 $L_{Aeq(1h)}$ internal
Hospital wards	35 $L_{Aeq(1h)}$ internal	40 $L_{Aeq(1h)}$ internal
Hospitals other uses	60 $L_{Aeq(1h)}$ external	65 $L_{Aeq(1h)}$ external
Open space – passive use (e.g. parkland, bush reserves)	60 $L_{Aeq(15h)}$ external	65 $L_{Aeq(15h)}$ external
Open space – active use (e.g. sports field, golf course)	65 $L_{Aeq(15h)}$ external	65 $L_{Aeq(15h)}$ external

[1] See technical notes to tables 1, 2 and 3 on page 10.

Technical notes to tables 1, 2 and 3

1. Specified noise trigger levels refer to noise at the receiver location.
2. Noise trigger levels refer to noise from rail transportation only and do not include ambient noise from other sources. Refer to technical notes 8 and 19 and section 3 for further advice.
3. The noise levels are external levels except where otherwise stated.
4. The trigger levels apply consistently to urban, suburban and rural settings. For heavy rail they do not differentiate between freight haulage, suburban commuter networks and regional lines.
5. 'Residential' land use typically means any residential premises and includes aged-care facilities and caravan parks incorporating long-term residential use. Refer to section 1.4.3 regarding proposed future land use developments. Where the status of the land use is in doubt, consult the relevant planning authority.
6. Noise levels at residences are assessed one metre in front of the most affected building façade. Where only free-field measurements can be made, the measured noise level is corrected [generally by + 2.5 dB] to account for the façade reflection effect. In the case of multi-level residential buildings, the external point of reference for measurement for the trigger is the two floors of the building most exposed to rail noise. On other floors, an internal noise level value 10 dB below the relevant external noise level value applies on the basis that windows that can be opened can do so sufficiently to provide adequate ventilation (refer to minimum ventilation requirements in the Building Code of Australia, 2010).

7. Where a redevelopment proposal is likely to exceed the existing rail noise levels as detailed in tables 1 or 3, the ‘increase’ in noise should be calculated to a single decimal place before comparing it with the 2 dB and 3 dB noise-increase trigger levels. However, the absolute noise levels should be calculated to the nearest whole decibel number before comparing them with the absolute trigger.
8. Noise from existing projects is considered when predicting noise for *redeveloped* projects. Consecutive new rail infrastructure projects could be developed over time leading to a cumulative increase in noise and vibration. However, each project would be subject to the requirements of the EP&A Act, and cumulative impacts would need to be reported within an environmental impact assessment for each subsequent rail infrastructure project.
9. $L_{Aeq(T)}$ (where T is the relevant time period) refers to the equivalent continuous noise level from all train movements occurring during the assessment time period. This should reflect the reasonable maximum use, or the ‘worst-case’ typical day rather than average use. Refer to section 3 for further advice.
10. L_{Amax} refers to the maximum noise level not exceeded for 95 per cent of rail pass-by events and is measured using the ‘fast’ response setting on a sound-level meter. The purpose of the L_{Amax} trigger levels is to cap the potential noise impacts associated with individual pass-by events. For projects where different types of rolling stock will be used (e.g. freight and passenger operations), the L_{Amax} noise level should be reported separately for each type of rolling stock and compared with the L_{Amax} (95 per cent) trigger levels.
11. Noise from safety warning devices such as horns and bells at level crossings should not exceed the L_{Amax} trigger levels. This noise should be taken into consideration in the noise assessment process. Section 3.3.2 and Appendix 7 provide further advice.
12. Internal noise levels refer to the noise level at the centre of the habitable room that is most exposed to the noise source and are applied with windows opened sufficiently to provide adequate ventilation. In cases where gaining internal access for monitoring is difficult, external noise levels of 10 dB(A) above the internal levels apply.
13. The noise level values for sensitive land uses, other than residential, apply for the periods when the premises are in use.
14. In assessing noise levels at passive and active open spaces as well as in hospital grounds, the noise level is assessed at the most affected point no closer than 50 m from the area boundary, i.e. within the passive or active open space area. Where passive and active open spaces have a boundary of less than 50 m, this provision is not applicable and the proponent should select a more appropriate distance and provide justification for doing so.
15. For external activities associated with schools, educational institutions and places of worship, the relevant passive or active open space categories apply.
16. In the case of mixed-use development each component of use should be considered separately. For example, in a mixed-use development containing residences and a childcare facility, the residential component should be assessed against the appropriate triggers for residences in tables 1 and 2, and the childcare component should be assessed against the triggers in table 3.
17. Where the category of the premises is not clear, seek advice from the relevant planning authority.
18. For sensitive land uses, $L_{Aeq(1h)}$ means the highest 10th-percentile hourly A-weighted L_{eq} during the period when the particular class of receiver building/place is in use. Alternatively, the highest $L_{Aeq(1h)}$ value can be used where insufficient data are available to provide a valid 10th-percentile level, provided that the value is representative.

19. For both new and redeveloped heavy or light rail projects, the noise trigger levels should be evaluated at the following two points in time:

New rail project

- timeframe 1: immediately after operations commence
- timeframe 2: for a design year (typically 10 years) after opening.

Rail redevelopment project

- timeframe 1: immediately after operations commence
- timeframe 2: for a design year (typically 10 years) after changed traffic conditions i.e. one year or other indicative period after operations commence.

A comparison should be made between:

- the rail noise levels if the project proceeds (termed the 'build option'), and
- the corresponding rail noise levels, due to general traffic growth that would have occurred if the project had not proceeded (termed the 'no build option'). The 'no build option' in this instance is the general traffic growth that would have occurred if the project had not proceeded (e.g. one year or another indicative time period in the future) as opposed to the existing noise levels.

Example of noise assessment evaluation

The following illustrates an example of how the noise trigger levels should be evaluated at the two points in time at affected receivers for a heavy or light rail project.

Existing noise levels (e.g. 2012)

While not directly utilised in the RING assessment, existing noise levels (ambient and rail traffic – see technical note 2, page 10) demonstrate the existing noise environment and can be used to validate predictions.

Timeframe 1: Year of project commencement (e.g. 2013)

i. 'no build' noise levels for 2013, including traffic growth that would have occurred if the project had not proceeded
ii. 'build' noise levels immediately after operations commence in 2013 assuming the project proceeded.

Timeframe 2: Design Year (e.g. 2023)

iii. 'no build' noise levels for 2023, including traffic growth that would have occurred if the project had not proceeded
iv. 'build' noise levels for 2023 assuming the project proceeded.

The 'absolute' noise levels are determined by comparing ii and iv (the 'build' scenarios) to the relevant trigger values in tables 1−3.

For a heavy rail redevelopment project, the 'increase' noise trigger is determined by comparing the 'no build' to the 'build' scenarios in each timeframe. That is, compare i to ii, and iii to iv.

20. There may be situations where it is reasonable to vary the standard time periods applied to the day and night periods. For example, there may be instances where the noise levels in an area begin to rise quickly before 7 am (the standard cut-off point between day and night) because of normal early morning activity by the general community. In these cases it is reasonable to consider varying the standard day and night-time periods to better reflect the actual temporal changes in noise for that location. Appropriate noise levels for these shoulder periods where night-time noise levels rise quickly to daytime noise levels may be negotiated on a case-by-case basis with the determining or regulatory authority (following community consultation).

Advice on applying the noise trigger levels and determining feasible and reasonable mitigation measures is provided in section 3.

2.5 Ground-borne noise trigger levels

Ground-borne noise is defined in ISO 14837 *Mechanical vibration – ground-borne noise and vibration arising from rail systems* as noise generated inside a building by ground-borne vibration generated from the pass-by of a vehicle on rail. It applies to both heavy and light rail. Ground-borne noise excludes direct airborne noise.

Ground-borne noise level values are relevant only where they are higher than the airborne noise from railways (such as in the case of an underground railway) and where the ground-borne noise levels are expected to be, or are, audible within habitable rooms.

Ground-borne noise differs from airborne noise because the actions available to reduce or avoid it are more limited. For example, airborne noise can often be reduced by actions such as closing windows, improving the acoustic insulation of the building façade or relocating noise-sensitive activities in the building to a location more remote from the noise source. These actions are likely to be relatively ineffective against ground-borne noise, because the noise is emitted by the building structure itself.

Retrospective measures to mitigate ground-borne noise generation can be more difficult and expensive than air-borne noise mitigation. This is because the ability to apply these measures can be restricted by the amount of head-room available in a tunnel or the ability of the track-bed to accommodate additional mitigation. It is therefore important to ensure that an adequate level of mitigation is applied during the design and construction of underground rail projects.

Limited research into the impacts of ground-borne noise is available, and information on practices applied overseas is also scarce. From a review of available material it appears the factors that can affect reaction to ground-borne noise include:

- the level of the noise
- how often it occurs
- whether an area is already exposed to rail noise and
- whether the area affected has a low-density of development (e.g. low-density residential) with associated low levels of ambient noise.

It appears reasonable to conclude that ground-borne noise at or below 30 dB L_{Amax} will not result in adverse reactions, even where the source of noise is new and occurs in areas with low ambient noise levels. Levels of 35–40 dB L_{Amax} are more typically applied and likely to be sufficient for most urban residential situations, even where there are large numbers of pass-by events.

