Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects

Department of Environment & Climate Change NSW

NSW GOVERNMENT
Department of Planning

Acknowledgments

The following agencies' contributions to, and support for, the development of the *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* are gratefully acknowledged:

- Transport Infrastructure Development Corporation
- RailCorp
- NSW Ministry of Transport
- NSW Premier's Department.

Published by:

Department of Environment and Climate Change NSW
59–61 Goulburn Street, Sydney
PO Box A290, Sydney South 1232
Phone: (02) 9995 5000 (switchboard)
Phone: 131 555 (information and publications requests)
Phone: 1300 361 967 (national parks information and publications requests)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

ISBN 978 1 74122 414 6
DECC 2007/187
April 2007

Printed on recycled paper

Contents

1. Introduction 1

1.1 Environmental benefits of rail
1.2 Role of the guideline in managing noise and vibration from rail activities
1.3 Objectives of the guideline
1.4 Rail infrastructure projects to which the guideline applies
1.5 Community consultation

2. Noise and vibration trigger levels 5

2.1 Airborne noise trigger levels for heavy rail
2.2 Ground-borne noise trigger levels
2.3 Vibration trigger levels

3. Assessment of noise and vibration impacts 11

3.1 Applying noise and vibration level values and determining feasible and reasonable mitigation levels
3.2 Shared rail corridor
3.3 Areas to cover in a noise and vibration impact assessment report
3.4 Measuring existing levels of rail noise and vibration
3.5 Mitigating noise from railways

Appendix I: Comparison of airborne noise levels for rail operations – national and international 21

Glossary of terms 24

References and further reading 25

These interim guidelines are being trialled for three years. Feedback on their operations is encouraged and this will be taken into account when finalising them after the trial is over.

Please send any comments about the interim guidelines to:

InterimRailNoiseMailbox@environment.nsw.gov.au

Please note that any submissions on the interim guideline, including your personal details, will be a matter of public record and will be stored in the DECC records system. If you don't want to have your personal details disclosed to members of the public once the final guidelines have been adopted, you can prevent this. Just indicate in your comment that you wish your personal details to remain confidential to DECC and not available for public access.

- *Find out more about your privacy rights at www.environment.nsw.gov.au/about/privacy.htm*
- *Contact your local DECC office for more information on the Privacy and Personal Information Protection Act.*

1. Introduction

Increased rail transport is an expected and desirable outcome of government policies that seek to improve air quality and transport planning and integrate land-use planning. Rail transport plays a vital part in efforts to achieve sustainable cities and preserve the environment. State Government initiatives such as the *Metropolitan Strategy* (DoP 2005), State Infrastructure Strategy 2006–07 to 2015–16 and *Action for Air* (NSW Government 1998) all encourage the increased use of rail in the future as a preferred mode of transport that minimises environmental impacts.

The benefits of rail include less fuel use, lower greenhouse gas emissions and air pollution, reduced road congestion and better safety. Nevertheless, rail noise (including vibration) can have adverse effects on residents living alongside railway lines, by disturbing sleep, causing stress and annoyance, and interfering with talking and hearing in general.

The growth of our rail transport network brings many benefits to the wider community but is accompanied by other factors such as increased train movements, extended rail operating periods and residential development along transport routes. These impacts need to be managed and balanced against protecting the amenity and wellbeing of the local community living beside rail lines.

Establishment of a more compact, efficient and accessible Sydney and an improvement in the air quality this will bring will be partly achieved by higher and more intensive residential development close to public transport. Because some rail operations are inherently noisy, relatively high noise levels may still occur even after all feasible and reasonable means of mitigation have been applied to the operations. This means that to achieve a desirable level of amenity and wellbeing for residents greater attention needs to be paid to the inclusion of noise control options in new residential developments around rail lines.

1.1 Environmental benefits of rail

According to ACIL Consulting (2000), the Australasian Railways Association in its Information Sheet 2 of 1998 reported that:

- Urban rail is twice as energy efficient as buses and 2.5 times more energy efficient than cars. Rail freight uses only one-third of the fuel required by road transport per tonne of freight hauled and produces less than one-third of the greenhouse gas emissions.
- One suburban train carrying 1000 people keeps 800 cars off the road, with significant savings in fuel use, greenhouse gas emissions and road congestion.
- One freight train between Melbourne and Sydney replaces 150 semi-trailers and saves 45,000 litres of fuel and 130 tonnes of greenhouse gases, compared with road haulage.
- Rail is still twice as energy efficient as road, even after fuel use has been included for rail line haul, road pick-up and delivery from rail terminals, manufacture of transport equipment and construction of roads and railway lines.
- Increased use of rail to absorb the growth in passenger and freight demand over the next 20 years will reduce Australia’s transport energy consumption, thus reducing the forecast increases in greenhouse gas emissions from road transport.

1.2 Role of the guideline in managing noise and vibration from rail activities

This is an interim guideline which will be trialled in new rail projects over the next three years. Following that, the guideline will be reassessed and revised in the light of public consultation before a final version is developed. This will ensure the community’s views are considered and reflected in the final guideline.

This interim guideline is designed to ensure that potential noise impacts associated with the ongoing expansion of rail developments are assessed in a consistent and transparent manner. Effective management of rail noise requires the combined efforts of rail infrastructure owners and developers, rail operators, train manufacturers, regulatory and planning authorities, and the community.

This interim guideline is one component of a comprehensive approach being developed to manage the environmental impacts of noise and vibration from the NSW rail system. The other parts of this approach include:

- A **Noise Management Manual** for rail developments and operations: This will outline best practice for the mitigation of rail noise and vibration, including operational approaches to managing their impacts. Rail agencies will lead a whole-of-government process to develop the manual.
- **Environmental management systems** (EMSs): Rail infrastructure owners and developers will develop EMSs appropriate for managing their respective environmental risks.
- **Environmental impact assessment guidelines for rail developments**: These will aid in providing a clear and consistent approach to meeting the requirements of the NSW planning legislation that supports proposals for rail developments. The NSW Department of Planning (DoP) will develop this in consultation with rail agencies and the Department of Environment and Climate Change NSW (DECC).
- **Rolling stock noise-emission standards**: These are being developed at a national level by the National Transport Commission (NTC). NSW is an active participant in this process and has promoted the need for national standards to ensure the ongoing viability of expanding rail usage. Rail agencies will lead NSW input into the process.
- A **Noise Abatement Program** will address existing levels of noise from the rail system on a priority basis and manage noise from rolling stock. Rail infrastructure managers will lead the development of this, with assistance from other relevant NSW agencies, such as DECC and the NSW Ministry of Transport, and rail operators.
- An appropriate **environmental planning instrument** under the *Environmental Planning and Assessment Act 1979* (EP&A Act) for new residential (and noise-sensitive) developments alongside rail lines will require the consideration and incorporation of noise and vibration mitigation measures. DoP will develop this with assistance from DECC and rail agencies.

