Environmental criteria for road traffic noise

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1 Introduction

1.1 Traffic noise impacts in NSW

Our road system provides extensive benefits in terms of the economic and social wellbeing of the community. However, we need to reach a balance between providing efficient road transport infrastructure and controlling the adverse affects of road use.

The Government's Action for Air Policy and the Integrated Transport Plan for NSW set in place overall strategies for reducing the use of motor vehicles, in the interests of avoiding their environmental effects.

This policy also needs to be understood in the context of the Government's metropolitan strategic objectives. The Metropolitan Strategy provides the broad framework for urban management in the Greater Metropolitan Region. A core goal of the Metropolitan Strategy is to establish a compact, efficient and accessible city. Encouraging higher density residential development and employment close to public transport and centres will be vital to achieving this goal. We must integrate land use and transport planning to increase accessibility and public transport use and reduce private vehicle use; we need responsible noise management to make this task easier.

Motor vehicle ownership in NSW has increased substantially over the last 30 years, from 260 vehicles per 1000 people in 1960 to 558 vehicles per 1000 people in 1991. General levels of road traffic noise throughout NSW have increased significantly through this period. There are currently four million vehicles registered in NSW, and 86% of all freight is moved by road.

A study conducted in 1986 (Hede et al. 1986) indicates the extent of road traffic noise impacts throughout Australia. The study involved interviews with a large random sample of the Australian population. Twenty-one per cent of Australians described themselves as being personally affected by noise pollution—more than for water, air or waste pollution. Of the sources of environmental noise, the most important was road traffic noise, with 17% of the population describing it as the noise they would most like to get rid of. The survey found that 6% of Australians were highly annoyed, and 21% moderately annoyed, by traffic noise, with 13% claiming disturbance to listening activities, and 12% claiming disturbance to sleep.

This research shows that we need programs to complement strategies that are geared towards reducing motor vehicle use with more effective ways of managing existing levels of traffic noise, through influencing the nature of road design, road use and development adjacent to roads.

The *Environmental Criteria for Road Traffic Noise* are a response to this need.

1.2 History of the criteria

The State Road Traffic Noise Task Force was established in 1989 to develop strategies for the control of traffic noise. The Task Force was composed of representatives from relevant State agencies, community groups, industry and the NRMA. The Task Force undertook a process of extensive public consultation and released its Final Report in November 1994.

The Final Report proposed under its general policy recommendations that the EPA finalise 'control guidelines and environmental criteria for road traffic noise' (p. 20).

1.3 Objectives of the criteria

The primary aims of this document are to:

- institute a more comprehensive and effective approach to managing road traffic noise
- refocus the approach to mitigating road traffic noise from relatively late in the road development process to a much earlier stage. This will allow land use planning and regulatory and policy decisions to be applied to avoid noise wherever possible, which is a less costly and more effective way to mitigate noise
- encourage the range of strategies that should be applied to reducing traffic noise (for example, traffic management, control of

vehicle emissions, and driver education), and prevent over-reliance on engineering noise controls, such as noise barriers

- revise the noise level targets so that the methodology and levels provide criteria that can assess noise impacts and recognise the benefits of all noise mitigation measures.

To control road traffic noise we need to:

- establish criteria that define acceptable noise levels
- establish standard methods for assessing and measuring noise impacts
- identify all the strategies that can be adopted to reduce traffic noise.

These are needed to provide a basis for:

- land use planners to consider how well judicious location and design of development can mitigate or avoid unacceptable noise impacts
- road designers and builders, regulators and the community to consider the nature and extent of measures to avoid or reduce noise from new roads or from the redevelopment of existing roads
- users of vehicles to consider how they can reduce noise.

The approach must reflect the fact that, in addition to road design and development controls, a number of other strategies must be used to reduce the impact of traffic noise. They include:

- governing maximum noise levels from individual vehicles
- developing programs to monitor and control noisy vehicles on the roads
- controlling noise from heavy vehicle exhaust and engine brakes
- implementing traffic management policies at local and regional levels (such as the use of dedicated truck routes, enforcement of quiet zones, and restricted access in residential areas during sleeping hours)
- continuing encouragement of the community to use public transport and to increase the numbers of passengers travelling in private vehicles.