When assessing the impact of ground-borne noise the noise trigger levels in table 4 (page 14) and the associated measurement methodology described in section 3 should be referenced. They are necessarily set to the lower end of the range of possible trigger values so that potential impacts on quieter suburban locations are addressed. In practice, higher levels of ground-borne noise than the trigger level for assessing impacts may be appropriate for urban areas where background noise levels are relatively high.

Table 4 Ground-borne noise trigger levels for heavy or light rail projects

Sensitive land use	Time of day	Internal noise trigger levels dB(A)
		Development increases existing rail noise levels by 3 dB(A) or more ***and*** resulting rail noise levels exceed:
Residential	Day (7 am–10 pm)	40 L_{ASmax}
	Night (10 pm–7 am)	35 L_{ASmax}
Schools, educational institutions, places of worship	When in use	40–45 L_{ASmax}

Technical notes to table 4

1. Specified noise levels refer to noise from heavy or light rail transportation only and do not include ambient noise from other sources.
2. The noise levels represent internal noise levels and are to be assessed near to, but not at the centre of the most affected habitable room. For example, at night this may be the bedroom experiencing the highest levels of ground-borne noise, while during the day another habitable room might experience the highest levels of ground-borne noise. The triggers are relevant only where ground-borne noise levels are audible and are of a higher level than airborne noise levels from rail operations.
3. 'Residential' land use typically means any residential premises and includes aged-care facilities and caravan parks incorporating long-term residential use. Refer to section 1.4.3 regarding planned land use developments. Where there is doubt as to the status of the land use, consult the relevant planning authority.
4. L_{ASmax} refers to the maximum noise level not exceeded for 95 per cent of rail pass-by events and is measured using the 'slow' (S) response setting on a sound-level meter.
5. For schools, educational institutions and places of worship, the lower value of the range is most applicable where low internal noise levels are expected, such as in areas assigned to studying, listening and praying.

2.6 Vibration trigger levels

Vibrations in buildings associated with rail network operations can cause disturbance and complaint in a similar manner to noise. It needs to be considered at the infrastructure planning stage as it is difficult to mitigate retrospectively.

A separate vibration guideline, *Assessing vibration: a technical guideline* (DEC 2006), covers continuous, impulsive and intermittent vibration from a variety of sources. Train movements on a rail network can cause vibration of an intermittent type. The vibration guideline contains information on 'preferred' and 'maximum' vibration values for assessing human responses to vibration. Consider the relevant 'preferred values' to be the triggers which initiate an assessment of feasible and reasonable mitigation measures under this guideline. See section 3 for guidance in applying these trigger levels.

3 Assessment of noise and vibration impacts

An assessment of rail noise and vibration impacts may be needed as part of an environmental assessment under the *Environmental Planning and Assessment Act 1979* (EP&A Act). It is not the role of this guideline to offer a detailed procedure on how to prepare an environmental assessment. However this section contains detailed advice on the key elements of a noise impact assessment and the following information should be taken into account when preparing such assessments for consideration by the appropriate regulatory or planning authority.

3.1 Applying noise and vibration trigger levels and determining feasible and reasonable mitigation measures

When the noise and vibration trigger levels identified in this guideline and the associated guideline *Assessing vibration: a technical guideline* (DEC 2006) are likely to be exceeded, the noise and vibration assessment should identify feasible and reasonable mitigation. The proponent for the project must prepare this assessment.

> Where the noise trigger levels are exceeded, assess the feasible and reasonable mitigation measures that could be implemented to reduce noise down towards the relevant absolute trigger level. If it is reasonable to achieve these levels, the proponents should do so. If not, then project-specific noise levels should be identified. It is not mandatory to achieve the trigger levels but the assessment should provide justification if they cannot be met. An assessment of the acceptability of residual impacts should also be provided.

A noise mitigation measure is feasible if it can be engineered and is practical to build, given project constraints such as safety and maintenance requirements. Selecting reasonable measures from those that are feasible involves judging whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the mitigation measure. Guidance on the interpretation of feasible and reasonable mitigation measures is provided at Appendix 6 and section 3.5 outlines possible mitigation measures.

For new lines and redevelopments, mitigation strategies should be considered in a hierarchical approach:

1. Controlling noise and vibration at the source.
2. Once the controls at the source are exhausted, controlling the transmission of noise and vibration.
3. Once source and transmission controls are exhausted, considering mitigation measures at the noise-sensitive receivers.

Figure 1 (page 17) outlines the process of using the noise and vibration trigger levels in this guideline and identifying feasible and reasonable mitigation where necessary. It also highlights the need for community involvement throughout the process of determining noise mitigation solutions.

3.2 Community consultation

The NSW rail network is geographically extensive. Large cross-sections of the community come into contact with the network as commuters, residents living along the rail corridor, and communities reliant on freight rail services. In this sense the rail network can be said to have many interactive partnerships. As with all partners, the activities of one can affect or impact on the other. The management of these impacts requires effective public involvement and communication strategies to help everyone understand the impact of rail activities on the community. This is best approached by providing the community with:

- information about proposed rail activities that may affect it
- the opportunity, where appropriate, for input and/or involvement in developments and activities that may affect it
- a means of ongoing communication once rail activities begin (i.e. complaint and response mechanisms).

The *Guidelines for major project community consultation* (DOP 2007) provides advice on community and stakeholder consultation.

Noise-mitigation planning for rail infrastructure projects is greatly assisted by effective community consultation throughout the environmental assessment process. This includes the formal public exhibition phase which invites written submissions in line with the requirements of the EP&A Act. These processes allow the community to participate in any mitigation selection process in a transparent, equitable and consistent way. Effective community involvement is particularly needed where impact assessment finds there will still be noise impacts even after applying all feasible and reasonable mitigation measures.

It is equally important for land-use planning authorities to ensure that existing and planned rail corridor use is considered when making and/or determining land-use planning instruments. This includes rezoning proposals and residential development applications. In this regard, land-use planning authorities are required to consider the *Development near rail corridors and busy roads – interim guideline* (DOP 2008), which sets internal noise levels for new developments. The shared responsibilities of land developers and rail industry need to be effectively managed (see section 1.4.3, page 5).

Figure 1 Typical noise and vibration impact assessment process for light and heavy rail projects

Assessment phase

For a heavy rail line proposal, determine if the project is to be assessed as a 'new' rail line or as a 'redevelopment' as these have different trigger levels. This is not required for light rail projects.

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Identify the area of study (i.e. potentially affected receivers). Predict rail noise and vibration for typical and high-traffic volume uses on the affected areas. Use the relevant noise and vibration trigger levels in tables 1, 2, 3 and 4 to decide if mitigation measures are needed (i.e. is the project likely to exceed those trigger levels?).

↓

If the triggers levels are likely to be exceeded, predict the level of noise and vibration likely to result from the project alone (and the total level of rail noise in the case of a redevelopment) as part of the environmental assessment process. Determine the feasible and reasonable mitigation measures that could be implemented to **reduce noise to reach the absolute trigger levels**.

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Where the absolute trigger levels cannot be met by implementing feasible and reasonable mitigation measures, determine the noise and vibration levels to be applied as project goals. This should be based on the steps above as well as discussions with the community and relevant agencies.

To determine the project-specific noise and vibration goals the following is recommended:

1. Determine the level by which the predicted noise and vibration levels for the project will exceed the triggers. For a redevelopment, this should include considering any change in noise levels (arising from the project) over existing rail noise.
2. Complete an analysis of feasible noise and vibration mitigation measures, then prioritise these to maximise the protection of the acoustic environment.
3. Identify achievable noise and vibration levels for the project taking into account reasonable mitigation measures.
4. Adopt project-specific noise and vibration levels; i.e. values identified from 1 to 4 above, and assign these to the project.
5. Consult with the affected community on the noise and vibration levels for the project and discuss the appropriateness of the achievable noise and vibration levels identified for the project in the environmental assessment and, where applicable, explain why trigger levels cannot reasonably be achieved.

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Planning approval

Proposed noise and vibration levels and/or mitigation measures for the project are considered by approval authorities for inclusion in planning approval conditions**.**

3.3 Preparing a noise impact assessment

This section outlines the areas to be included in an assessment report of the noise and vibration impacts from a light or heavy rail project. The consideration of feasible and reasonable mitigation measures forms part of the project's noise and vibration impact assessment. The extent of work and information required for each step will depend on the expected level of impact: the more significant the likely impact, the more detailed the assessment will need to be.

3.3.1 Shared rail corridor

The advice regarding shared rail corridors is most relevant for heavy rail operations where freight and passenger transport occurs in the same rail corridor and often on the same tracks. Some sections of heavy rail corridor have shared usages (i.e. passengers and freight) and some have shared ownership. In some cases there are dedicated freight lines, but in most cases tracks have shared usage.

Both situations add complexity to assessing the possible noise levels from the corridor and also may restrict the potential range of mitigation measures. In particular, where a large number of freight operators use different types of rolling stock, it becomes increasingly important to consider options such as control of noise at its source.