This interim guideline addresses noise and vibration from new rail infrastructure projects. Noise and vibration impacts from existing operations on the rail system **are not covered** by this guideline. However, the package being developed as outlined above will address noise and vibration impacts from existing rail operations, which have mostly grown over a long period of time. Residential developments close to rail lines have often followed the opening of the lines, and their design and construction have typically had less regard for noise and vibration impacts than is desirable. The reality is that there is no easy answer to existing levels of noise and vibration impacts from rail lines in a dense urban environment.

The NSW Government response for dealing with existing noise impacts from rail will include a means to address acute noise impacts on a priority basis and is expected to form part of the Noise Management Manual and Noise Abatement Program outlined above. The response will likely comprise a combination of interventions at specific receiver sites (e.g. barriers) and at source (i.e. rolling stock). Reduction of noise at source delivers results over a longer period but is far more cost-effective, as it reduces noise for a much greater number of people than is possible with site-specific noise barriers. An added benefit in not constructing barriers is that many of the problems associated with them, such as overshadowing, graffiti, and loss of visual amenity, are also avoided.

1.3 Objectives of the guideline

This guideline is designed to streamline decision-making processes by providing consistent and transparent procedures for the assessment and approval process for rail infrastructure developments that have potential noise and vibration impacts.

The noise trigger levels presented are those that trigger the need for a project to conduct an assessment of its potential noise and vibration impacts and examine what mitigation measures would be feasible and reasonable to apply to ameliorate these impacts. Importantly, the trigger levels are not intended to be applied automatically in any mandatory sense as conditions in statutory approvals or licences.

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 noise and vibration trigger levels identified in this guideline have been derived from a review of both overseas research into reaction to noise and vibration and the practices applied in other comparable countries to assess and mitigate rail noise and vibration.

1.4 Rail infrastructure projects to which the guideline applies

This guideline applies to rail infrastructure projects that are assessed and determined under the EP&A Act or licensed under the *Protection of the Environment Operations Act 1997* (POEO Act). The guideline takes a project-based approach with the assessment of impacts and potential mitigation measures applied to the area where works associated with a rail infrastructure project are taking place.

It is envisaged that this guideline will be used whenever there is a need to assess and potentially mitigate noise and vibration impacts for rail infrastructure projects, including:

New rail lines

A new rail line development applies where residential or noise-sensitive receivers are not subject to existing rail noise or where existing levels of rail noise are below the noise trigger levels for a new rail line development. Typically this will be a rail line being developed on a corridor that has not previously been a rail line, or an existing rail line that is being substantially realigned outside the existing corridor.

Redevelopment of existing rail lines

Redevelopment of an existing rail line applies where residential or noise-sensitive receivers are subject to existing rail noise at or above the noise trigger levels in Table 1 in Chapter 2 for a new rail line development. Typically this will be an existing rail line where it is proposed to carry out works that will increase its capacity to carry rail traffic or alter the track alignment through design or engineering changes. In practice this often means a duplication within an existing rail corridor.

Redevelopment does not cover minor works such as crossovers, sidings, turnouts, yards, loops, refuges, relief lines, straightening curves or the installation of track signalling devices where these works will not result in an increase in existing rail noise levels and a level of rail noise beyond the noise trigger levels contained in Tables 1 and 2.

For these rail infrastructure projects the potential noise and vibration would be compared against the noise and vibration trigger levels identified in this guideline to decide whether assessment of impacts and feasible and reasonable mitigation measures is necessary.

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 POEO Act, such as:

- rail activities not requiring an environment protection licence
- heritage railway operations
- the acceptability of development sites for sensitive land uses near rail lines.

This guideline **does not apply** to:

- existing railways where no development is occurring
- maintenance of the railway system
- projects involving maintenance facilities for rolling stock which should be assessed in accordance with the NSW *Industrial Noise Policy* (EPA 2000)
- light rail infrastructure projects
- occupational noise and vibration, which are separate issues administered by the WorkCover Authority under the *Occupational Health and Safety Act 2000*
- developments where railway systems activities are not being undertaken.

1.5 Community consultation

The NSW rail network is geographically extensive. Large cross-sections of the community come into contact with the network as commuters, residents neighbouring 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 inherently affect or impact on the other. The management of these impacts requires effective public involvement and communication strategies that will assist in determining the impact of rail activities on the community by providing the public with:

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

as well as continually improving community partnerships.

The scale of an activity and/or a change to an activity will determine the extent of public involvement. It is therefore essential this involvement is consistently, transparently and equitably factored into rail activities appropriate to both the potential impact and the benefit that can be gained from public involvement.

Noise-mitigation planning for rail infrastructure projects is also greatly assisted by effective community consultation during the project planning and assessment phases, such as planning focus meetings and consideration of written submissions, in line with the requirements of the EP&A Act. These processes allow for the community to participate in any mitigation selection process in a transparent, equitable and consistent way. In particular, effective public involvement is needed where impact assessment finds there will still be residual impacts even after the application of appropriate mitigation measures.

It is equally important for land-use planning authorities to adopt an interactive partnership with the rail industry to ensure that existing and planned rail corridor use is considered when making and/or determining land-use planning instruments, including rezoning proposals and development applications.

2. Noise and vibration trigger levels

This guideline addresses two types of noise and vibration impacts:

- Airborne noise from the operation of a surface rail line that is heard at, and within, noise-sensitive premises
- Ground-borne noise generated inside a building by ground-borne vibration generated from the pass-by of a vehicle on rail: These noise trigger levels apply at receiver locations above rail operations in tunnels where ground-borne noise levels from rail transport are likely to be greater than airborne noise levels.

Vibration that can be created by rolling stock movements also requires appropriate assessment and mitigation. Rail infrastructure proponents are directed to *Assessing vibration: A technical guideline* (DEC 2006) for methods of assessing potential impacts and ways to manage vibration from rail operations.