This document provides a framework that guides the consideration and management of traffic noise issues associated with new building developments near existing or new roads, and new or upgraded road developments adjacent to new or planned building developments. The framework must allow the best mix of short-, medium- and long-term strategies to be selected to meet the appropriate noise level, given existing and emerging conditions. Noise impacts and mitigation measures must be considered early in the planning process. Where planning approaches are appropriate, they can be the most effective and lowest cost means of mitigating noise impacts.

The framework embodies a non-mandatory performance-based approach. The criteria are applied as targets, but recognise that there will be situations where planning strategies are not feasible. Solutions that can be reasonably applied in the short term may not always meet the target. For these cases, a longer-term perspective needs to be taken to institute ongoing strategies that will minimise traffic noise impacts over time.

The approach embodied in this document is an important departure from the traditional approach, which relies almost solely on addressing traffic noise impacts in the road development process and through road engineering strategies such as noise barriers. The ‘engineering’ approach is proving to be increasingly costly and, equally importantly, does not always ensure that the community gets the best protection from excessive noise. It ignores the considerable (and often less costly) gains that can be secured through land use planning, regulation of vehicles, driver education and careful building design.

In relation to land use planning, road planning and road design, the noise level criteria set out in this document should be taken into account at an early stage in planning a new development near a planned or existing road, or in planning a new road or new road use. If this is done, the effects of road traffic noise can be assessed and controlled throughout the planning process. To the fullest extent possible, a new road should be aligned, designed and constructed to meet the criteria. If this is not practicable, other initiatives, such as controls on road-use behaviour—including speed or the use of exhaust brakes—and on land use and building design, will need to be instituted to reduce impacts.

Similarly, it is expected that if planners of new developments near roads consider these criteria, they will be able to develop formal planning mechanisms to avoid exposing future building occupants to excessive noise.

The policy is not designed to be applied to existing roads for the purpose of retrofitting engineering-based noise mitigation works. Nevertheless, the noise assessment methodology can be used to help assess the impact of existing roads, bridges or freeways on existing developments, and to develop feasible and reasonable approaches to reducing any excessive impacts over time.

A secondary aim of the policy is to institute an accurate way of measuring the level of noise impact in existing and potential situations. This will allow proper quantification of the extent of noise impact, and will also help assess the relative impacts for particular sites.

This will be particularly valuable for cost–benefit assessments of the options for mitigating noise from the redevelopment of existing road facilities, and also for selecting appropriate strategies for areas shown to have high levels of traffic noise. Strategies that may be adopted include enhancing road design (such as improving pavement quality and using noise barriers), enforcing noisy vehicle regulations, better traffic management, and (in the longer term) improved vehicle noise controls and better land use planning.

Ultimately the intentions are:

- to allow the Department of Urban Affairs and Planning and local councils to develop and set appropriate criteria, controls and uses for land affected by road traffic noise
- to help integrate land use planning and road transport planning
- to help road builders and managers to select feasible and reasonable noise mitigation measures where these prove to be necessary
- to discourage road users from owning and operating noisy vehicles.

1.4 Development of the criteria

The criteria have been developed on the basis of the most recent Australian and overseas data and research on best practice approaches to noise prediction and management.

The EPA has identified a number of areas in which the current approach to noise assessment and levels is deficient, including:

- for developments other than freeways, no specific account is taken of the potential of noise to cause sleep disturbance
- there are serious practical difficulties in the evaluation of the traffic noise level (TNL) index previously relied upon to guide new road developments
- the TNL index is based on technically achievable levels for road design, with no sensitivity to the relative cost or environmental effectiveness of other noise management strategies
- there are apparent deficiencies in using a single value for L_{Aeq} and L_{10} descriptors for predicting certain types of disturbance, particularly to sleep
- no criteria are provided for assessing and managing impacts on land use other than residential
- existing noise criteria for local roads have been developed over a period of time, resulting in a piecemeal approach that has relied on both L_{Aeq} and L_{10} descriptors and that does not differentiate day / night periods.