Where noise assessment needs to be carried out for a rail project in a shared rail corridor, these steps should be followed:

- identify the existing levels of rail noise
- identify the contribution to existing rail noise from each of the different usages (in the case of shared usage, freight compared with passengers) or from each of the different rail infrastructure owners (in the case of multiple owners)
- predict the noise arising from the operation of the rail project
- provide information on both contributed noise levels (distinguishing between shared usage or shared ownership) and the cumulative levels of rail noise, thus allowing relative noise contributions from usage type or owner to be identified.

The process from here on is as described below for any other light or heavy rail project. However, the range of feasible and reasonable mitigation measures considered needs to be appropriate for these operations.

3.3.2 Describe the track layout, sensitive development locations and proposed operations

1. Describe the alignment of the proposed track, including gradient and heights of cuttings and fill, and other track features, such as turnouts or crossovers, that may increase or decrease noise levels. Include diagrams showing the track alignment, land uses along the proposed development, and noise measurement locations. These should be at a scale large enough to delineate individual residential blocks.
2. Estimate rail traffic speeds and operating conditions, such as locomotive throttle settings, braking locations, signalling and safety warning devices including horn noise[1].
3. Identify the types of rolling stock used on track, i.e. not simply 'freight' and 'passenger'.
4. Estimate rail-traffic volumes immediately after commencing operations and at an indicative point in the future (e.g. 10 years or another specified period) after commencement. If traffic volumes are expected to remain steady, e.g. for light rail, explain why this should be so. See point 19 of the technical notes to tables 1, 2 and 3 (page 12) for advice on the assessment scenarios to be considered.

[1] Advice is provided in Appendix 7

5. For heavy and light rail, break this at least into the periods 7 am–10 pm and 10 pm–7 am (see point 20 of technical notes to tables 1, 2 and 3, page 13, if applicable). For heavy rail, specify the proportion of freight trains for each period. Determine the worst-case typical projected volumes over an average seven day week that does not include public holidays (refer to point 9 of technical notes to tables 1, 2 and 3, page 11).
6. Provide details of available and assumed data for the rail infrastructure project, including rail-traffic volumes and speeds, operating conditions, percentage of freight trains by time of day and length of trains (where relevant). Incorporate details of the calculation process, including known and assumed noise source heights for rail vehicles.

3.3.3 Determine the appropriate noise and vibration trigger levels

1. Identify affected land uses adjacent to the proposed rail project. For tunnels, this is the land use above the tunnel.
2. Determine the appropriate airborne noise trigger levels (and if relevant, ground-borne noise and vibration trigger levels) for each section of track. An assessment of vibration or ground-borne noise may not always be required. These should be assessed only where they are likely to be an issue. Where the assessment has established certain noise and/or vibration trigger levels are not appropriate to the project, the reason should be made clear in the assessment report.

3.3.4 Establish the level of existing rail noise and vibration (if present)

1. Monitor noise in the vicinity of the proposed rail project or land-use development using the measurement procedures described in section 3.4 to determine existing rail noise levels. In cases where non-rail noise makes a major contribution to ambient noise in the area, monitoring may be supplemented by calculating the rail noise component. All noise descriptors being used in the assessment should be monitored. These may include $L_{Aeq(1h)}$, $L_{Aeq(15h)}$, $L_{Aeq(9h)}$, L_{Amax}, L_{AE} (sometimes referred to as the 'sound exposure level' or 'SEL') and for vibration these may include instantaneous and/or the root mean square (r.m.s.) vibration levels. Consistent with the advice in *Development near rail corridors and busy roads – interim guideline*, where night-time freight operations occur, it is not sufficient to measure only daytime passenger-train noise levels (refer to section 3.4).
2. Provide details of noise-monitoring procedures, calculations of existing noise levels, or noise-modelling assumptions. This should include noise-measurement data from each site and rail traffic volumes and speeds, operating conditions and proportions of freight trains (where relevant). It should also include, where relevant, notes on atmospheric conditions, octaves for predicting noise, and topography and ground conditions between the noise source and the receivers. Where estimates of existing levels of rail noise are made, include information on the calculation procedure, including the assumptions used.

3.3.5 Predict the noise and vibration levels of the rail infrastructure proposal

1. Impact predictions should be conducted for the proposed commencement date and an indicative period into the future (e.g. 10 years or another specified period). These should be an estimate of projected traffic volumes that represent the expected future typical level of rail traffic usage. This includes reasonable maximum usages and not just average use, represented by the worst-case typical day (refer to point 9 of technical notes to tables 1, 2 and 3, page 11). Where this information is unavailable, the proponent should provide justification for the data used in the assessment. Natural growth of rail traffic noise that may have occurred if the project had *not* proceeded should be included for the 'no-build option'. See point 19 of the technical notes under tables 1, 2 and 3 (page 12). If mitigation measures are being proposed, the predictions should be for both the before and after mitigation periods. Some predictive models are discussed in Appendix 8.
2. The separate contribution of noise and, if relevant, vibration levels from different types of use (e.g. freight or passenger), should be calculated and reported. The total or combined noise and, if relevant, vibration levels should also be reported.
3. Clearly state all assumptions used in the prediction, and quote the expected accuracy along with the final predicted levels.
4. Calculate noise levels (including ground-borne noise and/or vibration where relevant), expressed in terms of the required descriptors, for each receiver (or representative group of receivers), assuming that no noise amelioration measures are introduced. Calculated levels should include noise from rail traffic on the new development and on any other track which may influence the total rail traffic noise level at the receiver.
5. Noise-level contributions from freight and passenger rail traffic, where relevant, should be reported separately along with the total rail noise. The increase in rail noise due to the project should also be reported.
6. Although the effect of weather on noise predictions is generally negligible for nearby rail receivers, where the predictive model has provision for specifying meteorological conditions, these should be set to zero wind speed, zero degrees Celsius per 100 metre atmospheric temperature gradient, 15°C and 70 per cent relative humidity. Similarly hard ground should be specified between rail and receiver where selection of the ground type is an option. Any deviation should be justified; for example, due to limitations of noise modelling software.

   Where alternative modelling factors are used, justification is to be given for their selection.

3.3.6 Identify potential mitigation measures

1. Mitigation measures should be considered in a hierarchical approach as outlined in section 3.1. This ensures mitigation options likely to offer the greatest benefit to the largest number of affected receivers are considered before more localised mitigation options. Where the predicted noise and/or vibration levels exceed the trigger levels, mitigation measures should be investigated. Examples of these include:
   - using alternative track alignments
   - controlling rail traffic (e.g. limiting times or speed)
   - using track measures (e.g. special track forms, rail fasteners) and potential operational measures (e.g. rail grinding)
   - identifying the rolling stock producing the highest levels of noise or vibration and taking action to rectify this
   - restricting the type of rolling stock (e.g. based on noise-emission levels)

- using rolling stock measures (e.g. maintain rolling stock to reduce noise emissions and retrofit noise mitigation where appropriate)
- constructing noise barriers or bunds
- treating the façade of residential buildings where night-time noise levels are the major concern to reduce internal noise levels in sleeping areas.

2. Provide a description of all mitigation measures proposed and the reasons these particular measures were selected. Reasons for omitting or dismissing mitigation options should also be discussed.
3. For the mitigation measures selected, recalculate noise levels taking into account their effect.
4. Provide a diagram showing noise level contours, or other methods of presenting the calculated noise level at each receiver, both with and without mitigation measures.
5. Report the noise and vibration levels the project can achieve after applying all feasible and reasonable mitigation measures. These are the project-specific levels that may be considered by an approval authority in assessing a project.
6. Where the relevant noise and vibration trigger levels will not be met at each receiver after applying all feasible and reasonable mitigation measures, quantify the residual level of noise and vibration impacts. Data should also be made available for each receiver, particularly where not all noise receivers are to receive mitigation.
7. In cases where (after the levels are calculated as set out above and mitigation measures evaluated) it is considered impractical to meet the noise trigger levels, provide an assessment demonstrating how all feasible and reasonable measures have been considered. An assessment of the acceptability of residual impacts should also be provided in such cases.

3.3.7 Develop a monitoring regime

Select an adequate number of representative locations along the length of the new or modified railway at which it is appropriate to later assess compliance, and present these along with the expected noise and vibration levels in a tabulated form.

A minimum of three sites is recommended, although the appropriate number would depend on the length and location of the project and should be determined in consultation with the planning authority.

3.4 Measuring existing levels of rail noise and vibration

The existing levels of rail noise and vibration will need to be measured when an assessment of the noise and vibration levels from a rail project is carried out. All measurements undertaken as part of a rail noise assessment should be accompanied by at least the following information:

- details of the equipment used (including last date of calibration) and equipment settings
- levels of accuracy of measurements
- relevant standards
- details of the location of measurement and the positioning of equipment
- details of operations and activities being measured, including the actual monitored train speeds
- where internal levels – noise and vibration – have been determined on the basis of external measurements, the method used, the accuracy of the method and all assumptions made
- a description of the dominant and background noise and vibration sources at the site.

3.4.1 Airborne noise

Procedures for measuring rail noise levels at receivers in terms of L_{Amax}, L_{Aeq} and third-octave band L_{max} levels are set out in *AS2377: Acoustics – methods for the measurement of railbound vehicle noise* (Standards Australia 2002). Note that this standard requires free-field rather than façade measurements of receptor impact. The external noise trigger levels in tables 1, 2 and 3 (pages 9−10) apply at the façade, and an appropriate adjustment will need to be applied (see technical notes to the tables on pages 10−13).