The noise trigger levels for airborne noise and ground-borne noise differentiate between noise impacts during the day and night. It is widely accepted that noise is generally more disturbing at night because of the more noise-sensitive activities occurring at that time of the day (e.g. listening activities and sleep); the large numbers of residents that are at home; and the increased intrusiveness of noise due to lower background levels at night.

Most European countries with criteria for rail noise apply separate noise levels for day and night. In the United States the night-time period is also given special attention by use of a noise descriptor that applies an acoustic penalty to night movements to account for increased annoyance of noise at night (see Appendix I for details).

2.1 Airborne noise trigger levels for heavy rail

The noise trigger levels address:

- An increase in rail noise due to rail infrastructure projects
- Absolute levels of rail noise: For residential receivers the noise trigger levels for absolute levels of rail noise have two components, L_{Aeq} and L_{Amax}. This combination addresses both the average level of noise (L_{Aeq}) over the day or night period and the maximum noise level (L_{Amax}) from pass-by events. The application of the L_{Amax} descriptor for residential land uses recognises that rail events are not adequately described solely by the L_{Aeq} descriptor when preservation of residential amenity and wellbeing are considered.

For other 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.

An increase in both rail noise and the absolute level of rail noise at the trigger values in Tables 1 and 2 must be met to initiate an assessment of rail noise impacts.

The increases in rail noise trigger levels for L_{Aeq} and L_{Amax} are set at levels where an increase in rail noise may become perceptible.

Table 1: Airborne rail traffic noise trigger levels for residential land uses

Type of development	Noise trigger levels dB(A)		
	Day (7 am–10 pm)	**Night (10 pm–7 am)**	**Comment**
New rail line development	Development increases existing rail noise levels ***and*** resulting rail noise levels exceed:		These numbers represent external levels of noise that trigger the need for an assessment of the potential noise impacts from a rail infrastructure project. An ‘increase’ in existing rail noise levels is taken to be an increase of 2 dB(A) or more in L_{Aeq} in any hour or an increase of 3 dB(A) or more in L_{Amax}.
	60 $L_{Aeq(15h)}$ 80 L_{Amax}	55 $L_{Aeq(9h)}$ 80 L_{Amax}	
Redevelopment of existing rail line	Development increases existing rail noise levels ***and*** resulting rail noise levels exceed:		
	65 $L_{Aeq(15h)}$ 85 L_{Amax}	60 $L_{Aeq(9h)}$ 85 L_{Amax}	

Table 2: Airborne rail traffic noise trigger levels for sensitive land uses other than residential

Sensitive land use	Noise trigger levels dB(A)	
	New rail line development	**Redevelopment of existing rail line**
	Development increases existing rail noise levels by 2 dB(A) or more in L_{Aeq} in any hour ***and*** resulting rail noise levels exceed:	
Schools, educational institutions – internal	40 $L_{Aeq(1h)}$	45 $L_{Aeq(1h)}$
Places of worship – internal	40 $L_{Aeq(1h)}$	45 $L_{Aeq(1h)}$
Hospitals	60 $L_{Aeq(1h)}$	60 $L_{Aeq(1h)}$
Hospitals – internal	35 $L_{Aeq(1h)}$	35 $L_{Aeq(1h)}$
Passive recreation	L_{Aeq} as per residential noise level values in Table 1 (does not include maximum noise level component)	
Active recreation (e.g. golf course)	65 $L_{Aeq(24h)}$	65 $L_{Aeq(24h)}$

Technical notes to Tables 1 and 2

1. Specified noise trigger levels refer to noise from rail transportation only and do not include ambient noise from other sources. However, they refer to noise from all rail traffic at the receiver location, not only noise due to the specific rail project under consideration.
2. The noise level values represent external levels except where otherwise stated.
3. ‘Residential’ typically means any residential premises located in a zone as defined in a planning instrument that permits new residential land use as a primary use. Where there is doubt as to the status of the residential land use, the relevant planning authority should be consulted.

4. $L_{Aeq(T)}$ (where T is the relevant time period) refers to the equivalent continuous noise level from all train movements (excluding shunting activities in designated shunting areas) occurring during the assessment time period.
5. L_{Amax} refers to the maximum noise level not exceeded for 95% of rail pass-by events and is measured using the 'fast' response setting on a sound-level meter.
6. Noise levels at residences are assessed 1 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(A)) 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 that are most exposed to rail noise, usually the ground and first floors. On other floors, an internal noise level value 10 dB(A) below the relevant external noise level value applies on the basis that openable windows are opened sufficiently to provide adequate ventilation (refer to minimum ventilation requirements in the Building Code of Australia).
7. Internal noise level values 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 level values 10 dB(A) above the internal level values apply.
8. The noise level values for sensitive land uses apply for the periods when the premises are in use.
9. In assessing noise levels at passive and active recreational areas as well as in hospital grounds, the noise level is assessed at the most affected point within 50 metres of the area boundary.
10. For external activities associated with schools, educational institutions and places of worship, the relevant passive or active recreation categories apply.
11. Where the category of the premises is not clear, seek advice from the relevant planning authority.
12. 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 measured $L_{Aeq(1h)}$ value can be used where insufficient measurements have been made to provide a valid 10th-percentile level **and** it can be demonstrated that the measured values are representative.
13. For new and redeveloped rail projects, the noise trigger levels apply both immediately after operations commence and for projected traffic volumes over an indicative period into the future that represents the expected typical level of rail traffic usage (e.g. 10 years or a similar period into the future).
14. Where noise above the noise trigger levels continues even after all feasible and reasonable mitigation measures have been applied to a project, other long-term strategies need to be applied to minimise impacts. These include reducing noise emissions from rolling stock by applying noise standards to new rolling stock; managing noise emissions from rolling stock already in use; and improved planning, design and construction of adjoining land-use developments.
15. 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 level values for these shoulder periods where night-time noise levels rise quickly to daytime noise levels may be negotiated with the determining or regulatory authority on a case-by-case basis.

The absolute L_{Aeq} rail noise trigger levels for heavy rail are based on social survey research and international and national practices. Research by Miedema and Oudshoorn (2001) and illustrated in Figure 1 provides the basis for considering the levels at which noise creates community annoyance and informs the airborne noise trigger levels in Table 1. The noise trigger levels are aligned with what is applied for road traffic noise by aiming to protect 90% of the population from being highly annoyed.