These *Environmental Criteria for Road Traffic Noise* are intended to address the above perceived deficiencies. (Details of the old EPA traffic noise guidelines, research findings and overseas approaches are set down in Appendixes A and B).

2 The criteria

2.1 Assessing noise impacts

Noise measurement and assessment methods are an integral part of implementing any set of noise criteria. Noise measurement procedures are described in Appendix C, together with a step-by-step methodology for assessing the noise impact from road traffic.

2.2 Road traffic noise criteria

Road traffic noise levels

A number of factors should be considered in setting road traffic noise levels:

- whether there is an existing road corridor and, if so, whether the road project is intended to increase traffic-carrying capacity substantially, or whether the mix of traffic would be substantially changed. Residents tend to be more sensitive to new noise sources than to existing noise sources of the same noise level. The difference in sensitivity has been identified in studies, and these are discussed in Appendix B4. Furthermore, existing road corridors generally provide less scope for reducing noise levels

- whether or not substantial changes to the alignment of a road are proposed, or whether the road is on a 'new' corridor. In cases where substantial road alignment changes are proposed or there is a new road corridor, there is maximum flexibility to select best measures to meet noise levels at the planning stage. This is a good opportunity to achieve optimum noise management through choosing a minimum impact alignment, appropriate road design, and / or appropriate management of development adjacent to an existing road

- whether the design / profile of a proposed road is to be altered substantially. In these cases, there is an opportunity to consider noise reduction options in the design phase (for example, putting a large proportion of the road in a tunnel, rather than at surface level).

- whether the criteria are being applied in relation to any redevelopment occurring adjacent to an established road. In these cases, there is an opportunity to use the orientation and / or design of the development to control or reduce noise impact.

- whether the area affected is in an urban or rural environment where existing noise levels will inevitably vary substantially, and where the response to additional noise will also vary.

All these factors have been considered in the development of the noise level criteria.

Functional categories of roads

In Table 1, roads have been classified according to the functional categories applied by the RTA. In the RTA *Road Design Guide 1996* roads are differentiated by a range of factors, including traffic volume, heavy vehicle use, through or local traffic, vehicle speeds and applicable traffic management options. The functional categories for roads consist of:

- arterial roads (including freeways), which carry predominantly through-traffic from one region to another, forming principal avenues of communication for urban traffic movements

- sub-arterial roads, which connect the arterial roads to areas of development and carry traffic from one part of a region to another. They may also relieve traffic on arterial roads in some circumstances.

- collector roads, which connect the sub-arterial roads to the local road system in developed areas

- local roads, which are the subdivisional roads within a particular developed area. These are used solely as local access roads.

It is noted that some industries (such as mines and extractive industries) are, by necessity, in locations that are often not served by arterial roads. Heavy vehicles must be able to get to their bases of operation, and this may mean travelling on local roads. Good planning practice recognises that we must acknowledge this type of road use and develop ways of managing any associated adverse impacts. To this end, the concept of 'principal haulage routes' has been endorsed by the Department of Urban Affairs and Planning's North Coast Extractive Industries Standing Committee. Ways of identifying 'principal haulage routes' and managing associated adverse impacts have not yet been fully defined. Where local authorities identify a 'principal haulage route', the noise criteria for the route should match those for collector roads, recognising the intent that they carry a different level and mix of traffic to local roads.

The criteria tables

Table 1 sets out the criteria to be applied to particular types of road and land uses, including residential-, rural- and urban-zoned lands occupied by dwellings. In Table 1 arterial roads (including freeways) and sub-arterial roads are grouped together and are referred to as freeways / arterial roads.

Table 2 recognises that in some cases there will be extra noise sensitivities (for example, in hospitals and schools) where more stringent standards are expected. For the specific land uses of schools, hospitals and places of worship and recreation, criteria have been set with regard to the principle that the characteristic activities for each of these land uses should not be unduly disturbed.