AS2377 outlines the meteorological conditions suitable for measuring rail noise. However, note that, following periods of inclement weather, wheel-rail discontinuities promoted by wheel and track slippage may be created, potentially leading to higher noise levels than would otherwise be the case.

The principal impacts of rail noise will be experienced relatively close to the rail line, although meteorological effects (e.g. winds and temperature inversions) can promote the propagation of noise. These should be taken into account when considering receivers at distances greater than 300 m. This is typically only an issue in rural areas where there are no residents in the near-vicinity of the line.

The conditions during the survey should be representative of typical rail noise events and sufficient details noted, including (but not limited to):

- the nature of the operation including rolling stock type and the number of movements, the time period when operation takes place, the number of cars, direction, track-form, operating speed and local features or events that can influence measurements. The relevant rail agency should be consulted to determine whether the monitoring period is representative of normal operation
- the character of the source, including the condition of the rolling stock and track, noting any discernible noise sources and/or defects that influence the measurements
- the weather conditions and site specific issues such as distance to the track and sensitive receivers, background noise and topography, including the presence of reflective surfaces and nature of the ground cover.

The duration and the number of noise measurements required to obtain a representative sample will be influenced by these factors. The duration of a survey to measure the noise of passenger trains on a busy line for example, is likely to be less than that for a survey of freight trains due to the number of pass-by events.

3.4.1.1 Determining the $L_{Aeq(T)}$ of rail vehicle movements

$L_{Aeq(T)}$ over the relevant time period T (e.g. day, night) is generally determined on the basis of measurements of individual movements in terms of $L_{Aeq(i)}$ or the A-weighted sound exposure level (L_{AEi}). The use of the L_{AEi} approach is recommended as it is less prone to errors. It is important to obtain a representative L_{AEi} measurement at the location of the most-affected receiver for each type of rail pass-by event likely to occur at the section of track measured. A rail pass-by event is defined by the type of vehicle and track (e.g. Tangara on near track, coal train on far track). This would involve first determining the types of vehicles likely to use the section of track and then taking sufficient measurements of each type of rail event. A representative L_{AEi} may then be determined by logarithmically averaging the individual measurements. Other information required before $L_{Aeq(T)}$ can be determined includes the number of each type of pass-by event likely to occur at the site over time period T.

Equation using LAEi

$$L_{Aeq(T)} = 10\log_{10}\frac{1}{T}\sum_{i=1}^{N}\left(n_i \times 10^{\left(\frac{LAE_i}{10}\right)}\right)$$

where:

- T is the total time in the relevant period in seconds (i.e. hours × 60 × 60)
- n_i is the number of events in each type of event (i.e. the number of Tangaras, the number of coal trains etc)
- N is the number of types of events (e.g. Tangaras and coal trains would be two types of events)
- L_{AEi} is the representative event L_{AE} of each type of event as determined from individual measurements at the most-affected receiver, which is then summed over the different type of events occurring at the site.

The relationship between the L_{eq} value produced by an event over a period of time, and the L_{AE} value for the event is given by:

- $L_{AE} = L_{Aeq(period)} + 10 \log_{10} T$

3.4.1.2 Determining L_{Amax} at a site

L_{Amax} measurements are required when assessing airborne levels and are measured by using the 'fast' response setting on a sound-level meter.

Noise from individual trains can vary for a number of reasons, including the condition of the wheels. When L_{Amax} levels are reported under this guideline, the noise levels from rail pass-bys equivalent to the L_{Amax} levels from the 50th and 95th percentiles of rail pass-bys should be reported. In determining the 50th and 95th percentile L_{Amax} levels, sufficient sample measurements (minimum of 20) to ensure a robust statistical analysis are required. Similarly, where measurement is not feasible and predictive modelling is used, the modelling must be shown to be sufficiently rigorous to provide a reliable result.

3.4.2 Ground-borne noise

For the purposes of this guideline, ground-borne noise levels should be measured (or determined) near to − but not at the centre of − the most-affected noise-sensitive room. The L_{Amax} noise descriptor and the 'slow' time response setting on the sound-level meter should be used. The 'most-affected noise-sensitive room' means the room where the structure-borne noise is the most significant, either in overall level, frequency spectrum or the time at which it occurs.

In some situations, it may not be possible to measure the ground-borne noise levels directly with a sound level meter due to the presence of extraneous noise. In these situations, measurement of ground-borne vibration levels could provide an estimate of the ground-borne noise level. If this method is adopted, all assumptions should be stated.

Ground-borne noise from individual trains can vary for a number of reasons including the condition of the wheels. When ground-borne L_{Amax} levels are reported under this guideline, the ground-borne noise levels from rail pass-bys equivalent to the ground-borne L_{Amax} levels from the 50th and 95th percentiles of rail pass-bys should be reported. In determining the 50th and 95th percentile ground-borne L_{Amax} levels, sufficient sample measurements to ensure a robust statistical analysis are required. Similarly, where measurement is not feasible and predictive modelling is used, the modelling must be shown to be sufficiently rigorous to provide a reliable result.

Further information on measuring ground-borne noise is contained in ISO 14837 *Mechanical vibration – ground-borne noise and vibration arising from rail systems* (ISO 2005). Another useful reference is the US Federal Transit Administration's *Transit noise and vibration impact assessment manual* (FTA 2006).

3.4.3 Vibration

Methods for measuring vibration from rail operations are covered in a separate guideline: *Assessing vibration: a technical guideline* (DEC 2006).

3.5 Mitigating noise from railways

This section gives a broad overview of ways to mitigate noise from rail operations. It is not intended to be prescriptive guidance. It will be the responsibility of the proponent to demonstrate the selected mitigation measures are appropriate, and to justify any mitigation measures proposed (or disregarded) as part of a noise impact assessment. This advice provides useful guidance to developers of rail infrastructure and rail traffic-generating developments to consider during the early stages of planning and design.

3.5.1 Types of mitigation measures

Measures for reducing noise and vibration impacts from railway operations follow three main control strategies:

- by reducing noise and vibration at the source
- in transmission to the receiver
- at the receiver.

These control strategies should be considered in a hierarchical way so that all the measures which reduce noise for a large number of receivers are exhausted before more localised mitigation measures are considered.

The scope for applying feasible and reasonable mitigation measures to existing railway corridors is generally more limited and potentially more costly than for new rail developments in greenfields. Implementing effective noise-management strategies is an integral part of the planning phase for rail projects and is potentially a cost-saving approach compared to retrospective mitigation.

3.5.1.1 Controlling noise and vibration at the source

For new rail line developments it is important that the route is carefully selected to avoid creating noise impacts. Particular attention should be paid to the proposed rail line's location in relation to existing and planned residential areas, and the possibility of using existing topographical features to mitigate noise.

Keeping rail vehicles and tracks well maintained is important and this should be given high priority in any mitigation strategy. Other types of sources that should be given high priority are those with annoying characteristics (e.g. tonality, impulsiveness). These include wheel squeal, brake squeal and the noise from track joints and turnouts as they generally evoke a strong community reaction. Noise mitigation that reduces these annoying characteristics would provide a benefit to the community, even where there may be no measurable changes in noise levels.

Examples of mitigation measures for noise and vibration at the source include:

- track measures − minimising sharp curves to reduce wheel squeal, rail grinding, welding to smooth discontinuities, lubrication, use of soft rail pads, and relocation of signals or turnouts to minimise impacts on sensitive receivers
- rolling stock measures − effective muffling of diesel locomotive exhaust noise, wheel truing, on-board wheel lubrication, use of disc brakes, dampening of wheels, use of resilient wheels, wheel vibration absorbers, low-squeal brake blocks and using rolling stock that meets noise limit requirements in environment protection licences.

Ideally, rolling stock should comprise locomotives that operate according to best practice and, where relevant, comply with the noise conditions in licences issued by NSW Environment Protection Authority. Application of best practices includes:

- scheduling noisy operations at the least-sensitive times
- selective use of certain tracks
- keeping equipment well maintained
- siting noisy operations behind structures
- employing ‘quiet’ practices when operating equipment
- running staff education programs on the need to avoid unnecessary noise.

As both track and rolling stock factors contribute to rolling noise, mitigation needs to address both to be effective. For example, the noise control achieved by just applying track mitigation measures is only as effective as the condition of the rolling stock that is using the track.

Reducing vibration levels and ground-borne noise can be achieved by including resilient elements in the tracks, such as rail pads or rubber mats inserted between the ballast and tunnel floor or on other types of sufficiently rigid supporting structures, such as steel bridges.

3.5.1.2 Controlling noise and vibration in transmission

This involves restricting the propagation of noise and/or vibration. Such measures include using noise barriers, installing resilient baseplates and ballast mats, and noise treatment of bridges.

Barriers should be used selectively. They are a high-cost approach and their effectiveness in controlling impacts will depend on the situation. Barriers are more effective if they are near the source or the receiver. Their effectiveness is also determined by their height, the material used (absorptive or reflective) and their density. The relationship of these design features to attenuation is well documented.