Because noise descriptors (such as $L_{Aeq(24h)}$, $L_{Aeq(night)}$ and L_{DN}) vary between different countries and jurisdictions, it is difficult to make a direct comparison between the trigger levels in this guideline and those used elsewhere. However reference to Appendix I, which outlines the noise levels set in other countries, indicates the noise trigger levels in this guideline are consistent with the range of levels adopted internationally.

The L_{DN} (Day-Night) shown in Figure 1 is L_{Aeq}-based and is measured over a 24-hour period that includes daytime noise and applies a 10-dB penalty to night-time noise.

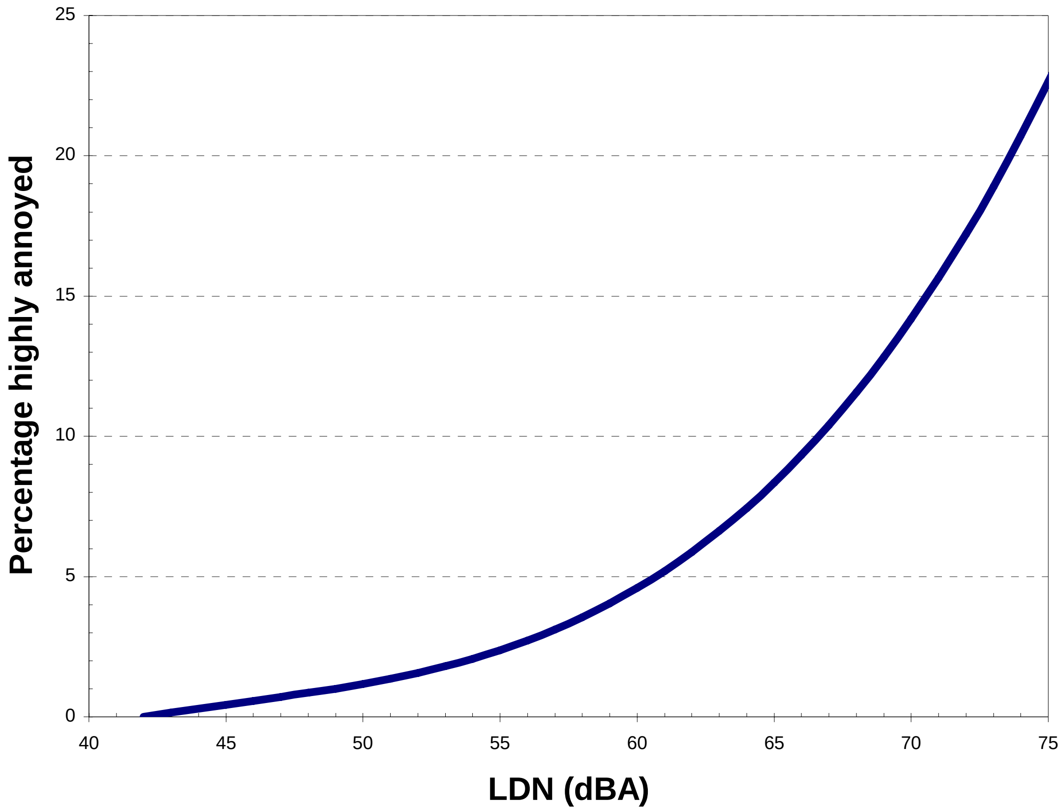

Figure 1: Percentage highly annoyed vs L_{DN} for rail noise (Miedema and Oudshoorn 2001)

2.2 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.

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 anyone affected by the noise 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.

Retrofitting mitigation measures to rail infrastructure to reduce ground-borne noise may also be more difficult and expensive than for airborne noise. 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.

Only limited research into the impacts of ground-borne noise is available, and information on practices applied overseas is also scarce. From a review of what is available it appears that 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
- 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 L_{Amax} are more typically applied and likely to be sufficient for most urban residential situations, even where there are large numbers of noisy events.

For a good night’s sleep, the World Health Organization (WHO) recommends that individual noise events exceeding 45 dB L_{Amax} indoors (measured on ‘fast’ response setting) should be avoided. However, WHO (Berglund, Lindvall and Schwela 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 which 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.

The noise trigger levels in Table 3 for ground-borne noise and the associated measurement methodology described in Section 3 of this guideline are aimed at providing a reasonable basis for triggering the assessment of impacts from ground-borne noise. 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 suitable for urban areas where background noise levels are relatively high.

Table 3: Ground-borne (internal) noise trigger levels

Receiver	Time of day	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_{Amax} (slow)
	Night (10 pm–7 am)	35 L_{Amax} (slow)
Schools, educational institutions, places of worship	When in use	40–45 L_{Amax} (slow)

Technical notes to Table 3

1. Specified noise levels refer to noise from rail transportation only and do not include ambient noise from other sources.
2. The noise level values represent internal noise levels and are to be assessed 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 this might be another habitable room experiencing the highest levels of ground-borne noise. They 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' typically means any residential premises located in a zone as defined in a planning instrument that permits new residential land use as a primary use. Where there is doubt as to the status of the residential land use, the relevant planning authority should be consulted.
4. L_{Amax} refers to the maximum noise level not exceeded for 95% of rail pass-by events and is measured using the 'slow' 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.

2.3 Vibration trigger levels

Vibration associated with movements on a rail network can cause disturbance and complaint in a similar fashion to noise.

A separate guideline, *Assessing vibration: A technical guideline* (DEC 2006), contains information on trigger levels for vibration covering continuous, impulsive and transient vibration. Train movements on a rail network can cause vibration of a transient type.

3. Assessment of noise and vibration impacts

An assessment of rail noise and vibration impacts may be needed as part of an environmental assessment, environmental impact assessment or review of environmental factors required under the EP&A Act, or under the provisions of the POEO Act.

3.1 Applying noise and vibration level values and determining feasible and reasonable mitigation measures

The noise and vibration trigger levels identified in this guideline and the associated guideline *Assessing vibration: A technical guideline* (DEC 2006) are used as indicators or trigger levels for when a noise and vibration assessment needs to be conducted for a project.