The noise criteria in Table 2 are to be applied for assessing impact and determining mitigation measures in the following situations:

- a new road or road redevelopment
- a new noise-sensitive land use development affected by road traffic noise
- a land use with the potential to create additional traffic on local and / or collector roads.

The values presented in the tables are intended to preserve amenity appropriate to the land use. The confidence for such an outcome occurring for the specified noise levels is based on well-documented social surveys defining a dose–response relationship between noise level and annoyance. These values are also supported by the comparison with overseas criteria.

Table 1. Road traffic noise criteria for proposed road or residential land use developments

For an explanation of the terms used here, see the sections 'Guide to terms used in the tables' and 'Technical notes to the tables' immediately following the tables.

TYPE OF DEVELOPMENT	CRITERIA		
	DAY (7 am–10 pm) dB(A)	NIGHT (10 pm–7 am) dB(A)	WHERE CRITERIA ARE ALREADY EXCEEDED
1. New freeway or arterial road corridor	$L_{Aeq(15hr)}$55	$L_{Aeq(9hr)}$50	The new road should be designed so as not to increase existing noise levels by more than 0.5 dB. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In some instances this may be achievable only through long-term strategies such as improved planning, design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards and regulation of in-service vehicles; greater use of public transport; and alternative methods of freight haulage.
2. New residential land use developments affected by freeway / arterial traffic noise	$L_{Aeq(15hr)}$55	$L_{Aeq(9hr)}$50	Where feasible and reasonable, existing noise levels should be reduced to meet the noise criteria via judicious design and construction of the development. Locations, internal layouts, building materials and construction should be chosen so as to minimise noise impacts.
3. Redevelopment of existing freeway / arterial road	$L_{Aeq(15hr)}$60	$L_{Aeq(9hr)}$55	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dB. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In many instances this may be achievable only through long-term strategies such as improved planning, design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards and regulation of in-service vehicles; greater use of public transport; and alternative methods of freight haulage.

TYPE OF DEVELOPMENT	CRITERIA		
	DAY (7 am–10 pm) dB(A)	**NIGHT (10 pm–7 am) dB(A)**	**WHERE CRITERIA ARE ALREADY EXCEEDED**
4. New collector road corridor	$L_{Aeq(1hr)}$60	$L_{Aeq(1hr)}$55	The new road should be designed so as not to increase existing noise levels by more than 0.5 dB. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In some instances this may only be achievable through long-term strategies, such as improved planning, design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards and regulation of in-service vehicles; greater use of public transport; and alternative methods of freight haulage.
5. New residential developments affected by collector traffic noise	$L_{Aeq(1hr)}$60	$L_{Aeq(1hr)}$55	Where feasible and reasonable, existing noise levels should be reduced to meet the noise criteria via judicious design and construction of the development. Locations, internal layouts, building materials and construction should be chosen so as to minimise noise impacts.
6. Redevelopment of existing collector road	$L_{Aeq(1hr)}$60	$L_{Aeq(1hr)}$55	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dB. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In many instances this may be achievable only through long-term strategies, such as improved planning, design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards and regulation of in-service vehicles; greater use of public transport; and alternative methods of freight haulage.
7. Land use developments with potential to create additional traffic on existing freeways / arterials	$L_{eq(15hr)}$60	$L_{eq(9hr)}$55	Where feasible, existing noise levels should be mitigated to meet the noise criteria. Examples of applicable strategies include appropriate location of private access roads; regulating times of use; using clustering; using 'quiet' vehicles; and using barriers and acoustic treatments. In all cases, traffic arising from the development should not lead to an increase in existing noise levels of more than 2 dB.