Barriers can take a number of forms, including freestanding walls, grass or earth mounds or bunds, and trenches or cuttings within which noise sources are sited.

3.5.1.3 Controlling noise and vibration at the receiver

Rail lines are an essential part of our urban infrastructure. Even after putting feasible and reasonable mitigation measures in place to manage the noise at its source, sometimes complementary management at the point of impact may be required. This might be due to the closeness of affected premises or physical, operational and economic constraints. Mitigation at the receiver is included among feasible and reasonable mitigation measures. Where new residential development is planned to occur around a rail line, appropriate building design, layout and construction techniques should be applied. This is to minimise noise intrusion and ensure sleeping areas are suitably shielded from high levels of noise. Land-use planning authorities are required to consider the *Development near rail corridors and busy roads – interim guideline* which sets mandatory internal noise levels for bedrooms and other ‘habitable’ rooms for new residential and other sensitive developments along rail lines.

Where a proposed rail development will affect an existing or approved development, treatment of buildings at the property (e.g. insulation, window-glazing for noise reduction, upgrading construction) can be considered as an option to mitigate noise. For this to be effective, an appropriate ventilation system, such as air conditioning (one that does not compromise the effect of noise insulation), often needs to be incorporated into the design. The *Development near rail corridors and busy roads – interim guideline* provides guidance on mitigation measures that could be a useful point of reference for retrospective mitigation.

Proponents may wish to utilise the following matrix, or develop a similar decision-making tool, to determine and justify what mitigation measures are feasible and reasonable. This may be taken into account by the planning authority.

Table 5 Example of 'Feasible and Reasonable' mitigation decision-making matrix for inclusion within an Environmental Impact Assessment

Mitigation option	Feasible mitigation test	Reasonable mitigation test	Justification for adopting or disregarding this option
Mitigation at the source • Option 1 • Option 2 etc.	Comment on whether the option under consideration is feasible. Refer to Appendix 6 for further advice.	Comment on whether the option under consideration is reasonable. Refer to Appendix 6 for further advice.	Provide details why the particular option under consideration will be included or disregarded, based on: • the noise impacts with and without the option • the noise mitigation benefits • the cost effectiveness of noise mitigation • community views. Refer to Appendix 6 for further advice.
Mitigation in the transmission path to the receiver • Option 1 • Option 2 etc.			
Mitigation at the receiver • Option 1 • Option 2 etc.			

Appendix 1 Rail noise initiatives

This guideline is one component of a range of actions to reduce rail noise. Other elements include:

- A **noise abatement program** to address existing acute levels of noise from the rail system on a priority basis. When implemented, this program will specify agreed methods for assessing and prioritising requests for mitigation from sensitive receivers.
- An **environmental planning guideline** – the *State environment planning policy (Infrastructure) 2007* for new residential and noise-sensitive developments alongside rail lines requires noise and vibration mitigation measures to be considered to meet mandatory internal noise levels. The SEPP specifies internal noise levels of 35 dB(A) $L_{Aeq(9h)}$ for bedrooms during night-time and 40 dB(A) $L_{Aeq(9h)}$ for other habitable rooms. *Development near rail corridors and busy roads − interim guideline* (DOP 2008) provides advice to developers on how to achieve these levels.
- An initiative led by the Rail Industry Safety and Standards Board to develop national **rolling stock standards** to reduce noise and other emissions from these sources.

Appendix 2 Environmental assessment requirements for rail traffic-generating developments

Land-use developments other than rail projects that are likely to generate additional rail traffic on an existing rail network should be assessed against the following requirements:

- Identify the typical offset distance/s of sensitive receivers from the rail line/s that are likely to be affected by increased rail movements.
- Quantify the existing level of rail noise at the offset distance/s identified above using the noise descriptors $L_{Aeq,15/9hr}$ and L_{Amax} (95th percentile) dB(A).
- Predict the cumulative rail noise level (i.e. from the existing and proposed rail movements) using a calibrated noise model (based on predicted increased rail movements) at the offset distances identified above.
- Compare the cumulative noise level with the rail noise assessment trigger levels: $L_{Aeq,15hr}$ 65 dB(A), $L_{Aeq,9hr}$ 60 dB(A), and L_{Amax} (95th percentile) 85 dB(A).
- Implement all feasible and reasonable noise mitigation measures where the cumulative noise level exceeds the noise assessment trigger levels and project-related noise increases are predicted.
- Where the L_{Aeq} noise level increases are more than 2 dB(A), which is equivalent to approximately 60 per cent of the total line or corridor rail traffic, and exceeds the relevant noise assessment trigger level, strong justification should be provided as to why it is not feasible or reasonable to reduce the increase.

Notes

1. A project-related noise increase is an increase of more than 0.5 dB over the day or night periods.
2. The geographical extent of the rail noise assessment ideally should be where project-related rail noise increases are less than 0.5 dB. This roughly equates to where project-related rail traffic represents less than 10 per cent of the total line or corridor rail traffic.
3. Guidance on the concept of 'feasible and reasonable' is outlined in Appendix 6.

Mitigating noise from rail traffic-generating developments

For a traffic-generating development like a coal mine, the proponent would not have control over the public rail infrastructure. Consequently they would have limited opportunities to implement mitigation, such as noise barriers. In such cases, control of noise and vibration at the source is the most effective means of mitigation. However, the land-use developer responsible for the additional rail traffic (such as a mine, quarry or industrial site) could contract to a rail service provider who would use best practice rolling stock, including locomotives approved to operate on the NSW rail network in accordance with environment protection licences issued by the EPA. At property (architectural) treatments should be considered for affected receivers, if reasonable.

Appendix 3 Non-network rail lines on or exclusively servicing industrial sites

Rail related activities (such as movement of rolling stock on rail loops or sidings, loading and shunting activities etc) occurring within the boundary of an industrial premises as defined in an environment protection licence are to be assessed as part of the industrial premises using the *NSW Industrial noise policy* (EPA, 2000) (INP).

Where a non-network rail line exclusively servicing one or more industrial sites extends beyond the boundary of the industrial premises, noise from this section of track should be assessed against the recommended acceptable L_{Aeq} noise levels from industrial noise sources for the relevant receiver type and indicative noise amenity area in Table 2.1 of the INP reproduced below.

Table 6 Recommended L_{Aeq} noise levels from industrial noise sources

Type of receiver	Indicative noise amenity	Time of day	L_{Aeq} noise level dB(A)	
			Acceptable	Recommended maximum
Residence	Rural	Day	50	55
		Evening	45	50
		Night	40	45
	Suburban	Day	55	60
		Evening	45	50
		Night	40	45
	Urban	Day	60	65
		Evening	50	55
		Night	45	50
	Urban/Industrial Interface – for existing situations	Day	65	70
		Evening	55	60
		Night	50	55
School classroom – internal	All	Noisiest 1-hr period when in use	35	40
Hospital ward − internal − external	 All All	Noisiest 1-hr period	 35 50	 40 55
Place of worship – internal	All	When in use	40	45
Area specifically reserved for passive recreation (e.g. national park)	All	When in use	50	55
Active recreation area (e.g. school playground, golf course)	All	When in use	55	60
Commercial premises	All	When in use	65	70
Industrial premises	All	When in use	70	75

Where the relevant noise level in Table 6 is exceeded, the proponent should consider feasible and reasonable action to reduce the noise down towards these levels and the noise impact assessment should provide justification if they cannot be met. There are several reasons for assessing the noise impacts of non-network rail lines extending beyond industrial sites using the identified trigger levels. These are:

- noise impacts from a freight line extending beyond an industrial site should be assessed in a manner consistent with other rail lines, which are not a continuous noise source (see tables 1 and 2)
- a more stringent noise trigger level for a non-network rail line is considered appropriate as the activity is not public infrastructure delivering as many public benefits as the rail network
- there is a greater range of opportunities to mitigate and effectively manage noise from non-network lines compared to noise on the NSW rail network.

Non-network rail lines servicing one or more industrial sites should develop a noise and vibration management plan, to be approved by the relevant planning authority. The following specific noise measures should be considered as part of this plan:

- noise control should be maximised during the design stage through route selection and physical mitigation including maximising the distance between the rail line and noise sensitive land-uses where practicable, including the use of cuttings and noise barriers where feasible and reasonable
- track design should avoid intermittent noise associated with the interaction of track and rolling stock (e.g. wheel squeal)
- rolling stock permitted to use the line should be restricted to locomotives that when they were new or substantially modified were approved to operate under an environment protection licence or a Pollution Control Approval pursuant to the former *Pollution Control Act 1970*
- timetabling of freight movement should minimise operation during sensitive evening and night periods, where possible
- locomotives should operate at lower speeds to reduce noise emissions
- drivers should be trained to minimise engine idling and unnecessary use of train horns as part of operating conditions.

3.1 Procedure for assessing non-network rail lines on or exclusively servicing industrial sites

When assessing non-network rail lines on or exclusively servicing industrial sites that extend beyond the boundary of licensed premises to a network line, the following procedures apply:

- use the noise levels identified in Table 6 for this section of track
- consider the relevant technical notes under tables 1, 2 and 3 (pages 10–13)
- the meteorological provisions in Section 5 of the *NSW Industrial noise policy* (EPA, 2000) apply, but the provisions of Section 4 of this policy ('modifying factor' adjustments) should be disregarded
- an environmental impact assessment for a non-network rail line should address the relevant matters outlined in section 3.3 to 3.5
- vibration should be assessed in accordance with the advice set out in section 2.6.