Figure 2 outlines the process of using the noise and vibration trigger levels contained in this guideline. The trigger values indicate when an assessment of noise and vibration impacts is needed to develop any project-specific noise and vibration levels and any feasible and reasonable mitigation measures that may need to be implemented. Figure 2 also highlights the need for community involvement throughout the process.

As a guide, 'feasible' and 'reasonable' mitigation measures can be defined as follows:

'*Feasibility*' relates to engineering considerations and what can practically be built or modified, given the opportunities and constraints of a particular site.

'*Reasonableness*' relates to a judgement which takes into account the following factors:

- noise-mitigation benefits – noise reduction provided, number of people protected
- cost of mitigation – total cost and cost variation with level of benefit provided
- community views
- aesthetic impacts
- noise levels for affected land uses – existing and future levels, and expected changes in noise levels
- benefits arising from the development or its modification.

In practice, the detail of the mitigation measures applied will depend to a large extent on project-specific factors. The outcome that is aimed for in this process is to balance the benefits for the wider community arising from the project and the costs and benefits of project-related mitigation measures which aim to minimise (as far as practicable) the local impacts. Conditions that flow from this process will be achievable and will 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.

Note that 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 (e.g. in the case of an underground tunnel or where past experience indicates that the proposal may result in vibration or structure-borne noise).

Figure 2: Typical noise and vibration impact assessment process for a rail project

Planning focus phase

Determine the environmental noise and vibration values that need to be protected and where, through discussions with the community and relevant agencies in planning focus meetings and by referring to this guideline.

↓

Use the noise and vibration trigger levels in Tables 1, 2 and 3 to decide if an assessment of impacts is needed.

↓

Step 1

If an assessment is needed, determine if the selected noise and vibration trigger levels are exceeded through a noise impact assessment as part of the environmental impact assessment process under the EP&A Act.

↓

Step 2

Determine noise and vibration level values that are applicable to the project:

1. Assess whether the exceedence of the noise and vibration level values selected for the project will result in environmental harm or community concern.
2. Complete a cost-benefit analysis of feasible and reasonable noise and vibration mitigation measures, then prioritise these to maximise the protection of the acoustic environment. Identify achievable noise and vibration levels for the project after mitigation has been applied.
3. Consult with the affected community to review the noise and vibration levels achievable for the project.
4. Adopt project-specific noise and vibration levels, i.e. values identified from 1–3 above, as appropriate to assign to the project
5. Produce a report (e.g. submissions report) that confirms the appropriateness of the achievable noise and vibration levels identified for the project.

↓

Planning approval

Achievable noise and vibration levels and/or mitigation measures for the project are included in the approval conditions.

3.2 Shared rail corridor

Some sections of 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 these are the same tracks with 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, the large number of freight operators and different types of freight rolling stock increase the need to consider alternative options, such as control of noise at its source.

Where a 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
- report separately on 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 noise from the construction and operation of the rail project
- report 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 rail project. However, the range of feasible and reasonable mitigation measures considered needs to be appropriate for these operations.

3.3 Areas to cover in a noise and vibration impact assessment report

This section outlines the areas to be covered in an assessment report into the noise and vibration impacts from a rail project. Note that 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.

Industrial developments which need to report on off-site noise and vibration impacts from rail traffic might also be able to use this as a guide.

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 use of horns, locomotive throttle settings, braking locations, shunting and signalling.

3 Estimate rail traffic volumes immediately after commencement of operations and at a point 10 years after commencement. Break this at least into the periods 7 am–10 pm and 10 pm–7 am, and specify the proportion of freight trains for each period. Preferably, obtain projected volumes for each hour and use average weekday volumes.

4 Provide details of assumed data for the new development, including rail traffic volumes and speeds, operating conditions and percentage of freight trains by time of day; and details of the calculation process, including assumed noise source heights for rail vehicles.

Determine the appropriate noise and vibration trigger levels

5 Identify affected land uses adjacent to the proposed rail project. For tunnels, this is the land use above the tunnel.

6 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 rejected certain noise and/or vibration trigger levels as not appropriate to the project, the reason should be made clear in the assessment report.

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

7 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 calculation of the rail noise component. Note that all noise descriptors that will be used in the assessment should be monitored. These may include $L_{Aeq(1h)}$, $L_{Aeq(15h)}$, $L_{Aeq(9h)}$, L_{Amax}, sound exposure level (SEL) and root mean square (rms) acceleration in m/s^2.

8 Provide details of noise monitoring procedures and/or calculations of existing noise levels. This should include noise-measurement data from each site and rail traffic volumes and speeds, operating conditions and proportions of freight trains. Where estimates of existing levels of rail noise are made, include information on the calculation procedure, including the assumptions used.

Predict the impacts of the rail infrastructure proposal

9 Impact predictions should be conducted for three scenarios: duration of construction; the proposed commencement date; and an indicative period into the future (e.g. 10 years or a similar period). These should be an estimate of projected traffic volumes that represent the expected future typical level of rail traffic usage. If mitigation measures are being proposed, the predictions should be for both the before- and after-mitigation periods.

10 The contribution of noise and (if relevant) vibration levels from different types of use (e.g. freight or passenger) should be calculated and reported separately. The total or combined noise and (if relevant) vibration levels should also be reported.

11 All assumptions used in the prediction should be clearly stated, and the expected accuracy should be quoted along with the final predicted levels.

12 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.

13 Noise level contributions from freight and passenger rail traffic should be reported separately along with the total rail noise. The increase in rail noise due to the project should also be reported.

Airborne noise predictive models

A number of 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 Traffic Noise (CoRN – 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. As each model has been essentially developed on the basis of the country of origin's own measurement data on its rolling stock fleet, 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 its use locally.

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 noise 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* (FTA 2006) and an analytical mathematical model developed by AEA Technology Rail called *CIVET* (*Change in vibration emitted by track*).

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 data bases.

Identify potential mitigation measures

14 Where the predicted noise and/or vibration levels exceed the trigger levels selected to protect the local environment resulting in environmental harm or community concern, ameliorative measures should be investigated. Examples of these include:

- alternative track alignments
- control of rail traffic (e.g. limiting times or speed)
- use of track measures (e.g. special track forms, rail fasteners and potential operational measures such as rail grinding)
- identification of the rolling stock producing the highest levels of noise or vibration and management to rectify this
- construction of noise barriers or bunds
- treatment of the façade of residential buildings where night-time noise levels are the major concern to reduce internal noise levels in sleeping areas
- restricting the type of rolling stock (e.g. based on noise emission levels)
- use of rolling stock measures (e.g. noise treatment of rolling stock)

15 Provide a description of all mitigation measures proposed and the reasons for the particular mitigation measures selected.