TYPE OF DEVELOPMENT	CRITERIA		
	DAY (7 am–10 pm) dB(A)	**NIGHT (10 pm–7 am) dB(A)**	**WHERE CRITERIA ARE ALREADY EXCEEDED**
8. Land use developments with potential to create additional traffic on collector road	$L_{Aeq(1hr)}$60	$L_{Aeq(1hr)}$55	Where feasible and reasonable, existing noise levels should be mitigated to meet the noise criteria. Examples of applicable strategies include appropriate location of private access roads; regulating times of use; using clustering; using 'quiet' vehicles; and using barriers and acoustic treatments. In all cases, traffic arising from the development should not lead to an increase in existing noise levels of more than 2 dB.
9. New local road corridor in a metropolitan area	$L_{Aeq(1hr)}$55	$L_{Aeq(1hr)}$50	The new road should be designed so as not to increase existing noise levels by more than 0.5dB. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In many instances this may be achievable only through medium-term and long-term strategies, such as regulation of exhaust noise from in-service vehicles; limitations on exhaust brake use; restricted access for sensitive areas or during sensitive times to low-noise vehicles; improved planning, design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards; and alternative methods of freight haulage.
10. New local road corridor in a rural area	$L_{Aeq(1hr)}$50	$L_{Aeq(1hr)}$45	
11. New residential developments affected by traffic noise from local roads	$L_{Aeq(1hr)}$55	$L_{Aeq(1hr)}$50	Where feasible and reasonable, existing noise levels should be mitigated to meet the noise criteria for occupants by judicious design and construction of the development. Relevant strategies will include optimum location and orientation of buildings on the site; planning internal layouts carefully; choosing the most appropriate building materials; and using good construction techniques.

TYPE OF DEVELOPMENT	CRITERIA		
	DAY (7 am–10 pm) dB(A)	**NIGHT (10 pm–7 am) dB(A)**	**WHERE CRITERIA ARE ALREADY EXCEEDED**
12. Redevelopment of existing local roads	$L_{Aeq(1hr)}$55	$L_{Aeq(1hr)}$50	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dB. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In many instances this may be achievable only through medium-term and long-term strategies, such as regulation of exhaust noise from in-service vehicles; limitations on exhaust brake use; restricted access for sensitive areas or during sensitive times to low-noise vehicles; improved planning, design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards; and alternative methods of freight haulage.
13. Land use developments with potential to create additional traffic on local roads	$L_{Aeq(1hr)}$55	$L_{Aeq(1hr)}$50	Where feasible and reasonable, existing noise levels should be mitigated to meet the noise criteria. Examples of applicable strategies include appropriate location of private access roads; regulating times of use; using clustering; using ‘quiet’ vehicles; and using barriers and acoustic treatments. In all cases, traffic arising from the development should not lead to an increase in existing noise levels of more than 2 dB.

Table 2. Road traffic noise criteria for sensitive land uses

For an explanation of terms used here see the sections ‘Guide to terms used in the tables’ and ‘Technical notes to the tables’ immediately following the tables.

SENSITIVE LAND USE	CRITERIA		
	DAY 7 am–10 pm dB(A)	NIGHT 10 pm–7 am dB(A)	NOISE MITIGATION MEASURES
1. Proposed school classrooms (For existing schools see Technical Note x)	$L_{Aeq(1h)}$ 40 (internal)	-	To achieve internal noise criteria in the short term, the most practicable mitigation measures are often related to building or façade treatments. In the medium to longer term, strategies such as regulation of exhaust noise from in-service vehicles, limitations on exhaust brake use, and restricting access for sensitive areas or during sensitive times to low noise vehicles can be applied to mitigate noise impacts across the road system. Other measures include improved planning, design and construction of sensitive land use developments; reduced new vehicle emission standards; greater use of public transport; and alternative methods of freight haulage. These medium- to long-term strategies apply equally to mitigating internal and external noise levels. Where existing levels of traffic noise exceed the criteria, all feasible and reasonable noise control measures should be evaluated and applied. Where this has been done and the internal or external criteria (as appropriate) cannot be achieved, the proposed road or land use development should be designed so as not to increase existing road traffic noise levels by more than 0.5 dB(A) for new roads and 2 dB(A) for redeveloped roads or land use development with potential to create additional traffic.
2. Hospital wards	$L_{Aeq(1h)}$ 35 (internal)	$L_{Aeq(1h)}$ 35 (internal)	
3. Places of worship	$L_{Aeq(1h)}$ 40 (internal)	$L_{Aeq(1h)}$ 40 (internal)	
4. Active recreation (for example, golf courses)	Collector and local roads: $L_{Aeq(1h)}$ 60 Freeway/ arterial roads: $L_{Aeq(15h)}$ 60	-	
5. Passive recreation and school playgrounds	Collector and local roads: $L_{Aeq(1h)}$ 55 Freeway/ arterial roads: $L_{Aeq(15h)}$ 55	-	