Appendix 4 Comparison of airborne noise levels for rail operations in Australia and overseas

Criteria are generally set for new or planned developments but may also be applied to existing operations (as in Switzerland) as well as to guide when action is required to reduce noise levels (see the alarm/priority criteria used in Denmark, the Netherlands, Norway, the United Kingdom, Switzerland and Canada). The criteria for existing operations are typically set at 5 dB above those for new or planned developments. Where alarm/priority criteria are set, these are 5–10 dB above the criteria for existing operations; where criteria have not been set for existing situations, the alarm/priority criteria are 5–10 dB above those set for new or planned developments.

Alarm/priority criteria shown in the table below are typically the legislated noise levels that require ameliorative action by government agencies or proponents, such as noise barriers or building treatments.

The levels used overseas are mostly legislated levels, whereas NSW noise trigger levels are non-mandatory targets that can be used to initiate an assessment of noise impacts and consideration of feasible and reasonable mitigation measures.

Table 7 Comparison of airborne rail noise criteria

Country	Existing rail line or redevelopment of existing line, dB	New rail line, dB	Alarm/ priority, dB	Comments
Australia				
New South Wales	65 $L_{Aeq(day)}$ 60 $L_{Aeq(night)}$ 85 L_{Amax}	60 $L_{Aeq(day)}$ 55 $L_{Aeq(night)}$ 80 L_{Amax}	n/a	Triggers for assessment purposes. Light rail triggers are set at 60/50 dB $L_{Aeq\ (day,night)}$ and 80 dB L_{Amax}
Victoria	65 $L_{Aeq(day)}$ 60 $L_{Aeq(night)}$ 85 L_{Amax}	60 $L_{Aeq(day)}$ 55 $L_{Aeq(night)}$ 80 L_{Amax}		The *Passenger Rail Infrastructure Noise Policy* (April 2013) aims to guide transport bodies and planning authorities in their consideration of rail noise and identifies thresholds above which action should be taken to minimise or mitigate noise.
South Australia	65 $L_{Aeqday)}$ 60 $L_{Aeq(night)}$ 85 L_{Amax}	60 $L_{Aeq(day)}$ 55 $L_{Aeq(night)}$ 80 L_{Amax}	n/a	The *Guidelines for the assessment of noise from rail infrastructure* (April 2013) provide guidelines for the assessment of noise from rail operations. They give advice for development proposals and local plans, and underpin operating conditions for activities licensed under the *Environment Protection Act 1993.*
Queensland	*Planning levels* (to be progressively achieved) 65 $L_{Aeq(24h)}$ 87 L_{Amax} * *Interim levels* (to be achieved now) 70 $L_{Aeq(24h)}$ 95 L_{Amax}*	Planning Levels 65 $L_{Aeq(24h)}$ 87 L_{Amax} *	n/a	The *Code of practice for railway noise management, 2007* (version 2) was developed by Queensland Rail to demonstrate compliance with general environmental duty under the *Environment Protection Act 1994*. The code has been approved for use by the State Minister for Environment under section 548 of the Act. New noise-sensitive developments proposed alongside rail corridors need to meet criteria set out in the Queensland Development Code (MP 4.4) which includes internal noise limits. *The L_{Amax} is assessed as a single event maximum level and is defined as the arithmetic average of the highest 15 maximum levels over a given 24-hour period.

Country	Existing rail line or redevelopment of existing line, dB	New rail line, dB	Alarm/ priority, dB	Comments
Tasmania	*Planning levels* 65 $L_{Aeq(24h)}$ 87 L_{Amax} *Interim levels* 70 $L_{Aeq(24h)}$ 95 L_{Amax}	65 $L_{Aeq(24h)}$ 87 L_{Amax}	n/a	No formal criteria relating to rail. Freight services only operate in Tasmania and these use current Queensland criteria.
Western Australia	Major upgrades are dealt with on a case basis.	55−60 $L_{Aeq(day)}$ 50−55 $L_{Aeq(night)}$	n/a	Under *WA State Planning Policy 5.4 Sept. 2009,* assessment is triggered at the lower level known as the *noise target*. The upper levels are *noise limits* above which noise-reduction measures need to be implemented. Assessments need to assume one train per hour at night which indirectly reduces maximum noise. New noise-sensitive development near existing rail lines needs to meet criteria for new rail lines.
European countries				
Austria	n/a	65–70 $L_{Aeq(day)}$ 55–60 $L_{Aeq(night)}$	n/a	Includes 5 dB bonus[1].
Denmark	n/a	63 $L_{Aeq(24h)}$ 85 L_{Amax}	68 $L_{Aeq(24h)}$ – insulation trigger	Includes 5 dB bonus. At 68 dB(A) the owner must contribute 50 per cent to cost of insulation, 25 per cent at 73 dB(A) and 10 per cent at < 78 dB(A).
Finland	n/a	58 $L_{Aeq(day)}$ 53 $L_{Aeq(night)}$	n/a	
France	n/a	63 (60) $L_{Aeq(day)}$ 58 (55) $L_{Aeq(night)}$	n/a	Bracketed values are for TGV lines.
Germany	Planning values for new dwellings: 58–63 $L_{Aeq(day)}$ 48–53 $L_{Aeq(night)}$	67 $L_{Aeq(day)}$ 57 $L_{Aeq(night)}$	n/a	Includes 5 dB bonus.
The Netherlands	n/a	63 $L_{Aeq(day)}$ 58 $L_{Aeq(evening)}$ 53 $L_{Aeq(night)}$	68 L_{Aeq} (at this level the state is responsible for correcting noise problem) 73 L_{Aeq} absolute maximum level allowed and only provided an indoor level of 40 L_{Aeq} can be met.	Includes 5 dB bonus.

[1] Criteria for rail are generally 5 dB higher than those for road as rail is considered less annoying.

Country	Existing rail line or redevelopment of existing line, dB	New rail line, dB	Alarm/ priority, dB	Comments
Norway	n/a	55–60 $L_{Aeq(24h)}$ 80 L_{Amax} 45–55 L_{Amax} (indoors)	Pay out at $L_{Aeq(24h)}$ > 65 or L_{Amax} > 90 Otherwise if resident does not agree, then insulate to $L_{Aeq(24h)}$ < 35 and L_{Amax} < 55	
Sweden	n/a	58 $L_{Aeq(24h)}$ 45 L_{Amax} (indoors)	n/a	
Switzerland	60-65 $L_{Aeq(day)}$ 50-55 $L_{Aeq(night)}$ 'Impact threshold' Levels below this considered to have no impacts.	55-60 $L_{Aeq(day)}$ 45-50 $L_{Aeq(night)}$ 'Planning value' Levels for design of new developments	70 $L_{Aeq(day)}$ 65 $L_{Aeq(night)}$ 'Alarm values' levels at which assessment of remediation is required.	Levels presented are for residential classifications of which there are two – more sensitive zones are 5 dB lower than the less sensitive zones. For commercial and industrial add 5 and 10 dB, respectively. Railway bonus 5 to 15 dB depending on number of trains: the higher the number the lower the bonus. The levels quoted allow a 5 dB bonus.
United Kingdom	n/a	n/a	68 $L_{Aeq(day)}$ 63 $L_{Aeq(night)}$	Criteria used to determine insulation requirements.
North America				
Canada	n/a	35 $L_{Aeq(night)}$ (bedroom) 40 $L_{Aeq(day)}$ (living areas) 55 $L_{Aeq(day)}$ (outdoor)	n/a	
United States	n/a	52–65 $L_{Aeq\ (1h)}$ (serenity) 52–65 L_{Adn} (residences) 57–70 $L_{Aeq\ (1h)}$ (schools etc.) (5 dB onset adjustment for high-speed maglev [magnetic levitation] operations)	n/a	Depends on existing noise levels. Criteria stated vary, as corresponding existing noise levels vary from 43–63 dB(A). Criteria represent onset of impact and also are cumulative levels (i.e. existing plus new).
Asia				
Hong Kong	n/a	60 $L_{Aeq(30\ min)}$ (day and evening) 50 $L_{Aeq(30\ min)}$ (night) 85 L_{Amax} (night)	n/a	Values given for residential areas not affected by other noise sources. For increasingly affected areas add 5 and 10 dB to the L_{Aeq} criteria.
Japan	n/a	70 L_{Apeak} (residential) 75 L_{Apeak} (commercial, industrial with residences)	n/a	For the Shinkansen Superexpress railway. Measured as the energy mean of the highest 10 out of 20 successive train measurements between 6 am and midnight (with meter set to slow response).

[1] Criteria for rail are generally 5 dB higher than those for road as rail is considered less annoying.