16 For the mitigation measures selected, recalculate noise levels to take into account the effect of the proposed mitigation measures.

17 Provide a diagram showing noise level contours, or other methods of presenting the calculated noise level at each receiver, both with and without ameliorative measures.

18 Report the noise and vibration levels that the project can achieve after the application of all feasible and reasonable mitigation measures. These are the project-specific levels that may be considered for inclusion in conditions.

19 Where the relevant noise and vibration trigger levels will not be met after applying all feasible and reasonable mitigation measures, quantify the residual level of noise and vibration impacts.

20 In cases where (after the levels are calculated as set out above and ameliorative measures evaluated) it is considered impractical to meet the noise trigger levels, provide an assessment that justifies how all feasible and reasonable measures have been considered and recommend actions that could further ameliorate the residual level of noise impact in the long term.

Develop a monitoring regime

Select 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 (from steps 7, 8 and 9 above) in tabulated form.

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 impacts 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
- 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.

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 noise trigger levels in Tables 1 and 2 apply at the façade, and an appropriate adjustment (see footnotes to the tables) will need to be applied.

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) promoting the propagation of noise should be taken into account when considering receivers at distances greater than 300 metres. This is typically only an issue in rural areas where there are no residents in the near vicinity of the line.

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 SEL_i and solution of the relevant equation below. It is important to obtain a representative $L_{Aeq(i)}$ or SEL_i 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, such as near and 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 $L_{Aeq(i)}$ or SEL_i 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 and, if $L_{Aeq(i)}$ is used, the average time period of each type of event.

Equation using SELi

$$L_{Aeq(T)} = 10 \times \log_{10}(1/T \times (\sum n_i \times 10^{0.1 \times SELi}))$$

where:
T is the total time in the relevant period in seconds (i.e. hours x 60 x 60)
n_i is the number of each type of event
SEL_i is the representative event SEL of each type of event as measured at the most-affected receiver and is summed over the different type of events occurring at the site.

Equation using $L_{Aeq(i)}$

$$L_{Aeq(T)} = 10 \times \log_{10}(1/T \times (\Sigma (n_i \times t_i \times 10^{0.1LAeq(i)}))$$

where:
T is the total time in the relevant period in seconds (i.e. hours x 60 x 60)
t_i is the average time of each type of event in seconds
n_i is the number of each type of event
$L_{Aeq(i)}$ is the representative L_{Aeq} level for each type of event as measured at the most-affected receiver and is summed over the different type of events occurring at the site.

Accompanying information in support of a quoted $L_{Aeq(T)}$ should include the general measurement and equipment information described earlier in this section, as well as:

- justification that sufficient measurements have been undertaken for each type of event
- justification of the number of each type of event used based on the types of vehicles likely to be used on the section of track. This could include evidence that the infrastructure owner/operator and rail vehicle operators have been consulted with regard to the typical or expected use of the railway section.

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 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.

Ground-borne noise

For the purposes of this guideline, ground-borne noise levels should be measured (or determined) at the centre of the most-affected noise-sensitive room by using the L_{Amax} noise descriptor and the 'slow' time response setting on the sound-level meter. 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.

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* (International Organization for Standardization 2005). Another useful reference is the US Federal Transit Administration's *Transit noise and vibration impact assessment* manual (FTA 2006).

Vibration

Methods for measuring vibration from rail operations are covered in a separate DECC 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 also provides useful guidance to developers of rail infrastructure in the early stages of planning and design.

Types of mitigation measures

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

- controlling noise and vibration at the source
- controlling the transmission of noise and vibration
- controlling noise and vibration at the receiver.

The scope for applying feasible and reasonable mitigation measures to existing railway operations is generally more limited than for new rail developments, and this step is almost inevitably far more costly. This underscores the importance of effective noise management strategies as an integral part of the planning for new rail projects.

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. In particular, attention should be paid to the location of the proposed rail line 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 (Hemsworth and Hubner 1999) 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), such as 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 measured noise levels.

Examples of mitigation measures at the source include:

- track measures: rail grinding, welding to smooth discontinuities, lubrication, use of soft rail pads, and relocation of signals or turnouts
- rolling stock measures: effective muffling of diesel locomotive exhaust noise, wheel truing, on-board wheel lubrication, use of disc brakes, dampening of wheels, and use of resilient wheels, wheel vibration absorbers and low-squeal brake blocks.

In applying mitigation measures at the source it is recommended that the principles of 'best management practice' (BMP) and 'best available technology economically achievable' (BATEA) be followed.

BMP: This is the adoption of particular operational procedures that minimise noise while retaining efficient operations. When a mitigation strategy that incorporates expensive engineering solutions is being considered, the extent to which cheaper, non-engineering-oriented BMP can contribute to the required reduction of noise should be taken into account. Application of BMP includes the scheduling of noisy operations at least-sensitive times, selective use of certain tracks, keeping equipment well maintained, siting noisy operations behind structures, employing 'quiet' practices when operating equipment, and running staff-education programs.

BATEA: This involves ensuring operations incorporate the most advanced and affordable technology to minimise noise output. Affordability is not necessarily determined by the price of technology alone. Increased productivity may also result from using more advanced technology offsetting the initial outlay: for example, 'quieter' trains can be operated over extended hours without causing impact. Where BMP fails to achieve the required noise reduction by itself, the BATEA approach should then be considered.

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. Vincent (2000) provides a useful analysis on the differing contributions of track and rolling stock measures in reducing overall emissions.

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.

Controlling noise and vibration in transmission

This involves restricting the propagation of noise and/or vibration. Such measures include the use of noise barriers, installation of 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.

Controlling noise and vibration at the receiver

Rail lines are an essential part of our urban infrastructure. Even after the application of BMP and BATEA, the closeness of affected premises and the physical, operational and economic constraints may be such that measures to manage the problems at source or to intercept noise in transmission may need to be complemented by management at the point of impact. Where new residential development is planned to occur around a rail line, appropriate building design, layout and construction techniques should be applied to minimise noise intrusion and provide suitable internal noise levels for sleeping and external areas shielded from high levels of noise.