Guide to terms used in the tables

Freeway/arterial includes sub-arterial roads and refers to roads handling through-traffic, with characteristically heavy and continuous traffic flows during peak periods. Through-traffic is traffic passing through a locality bound for another locality.

New freeway/arterial refers to a freeway, arterial or sub-arterial road that is proposed on a 'corridor' that has not previously been a freeway, arterial or sub-arterial road; or an existing freeway, arterial or sub-arterial that is being substantially realigned.

Redevelop existing freeway/arterial refers to an existing freeway, arterial or sub-arterial corridor where it is proposed to increase traffic-carrying capacity, change the traffic mix or change the road alignment through design or engineering changes. Redevelopment does not cover minor road works designed to improve safety, such as straightening curves, installing traffic control devices or making minor road alignments.

Collector road refers to a road situated in a built-up area that collects local traffic leaving a locality and connects to a sub-arterial road.

Redevelop existing collector road refers to changes to a collector road corridor where it is proposed to increase the traffic-carrying capacity, change the traffic mix or change the road alignment through design or engineering changes. Redevelopment does not cover minor road works designed to improve safety, such as straightening curves, installing traffic control devices or making minor road alignments.

Local road—metropolitan refers to a road situated in built-up areas and handling local traffic. These roads characteristically have intermittent traffic flows. Metropolitan refers to the built-up area of a city or town, and includes both the urban zone of the CBD and adjacent localities, and the suburban zone situated between the urban and rural zones.

Local road—rural refers to a road situated in rural areas and handling local traffic with characteristically intermittent traffic flows.

Redevelop existing local road refers to changes to a local road corridor where it is proposed to increase the traffic-carrying capacity, change the traffic mix or change the road alignment through design or engineering changes. Redevelopment does not cover minor road works designed to improve safety, such as straightening curves, installing traffic control devices or making minor road alignments.

Land use development with potential to create additional traffic on existing roads implies increases to the magnitude of the traffic flow and / or changes to the traffic mix brought about by new land use developments or significant alterations to existing land use developments, which may not involve any construction to the road. This category does not cover minor changes that are not subject to either development consent or amendment to an EPA licence.

New residential development affected by traffic noise addresses the acceptable level of road traffic noise impact for new residential developments.

Technical notes to the tables

Details of the approaches to take when measuring and predicting noise are set out in Appendix C, but it is worthwhile to note here the key points in interpreting the specified noise levels from a technical perspective.

i Specified noise values refer to noise from traffic on roads, road bridges and freeways, and do not include ambient noise from other sources. However, they rely on all traffic noise at the receiver location—not only noise due to the project under consideration.

ii $L_{Aeq(1hr)}$ represents the highest tenth percentile hourly A-weighted L_{eq} during the period 7 am to 10 pm or the period 10 pm to 7 am (whichever is relevant). If this cannot be defined accurately, use the highest hourly A-weighted L_{eq} noise level. More information on L_{Aeq} is in Appendix C.

—$L_{Aeq(15hr)}$ represents the L_{eq} noise level for the period 7 am to 10 pm.

—$L_{Aeq(9hr)}$ represents the L_{eq} noise level for the period 10 pm to 7 am.