Appendix 5 Studies in reactions to noise

5.1 Noise and annoyance

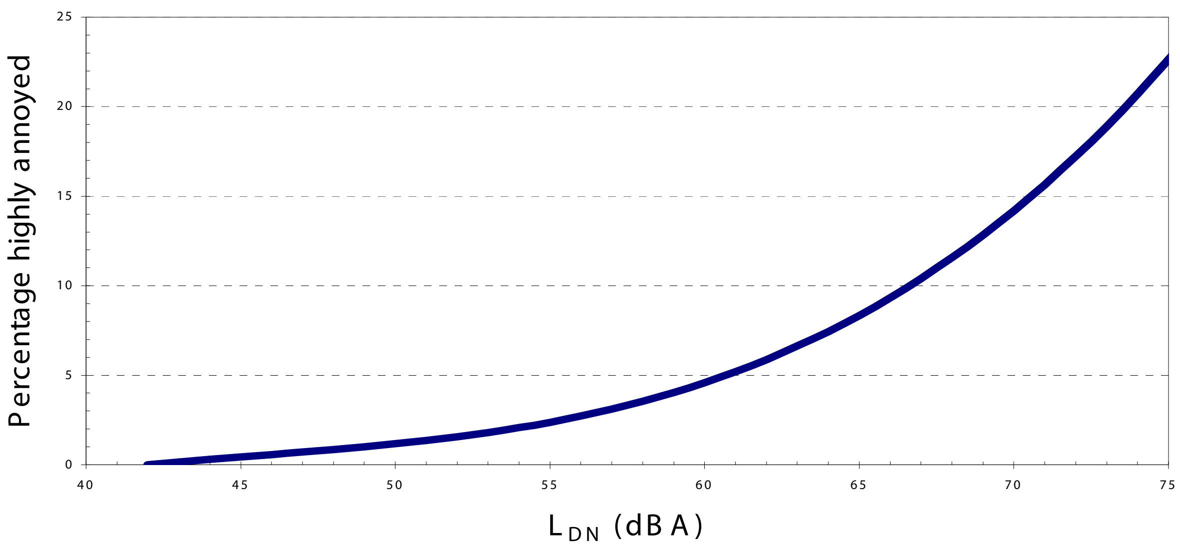
Social survey research over the last 30 years in various countries has shown that reaction to noise varies widely from individual to individual. Because of this, it is not possible to adopt noise levels that will guarantee no one will experience an impact.

The trigger levels in this document (see section 2) aim to protect at least 90 per cent of the population living in the vicinity of rail lines from being highly annoyed by rail noise. This approach is consistent with that applied to road traffic noise but acknowledges that rail is generally accepted to be less annoying than road noise at the same level.

The absolute L_{Aeq} rail noise trigger levels for heavy rail in this guideline are based on social survey research and national practices. Research by Miedema and Oudshoorn (2001), illustrated in Figure 2 (below), provides the basis for considering the level of noise that creates community annoyance and informs the airborne noise trigger levels in table 1 (page 9).

The LDN (Day−Night average sound level) shown in Figure 2 measures the average noise energy over a 24-hour period and applies a 10 dB penalty to night-time noise to take account of increased annoyance at night. Figure 2 presents the percentage of people reporting high annoyance to rail noise against a range of noise levels. It shows that more than 10 per cent of people report high annoyance to noise when it exceeds approximately 67 L_{DN} (dBA).

Figure 2 Percentage highly annoyed vs L_{DN} for rail noise (Miedema & Oudshoorn 2001)



The L_{DN} descriptors used in the work of Miedema and Oudshoorn are not generally used in Australia. Figure 3 (page 35) demonstrates how these compare to the descriptors of $L_{Aeq(15h)}$ and $L_{Aeq(9h)}$ used in this guideline. The trigger values of 65 dB(A) $L_{eq(15hr)}$ and 60 dB(A) $L_{eq(9hr)}$ used in table 1 (page 9) of this guideline for heavy rail redevelopments, correlate to protecting approximately 90 per cent of receivers from being highly annoyed by rail noise.

Figure 3 Example of differences between some noise descriptors

The following example demonstrates the variation in decibels for different descriptors. An $L_{Aeq(15hr)}$ 65 dB(A) and $L_{Aeq(9hr)}$ 60 dB(A) correlates with a value of 63.7 dB(A) for $L_{Aeq(24hr)}$ and a value of 67.5 dB(A) for L_{DN}.

dB(A)	
$L_{Aeq(15hr)}$ 65	$L_{Aeq(9hr)}$ 60
$\equiv L_{Aeq(24hr)}$ 63.7	
$\equiv L_{DN}$ 67.5	

$$L_{Aeq(24hr)} = 10\log\left(10^{6.5} * \frac{15}{24}\right) + \left(10^{6.0} * \frac{9}{24}\right) = 63.7\text{dB(A)}$$

$$L_{DN} = 10\log\left(10^{6.5} * \frac{15}{24}\right) + \left(10^{7.0} * \frac{9}{24}\right) = 67.5\text{dB(A)}$$

The L_{DN} calculation adds a 10 dB penalty to the night- time period.

5.2 Health effects of noise exposures

Several studies have shown that excessive noise from transport modes can lead to sleep disturbance and other health impacts, not just annoyance. Recent research − WHO 2011, Bluhm et al 2007, Muzet 2007, Grazuleviciene et al 2004, − supports earlier findings that the shorter-term health effects of sleep disturbance due to excessive noise exposure can affect quality of life during the subsequent waking hours. Symptoms may include fatigue, moodiness, irritability, headaches, stomach upsets, lack of concentration and reduced work ability, but these symptoms can be associated with many other causes. These shorter-term effects do not appear to be reduced through repeated exposure and habituation.

There is also evidence that noise has an effect on children's learning ability (enHealth Council 2004). The study reported that children exposed to high levels of environmental noise may display sustained and visual attention deficits, difficulty concentrating, reduced auditory discrimination and speech perception, poorer memory that requires high processing demands of semantic material, and reduced reading ability and school performance on national standardised tests.

Longer-term effects on health are more difficult to quantify, although links have been confirmed between noise exposure and health impacts (WHO 1999, 2009, 2011, enHealth Council 2004).

A summary of the current literature concerning sleep disturbance due to noise indicates several characteristics that influence sleep disturbance. They are the number of noisy events heard distinctly above the background level, the emergence of these events and the highest noise level.

When developing the *Night noise guidelines for Europe* (WHO 2009), the WHO European office reviewed available research to examine the effects of night noise on sleep and the relationship between sleep and health. The review concluded there is sufficient evidence to indicate night noise is related to sleep disturbance and disturbed sleep is associated with a number of adverse effects on health. Based on this review, the WHO recommends an interim target of 55 dB(A) for airborne noise. This is an indicator of long-term health effects and is a representation of a one year external L_{Aeq} over an eight-hour (night) period and cannot be compared directly with the noise trigger levels within this guideline.

L_{Aeq}, which is the energy average level of a noise signal over a given period, accounts for the number and level of the louder events in a signal. This is due to the high amount of energy such events carry. However, the consensus is that L_{Aeq} by itself is an inadequate predictor of the potential of a varying noise to disturb people. The L_{Amax} descriptor addresses the maximum noise level due to individual pass-by events and provides a way to account for the potential disturbance from such individual events. For the time being, the L_{Amax} noise level descriptor and the number of anticipated L_{Amax} events during the night-time period will continue to be included in rail-noise assessments.

While research is making considerable advances towards building a whole picture of the relationship between noise exposures and human health, it has some way still to go before these can be translated into practical and justifiable criteria. Research will continue to be monitored.

5.2.1 Ground-borne noise and sleep disturbance

For a good night's sleep, the World Health Organization (WHO) recommends avoiding individual noise events exceeding 45 dB L_{Amax} indoors (measured on 'fast' response setting). However, WHO (1999) also notes that the effects of noise may be greater:

- in areas with low background sound levels
- for sources with combinations of noise and vibrations
- for noise sources with low-frequency components.

All of these may be present in ground-borne noise. It is also possible to conclude that the WHO level is based on airborne noise events. Hence, levels for ground-borne noise lower than 45 dB L_{Amax} (indoors) appear desirable. This is reflected in the triggers for ground-borne noise depicted in table 4 (page 14) of this guideline.

5.3 Responses to change in noise level

There is evidence to suggest that reaction to a newly introduced noise source is considerably higher than reaction to a source that has been present for some time. One study conducted in Japan (reported in Schultz 1979), compared the reaction to noise near a newly-opened Shinkansen (high speed train) line with the reaction near a line that had been open for eight years. For the same noise level, reaction was higher near the newly opened line. The difference in reported annoyance was equivalent to a difference of approximately 8 dB in noise exposure (L_{Aeq}). The difference in reported awakenings from sleep was equivalent to a difference of 7 dB in maximum noise levels.

Data from road noise studies further support the above findings for rail. Road studies (Brown 1987, Geoplan Resource Planning 1992) have indicated that where noise exposure is suddenly and substantially increased, reaction is higher than would be predicted from studies of steady conditions. These findings add further support for designing new rail systems in greenfields that support more stringent noise levels than redevelopments in existing rail corridors.

Appendix 6 Feasible and reasonable mitigation

‘Feasible’ and ‘reasonable’ mitigation is defined as follows.

A **feasible** mitigation measure is a noise mitigation measure that can be engineered and is practical to build, given project constraints such as safety, maintenance and reliability requirements. It may also include options such as amending operational practices (e.g. changing timetable schedules) to achieve noise reduction.