More details on mitigation measures for new residential developments may be available from the relevant local council, and extra details can also be found in Section 3.4 of *Environmental criteria for road traffic noise* (EPA 1999). The Rail Infrastructure Corporation (2003) has also produced interim guidelines, *Consideration of rail noise and vibration in the planning process*.

Where a proposed rail development will affect an existing development, acoustic treatment of buildings (e.g. insulation, double-glazing, upgrading construction) can be considered as an option to mitigate noise. For this to be effective, an appropriate ventilation system that does not compromise the effect of noise insulation, such as air conditioning, often needs to be incorporated into the design.

Appendix I: Comparison of airborne noise levels for rail operations – national and international

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 (e.g. the alarm/priority criteria used in Queensland, Denmark, the Netherlands, Norway, UK, Switzerland and Canada). The criteria for existing operations are typically set at 5 decibels above those for new or planned developments. Where alarm/priority criteria are set, these are 5–10 decibels above the criteria for existing operations; where criteria have not been set for existing situations, the alarm/priority criteria are 5–10 decibels 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, 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.

Comparison of airborne noise criteria worldwide

Country	Existing rail line	New rail line	Alarm/ priority	Comments
Australia				
New South Wales (*Proposed trigger*)	65 $L_{Aeq(day)}$ 60 $L_{Aeq(night)}$ 85 L_{Amax}	60 $L_{Aeq(day)}$ 55 $L_{Aeq(night)}$ 80 L_{Amax}	na	Pollution reduction programs required where goals are not met
Victoria	60 $L_{Aeq(24\ h)}$	55 $L_{Aeq(24\ h)}$ 80 L_{Amax}	na	No specified criteria. Criteria stated here were formulated specifically for the proposed Melbourne Airport rail link. No plans to make these the general criteria for rail.
South Australia	60 $L_{Aeq(24h)}$ 85 L_{Amax}	55 $L_{Aeq(24h)}$ 80 L_{Amax}	na	Use current NSW criteria as interim criteria
Tasmania	60 $L_{Aeq(24h)}$ 85 L_{Amax}	55 $L_{Aeq(24h)}$ 80 L_{Amax}	na	Use current NSW criteria
Queensland	na	65 $L_{Aeq(24h)}$ 87 L_{Amax}	70 $L_{Aeq(24h)}$ 95 L_{Amax}	Code of Practice developed by industry to demonstrate compliance with general environmental duty under *Environment Protection Act 1994*. The Code supports additional access charges for services exceeding noise criteria.
European countries[1] (façade limits)				
Austria	na	65–70 $L_{Aeq(day)}$ 55–60 $L_{Aeq(night)}$	na	Includes 5-dB bonus

Country	Existing rail line	New rail line	Alarm/ priority	Comments
Denmark	na	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% to cost of insulation; 25% at 73 dB(A); 10% at < 78 dB(A)
Finland	na	58 $L_{Aeq(day)}$ 53 $L_{Aeq(night)}$	na	
France	na	63 (60) $L_{Aeq(day)}$ 58 (55) $L_{Aeq(night)}$	na	0- or 3-dB bonus; 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 $L_{Aeq(night)}$	na	Includes 5-dB bonus
The Netherlands	na	63 $L_{Aeq(day)}$ 58 $L_{Aeq(evening)}$ 53 $L_{Aeq(night)}$	68 L_{Aeq} (at this level 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
Norway	na	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 insulation to $L_{Aeq(24h)}$ < 35 and L_{Amax} < 55	
Sweden	na	58 $L_{Aeq(24h)}$ 45 L_{Amax} (indoors)	na	
Switzerland	65 $L_{Aeq(day)}$ 55 $L_{Aeq(night)}$	60 $L_{Aeq(day)}$ 50 $L_{Aeq(night)}$	75 $L_{Aeq(day)}$ 70 $L_{Aeq(night)}$	Levels presented for residential area category only. For very sensitive subtract 5 dB, 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 include a 5-dB bonus.

Country	Existing rail line	New rail line	Alarm/ priority	Comments
United Kingdom	na	na	68 $L_{Aeq(day)}$ 63 $L_{Aeq(night)}$	Includes 2- to 3-dB bonus; criteria used to determine insulation requirements
North America				
Canada[2]	na	35 $L_{Aeq(night)}$ (bedroom) 40 $L_{Aeq(day)}$ (living areas) 55 $L_{Aeq(day)}$ (outdoor)	na	
United States[3]	na	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)	na	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[4]	na	60 $L_{Aeq(30min)}$ (day and evening) 50 $L_{Aeq(30min)}$ (night) 85 L_{Amax} (night)	na	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[5]	na	70 L_{Apeak} (residential) 75 L_{Apeak} (commercial, industrial with residences)	na	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] UK DOT 1991; Lambert and Vallet 1994; Gottlob 1995; Ljunggren 1996; Oertli and Wassmer, 1996; Hubner 1997

[2] Ministry of the Environment and Energy 1997

[3] FTA 2006

[4] Environment Protection Department Hong Kong

[5] Ministry of the Environment 1993

Glossary of terms

'A' weighting	Method of frequency weighting the electrical signal within a noise-measuring instrument to simulate the way the human ear responds to a range of acoustic frequencies
Crossovers	Two turnouts connecting two nearby and usually parallel lines
dB	Abbreviation for 'decibel', which is a measure of sound pressure level
dB(A)	The 'A' denotes that the sound pressure level has been 'A-weighted' so that the scale approximates the response of the human ear. Most community noise is measured in A-weighted decibels.
L_{A10}	Noise level in dB(A) exceeded for 10% of a specified time period. For a 1-hour period the level would be exceeded for 6 minutes but would be less for the remaining 54 minutes.
L_{A90}	Noise level in dB(A) exceeded for 90% of a specified time period. For a 1-hour period the level would be exceeded for 54 minutes but would be less for the remaining 6 minutes. This approximates the average minimum noise level and is often referred to as the background noise level.
L_{Aeq}	The L_{eq} represents the average noise energy during the measurement period. When the energy level is A-weighted it may be written as L_{Aeq}.
$L_{Aeq(1h)}$ Day	Highest 10th percentile L_{Aeq} 1-hour measurement recorded between 7 am and 10 pm
$L_{Aeq(1h)}$ Night	Highest 10th percentile L_{Aeq} 1-hour measurement recorded between 10 pm and 7 am
$L_{Aeq(15h)}$	Logarithmic average of the hourly L_{Aeq} measurements recorded between 7 am and 10 pm
$L_{Aeq(24h)}$	Logarithmic average of the hourly L_{Aeq} measurements recorded over a 24-hour period
$L_{Aeq(9h)}$	Logarithmic average of the hourly L_{Aeq} measurements recorded between 10 pm and 7 am
L_{Amax}	Highest noise level in dB(A) measured during the specified time period. A time response (fast, slow or impulse) must be specified.
L_{Apeak}	Absolute highest noise level in dB(A) measured during the specified time period when time response is not used
L_{DN}	Day-night average sound level. An L_{Aeq} with a 10 dB(A) penalty for environmental noise occurring between 10 pm and 7 am to take account of increased annoyance at night.
RMS	Root mean square
Rolling stock	Railway vehicles including electric trains, locomotives, carriages, wagons, track vehicles and buffet cars
SEL or L_{AE}	Sound exposure level. 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.
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 on short-radius curves