—The 'A' weighted L_{eq} noise level descriptor has been chosen for use with the criteria, and is designed to measure a level of annoyance reaction caused by road traffic noise. As explained in Appendix B, social surveys have shown that for existing noise, a level of L_{Aeq} 55 dB(A) equates to about 10% of a population exposed to this noise level being highly annoyed.

—Freeways and arterial roads handle high volumes of through-traffic over extended periods of time; hence the need for a noise descriptor that measures noise exposure for the full day and night periods. Local roads in metropolitan areas, by contrast, handle only intermittent local traffic and require a shorter measurement period.

iii In assessing noise levels at residences, the noise level is to be measured at 1 m from the facade that is the most exposed to traffic noise, and at a height of 1.5 m from the floor level. The residential noise level criterion includes an allowance for noise reflected from the facade ('facade correction'). If reflection during measurement is unlikely (as, for instance, when measuring on open land before a residence is built), add an appropriate correction—generally 2.5 dB(A)—to the measured value.

iv Where internal noise levels are specified, they refer to the noise level at the centre of the habitable room that is most exposed to the traffic noise.

v In the case of multi-level residential buildings, the external point of reference for measurement for the criteria is the two floors of the building that are most exposed to traffic noise (generally the ground and first floors). On other floors, the guideline is that the internal noise level should not exceed a value 10 dB below the relevant external noise level on the basis of openable windows being opened sufficiently to provide adequate ventilation (Refer to Building Code of Australia for additional information.) For most residences this equates to a minimum of 20% of the window area left open.

vi For all road developments, the criteria should apply on the basis of the traffic volumes projected for 10 years' time. The noise criteria should also apply immediately after the road opens. In the case of buildings used for education or health care, noise level criteria for spaces other than classrooms and wards may be obtained by interpolation from the 'maximum' levels shown in Australian Standard 2107 *Acoustics—Recommended design sound levels and reverberation times for building interiors*.

vii For commercial and industrial developments, information on desirable noise levels is contained in Australian Standard 2107 *Acoustics—Recommended design sound levels and reverberation times for building interiors.*

viii In Table 1, for categories 3, 6 and 12 (redevelopment of existing roads) and 7, 8 and 13 (land use developments with the potential to create additional traffic), where the existing road traffic noise levels lie within 2 dB of the noise criteria, the 2 dB allowance can be applied where all feasible and reasonable mitigation measures have been used. The same approach applies to categories 1, 4, 9 and 10 (new road corridors) in Table 1, where a 0.5 dB allowance is assigned.

ix If the existing noise level is below the criteria but within 2 dB of the criteria, then the 2dB allowance may be applied to the existing noise level.

x In cases where existing schools are affected by noise from proposed roads, the daytime criterion is $L_{Aeq(1h)}$ 45dB(A) (internal).

Maximum noise levels

Unlike L_{Aeq} levels and annoyance reactions, the relationship between maximum noise levels and sleep disturbance is not currently well defined. (See Appendix B.) In addition, the effects of sleep disturbance on health are not clear. While research indicates that noise at low levels can cause autonomic reactions (including changes in gastrointestinal activity and cardiovascular responses), there is no clear indication of what, if any, impact these reactions may have on health.

Based on a review of the relevant research (see Appendix B), the following conclusions have been drawn.

- Sleep disturbance occurs through two mechanisms: changes in sleep state and awakenings.
- Awakenings are better correlated to subjective assessments of sleep quality than are changes in sleep state.

- Factors (other than noise) that contribute significantly to awakening reactions include sleep state and subject age.

- The maximum noise level, the extent that noise exceeds the ambient noise level, and the number of noise events, all contribute to sleep disturbance.

There are some unresolved points regarding sleep disturbance and maximum noise levels. Even where noise is not a factor, awakenings may still occur. Typically this level of awakening is 1 to 1.5 per night. Thus, some level of sleep disturbance through awakenings that are not related to noise incidents is quite usual. Further, the number of additional awakenings that would have a significant effect on health and wellbeing is yet to be demonstrated. Similarly, the extent to which sleep state and other sleep disturbance indicators affect health is still to be determined.