Selecting **reasonable** measures from those that are feasible involves judging whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the mitigation measure. To make such a judgement, consider the following.

- Noise impacts:
  - existing and future levels, and projected changes in noise levels
  - level of amenity before the project, e.g. the number of people affected or annoyed
  - any noise performance criteria for the development, e.g. internal noise levels for certain rooms
  - the amount by which the triggers are exceeded.
- Noise mitigation benefits:
  - the amount of noise reduction expected, including the cumulative effectiveness of proposed mitigation measures – ideally, a noise wall/mound should be able to reduce noise levels by at least 5 decibels
  - the number of people protected.
- Cost effectiveness of noise mitigation:
  - the total cost of mitigation measures, taking into account the physical attributes of the site, e.g. topography, geology, and the cost variation to the project given the expected benefit
  - noise mitigation costs compared with total project costs, taking into account capital and maintenance costs
  - ongoing operational and maintenance cost borne by the community, e.g. running air conditioners or mechanical ventilation.
- Community views:
  - engage with affected land users when deciding about aesthetic and other impacts of noise mitigation measures
  - determine the views of all affected land users, not just those making representations, through early community consultation
  - consider noise mitigation measures that have majority support from the affected community.

Take into account the above considerations when determining which locations should be mitigated first. In practice, the detail of the mitigation measures applied will largely depend on project-specific factors. The outcome this process aims to achieve is to balance the project’s benefits for the wider community against the costs and benefits of mitigation measures. These are the measures that minimise, as far as practicable, the local impacts of the project. Project approval conditions that flow from this process should be achievable. They need to provide clarity and confidence for the proponent, local community, regulators and the ultimate operator that the proposed mitigation measures can achieve the predicted level of environmental protection.

Appendix 7 Horn use as a safety measure

The noise triggers in this guideline apply to noise from safety devices such as warning horns and bells at level crossings as this is a normal part of operational rail noise. This noise should be taken into account when predicting noise levels and reported in terms of the $L_{Aeq(15hr)}$, $L_{Aeq(9hr)}$ and L_{Amax}. It is recommended that the design of new and upgraded railway lines consider noise from safety devices and aim to reduce noise levels from such devices whenever possible.

A noise impact assessment (NIA) should consider whether a project will result in situations that may cause regular horn usage or potentially alter existing horn usage (locations, frequency of occurrence etc). If noise impacts are likely to result, this should be pointed out in the NIA. The proponent/determiner can then consider whether mitigation is feasible and reasonable. For example, flyovers could be considered instead of level crossings; operational practices, such as mandating the use of city horns (in lieu of country horns, which are louder), could be considered at locations likely to be noise sensitive where safety would not be compromised.

Appendix 8 Noise predictive models

8.1 Airborne noise predictive models

Several models are available for predicting airborne noise levels at receptors as a result of railway operations. They include the Nordic Rail Prediction Method, Schall 03 (German), OAL30 (Austrian) and Calculation of Railway Noise (United Kingdom).

All models can calculate the L_{Aeq} level. The Nordic model calculates L_{Amax} in addition to L_{Aeq} and may be advantageous to use. Each model has been essentially developed on the basis of the country of origin's own measurement data on its rolling stock fleet. So there are differences in the propagation calculations between models. It is therefore important that the model or procedure chosen is validated for the project prior to local use.

8.2 Vibration and ground-borne noise predictive models

The prediction of vibration and ground-borne noise associated with transportation projects is a developing field, and as yet no widely accepted models are available. Procedures currently used are essentially based on a combination of measurement and the use of empirical formulae. ISO 14837 *Mechanical vibration- Ground-borne and vibration arising from rail systems* (ISO 2005) provides advice on developing models of ground-borne noise and vibration. Other examples of assessment procedures include the US Federal Transit Administration's *Transit noise and vibration impact assessment manual* (FTA 2006).

It is important that any method or procedure used to predict vibration and ground-borne noise for a project is clearly described and validated before use, e.g. via test measurements and calculations, published studies, and comparison with existing databases.

Appendix 9 Noise triggers for light rail

Existing light rail operations in Sydney were developed using noise criteria similar to the trigger levels in table 2 except that:

- noise parameters were specified for day, evening and night periods (these have been changed to day/night periods)
- the L_{Amax} triggers have been slightly reduced.

The noise criteria used for day/evening/night periods were 60/55/50 dB L_{Aeq}. The daytime period was defined as being from 7 am to 7 pm, the evening period from 7 pm to 11 pm and the night period from 11 pm to 7 am.

This guideline brings the day/evening/night periods in line with the day/night periods used for other rail projects but the noise triggers remain more stringent than those for heavy rail, reflecting the capacity for light rail to deliver a quieter mode of transport. Specifying day/night criteria only will make it easier for people to compare noise from different modes of transport.

Glossary

'A' frequency-weighting	An adjustment made to sound level measurement, by means of an electronic filter, in line with international standards. This approximates the response of the human ear at lower sound pressure levels.
Crossovers	Two turnouts connecting two nearby and usually parallel lines.
dB	Abbreviation for decibel. The magnitude of a level in decibels is 10 times the logarithm to the base 10 of the ratio of two powers or quantities, such as sound intensity, acoustic power or sound-energy density. Sound pressure levels (SPL or L_P) and sound power level (SWL or L_W) are expressed in decibels.
dB(A)	The 'A' refers to an adjustment made to sound level measurement, by means of an electronic filter, in line with international standards. This approximates the response of the human ear at lower sound pressure levels. Most community noise is measured using the 'A' frequency weighted sound pressure level in decibels.
EP&A Act	*Environment Planning and Assessment Act 1979*
Feasible and reasonable	See Appendix 6.
Ground-borne rail noise	Internal noise radiated by the building structure due to ground-borne vibration produced by rail vehicle movements.
Habitable room	Any room in a residential dwelling other than a garage, storage area, bathroom, laundry, toilet or pantry.
Heavy rail	See section 1.4.1.
Infrastructure SEPP	State Environmental Planning Policy (Infrastructure) 2007.
L_{A10}	Noise level in dB(A) exceeded for 10 per cent of a specified time period. For a 1-hour period the level would be exceeded for a total of 6 minutes but would be less for the remaining 54 minutes.
L_{A90}	Noise level in dB(A) exceeded for 90 per cent of a specified time period. For a 1-hour period the level would be exceeded for a total of 54 minutes but would be less for the remaining 6 minutes. This is often referred to as the average minimum noise level or the background noise level.
L_{eq} and L_{Aeq}	The L_{eq} represents the average noise energy during the measurement period which is equivalent to the fluctuating sound level actually occurring. When the energy level is A-weighted it may be written as L_{Aeq}. See also dB(A).
$L_{Aeq(1h)}$	The highest 10th percentile L_{Aeq} 1-hour measurement recorded for the relevant time period (e.g. when in use, between 7 am and 10 pm during the day). Refer to technical note 18 (page 11).
$L_{Aeq(15h)}$	The L_{Aeq} noise level between 7 am and 10 pm.
$L_{Aeq(9h)}$	The L_{Aeq} noise level between 10 pm and 7 am.
L_{Amax}	This is the maximum value of the sound pressure level that occurs during any given period. Note that the L_{Amax} trigger values refer to the maximum noise

	level not exceeded for 95 per cent of rail pass-by events. A technical definition is the highest noise level in dB(A) measured during the specified time period. A time response (fast, slow or impulse) must be specified and may be given as, for example, L_{AFmax} or L_{ASmax}.
L_{DN}	Day−night average sound level. An $L_{Aeq(24hr)}$ with a 10 dB(A) penalty for environmental noise occurring between 10 pm and 7 am to take account of increased annoyance at night.
Light rail	See section 1.4.2.
New rail line	See section 1.4.1.1.
POEO Act	*Protection of the Environment Operations Act 1997.*
Redeveloped rail line	See section 1.4.1.2.
Rolling stock	Railway vehicles, including electric trains, locomotives, carriages, wagons, track vehicles and buffet cars.
L_{AE} (or SEL)	Sound exposure level, L_{AE}. A parameter closely related to L_{Aeq} for assessment of events (trains, aircraft, etc.) that have similar characteristics but are of different duration. The L_{AE} value contains the same amount of acoustic energy over a ‘normalised’ 1-second period as the actual noise event under consideration. This is sometimes abbreviated as SEL (sound exposure level). The term L_{AE} is described in Australian Standard (AS) 1055.1: 1997 ‘*Acoustics – description and measurement of environmental noise. part 1: general procedures*’.
Sound pressure level, Lp (or SPL)	This is the level of noise, usually expressed in dB(A), as measured by a standard sound level meter with a pressure microphone. The sound pressure level in dB(A) gives a close indication of the subjective loudness of noise. A technical definition for the sound pressure level, in decibels, is 20 times the logarithm (base 10) of the ratio of any two quantities related to a given sound pressure to a reference pressure (typically 20 μPa equivalent to 0 dB).
Turnouts	Assemblies of rails, switches and crossings where two tracks converge into one.
Wheel squeal	Mid- to high-frequency tonal squeal noise produced by the stick-slip action between the wheels and rails.

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