References and further reading

ACIL Consulting 2000, *Rail in sustainable transport,* report to the Rail Group of the Standing Committee on Transport, ACIL Consulting, Brisbane

Andersen, T.V., Kuhl, K. and Relster, E. 1988, 'Reactions to railway noise in Denmark: A correction', *Journal of sound and vibration*, 120(2), 339–40

Anderson, D. 2004, 'An acoustician's guide to railway terminology and common pitfalls with acoustic terminology when applied to rail', *Proceedings of the Australian Acoustical Society Conference*, Surfers Paradise

Berglund, B., Lindvall, T. and Schwela, D. (eds) 1999, *Guidelines for community noise*, World Health Organization, Geneva

DEC 2006, *Assessing vibration: A technical guideline*, Department of Environment and Conservation NSW, Sydney

DEC 2006, *NSW State of the Environment 2006*, Department of Environment and Conservation NSW, Sydney

Department of Transport NSW 1999, *Action for Transport 2010*, Sydney

Department of Urban Affairs and Planning NSW 2001, *Ideas for community consultation: A discussion on principles and procedures for making consultation work*, report prepared by L. Carson and K. Gelber, Sydney

DoP 2005, *Metropolitan strategy: City of cities – A plan for Sydney's future*, Department of Planning, Sydney

EPA 1999, *Environmental criteria for road traffic noise*, NSW Environment Protection Authority, Sydney

EPA 2000, *Industrial noise policy*, NSW Environment Protection Authority, Sydney

Fitzgerald, B.M. 1996, 'The development and implementation of noise control measures on an urban railway', *Journal of sound and vibration*, 193(1), 377–85

FTA 2006, *Transit noise and vibration impact assessment*, US Federal Transit Administration, Washington

Gottlob, D. 1995, 'Regulations for community noise', *Noise/news international*, December, 223–36

Heckl, M.A. and Abrahams, I.D. 2000, 'Curve squeal of train wheels, part 1: Mathematical model for its generation', *Journal of sound and vibration*, 229(3), 669–93

Hemsworth, B. 2000, 'Reducing groundborne vibrations: State-of-the-art study', *Journal of sound and vibration*, 231(3), 703–09

Hemsworth, B. and Hubner, P. 1999, 'European cooperation on railway noise', *Proceedings of Internoise 99*, Fort Lauderdale, Florida, 195–99

Hubner, P. 1997, 'Swiss tackle the noise nuisance', *Noise and vibration worldwide*, 28(4), 14–18

International Union of Railways 2000, *UIC panorama: Railway noise abatement special*, July newsletter, UIC, Paris

ISO 2005, *ISO 14837: Mechanical vibration – Ground-borne noise and vibration arising from rail systems, Part 1 General guidance*, International Organization for Standardization, Geneva

Kerr, M., Kalousek, J., Elliot, G., Mau, F. and Anderson, D. 1998, 'Squeal appeal: Addressing noise at the wheel/rail interface', *Conference on railway engineering*, Rockhampton, 317–24

Kurze, U.J. 1996, 'Tools for measuring, predicting and reducing the environmental impact from railway noise and vibration', *Journal of sound and vibration*, 193(1), 237–51

Lambert, J. and Vallet, M. 1994, *Study related to the preparation of a communication on a future EC noise policy*, LEN Report No. 9420, Bruxelles

Lambert, J., Champelovier, P. and Vernet, I. 1996, 'Annoyance from high speed train noise: A social survey', *Journal of sound and vibration*, 193(1), 21–28

Ljunggren, S. 1996, 'Noise from underground railways: A "state of the art" review', *Proceedings of Internoise 96*, Liverpool, UK, 409–14

Miedema, H.M.E. and Oudshoorn, C.G.M. 2001, 'Annoyance from transportation noise: Relationships with exposure metrics DNL and DENL and their confidence intervals', *Environmental health perspectives*, 109(4), 409–16

Ministry of the Environment 1993, *Environmental quality standards: Article 16 of Basic Environment Law (Law No. 91 of 1993)*, Government of Japan, Tokyo

Ministry of the Environment and Energy 1997, *Noise assessment criteria in land use planning*, Publication LU-131, Ontario, Canada

NSW Government 1998, *Action for air: The NSW Government's 25-year air quality management plan*, Sydney

Oertli, J. and Wassmer, D. 1996, 'Rail noise control in Switzerland: Legislation, environment, politics and finances', *Journal of sound and vibration*, 193(1), 403–06

Öhrström, E., Skånberg, A., Svensson, H. and Gidlöf-Gunnarsson, A. 2006, 'Effects of road traffic noise and benefit of access to quiet', *Journal of sound and vibration*, 295, 40–59

Rail Infrastructure Corporation 2003, *Consideration of rail noise and vibration in the planning process*, Sydney

Soundscape – Support to Health – Sweden. – www.soundscape.nu

Standards Australia 2002, *AS2377: Acoustics – Methods for the measurement of railbound vehicle noise*, Sydney

Swiss Federal Railways SBB 2000, *Environmental report 1999*, SBB AG Rail Environmental Centre, Bern

UK DOT 1991, *Railway noise and insulation of dwellings: Report of the Mitchell Committee*, Department of Transport, London

Vincent, N. 2000, 'Rolling noise control at source: State-of-the-art survey', *Journal of sound and vibration*, 231(3), 865–76