Therefore, at the current level of understanding, it is not possible to establish absolute noise level criteria that would correlate to an acceptable level of sleep disturbance.

This does not mean that we should avoid considering maximum noise levels. It does mean that we should start to consider these levels broadly, and that we should start more rigorous assessment and research on the sleep disturbance effects of traffic noise.

At our present level of understanding, it is important that all of the noise characteristics of road traffic noise known to affect sleep are assessed.

This means that we should assess the likely maximum noise levels from road traffic, the extent to which these maximum noise levels exceed the ambient noise level, and the likely number of noise events from road traffic during the night.

Because the relationship between noise, sleep disturbance and health is not fully understood at this stage, is not possible to define fully how the different noise characteristics of road traffic should be measured to best estimate effects on sleep.

The intention is to refine the definition of the important noise characteristics of road traffic noise as understanding improves.

Maximum noise levels during each hour of the night-time period should be assessed and reported to give an indication of the likelihood of awakening reactions.

Where noise levels are already exceeded

The fourth column in the tables shows the preferred approach where existing noise levels already exceed the noise criteria.

In areas where the criteria are exceeded by high existing levels of road traffic noise, the capacity to employ noise reduction measures will depend on current circumstances and on whether any change to the road and / or adjoining development is also proposed. The most stringent criteria apply to the development category with the most noise reduction options, and the least stringent criteria apply where there is little potential for noise control. This is discussed more fully below.

As a general principle, where reduction of existing noise levels is possible, a reduction in noise levels in line with the noise criteria is desirable. The best combination of short-term and long-term measures should be applied. In some instances it is expected that reduction in traffic noise levels will be practicable only over time. Long-term measures, such as reducing vehicle noise emissions through new Australian Design Rules (ADRs), considering existing noise levels in planning decisions, and developing alternative methods of transport, are examples of applicable long-term strategies.

New road development in greenfield sites is likely to present a wide range of potential noise control measures and would not be expected to add to existing noise levels from road traffic noise by more than 0.5 dB.

The redevelopment of existing corridors offers a more limited range of noise control measures because of likely limitations to using corridor route adjustment, proximity of residents to the road and limited road re-design options. Construction activity may, however, provide some potential at least to contain noise increases as a result of the development. Measures should be formulated with a view to achieving the noise criteria. However, where this is demonstrated not to be feasible, it is expected that strategies be implemented to contain any increases to 2 dB above the prevailing noise level before re-development begins.

Upgrading of roads not designed to increase road traffic inherently should not create significant noise impacts.

New industrial, commercial or residential developments that generate additional traffic on existing roads are likely to provide limited potential for noise control, because such developments are not usually linked to road improvements. The criteria recognise the difficulties in these cases by specifying that any road traffic noise increase should be limited to 2 dB above existing levels before the development takes place, where it is shown that meeting the criteria is not feasible and reasonable.

Where there is new residential development that can be affected by noise from existing roads, it is expected that developers will be able to use a number of noise control options to mitigate traffic noise. These options include designing developments so that sensitive land uses are protected from excessive noise through the use of options such as optimum location and orientation on the site, well-planned internal layouts, noise insulating building materials and construction methods that facilitate noise control.

Similarly, these principles can be applied to schools, hospitals, places of worship and the location of recreational areas.

Opportunities are more limited for existing land uses affected by existing roads, but where opportunities such as building improvements arise, noise control measures should be applied as far as practicable.

In the longer term, for all development and existing use categories, strategies should be developed for overall reductions in road traffic noise using the criteria as the target.

Internal noise levels

It is preferable for internal noise level criteria to be set by the relevant planning or building authority. The internal levels that are set may vary depending on the type of development the planning authority wants to encourage for an area. The Hornsby Shire and Sydney City councils have codes for internal noise level criteria in place. Sleeping areas are usually the most sensitive to noise impact, so in the absence of any local codes internal levels of 35–40 dBA at night are recommended. As a guide for other living areas, internal noise levels 10 dB below external levels are recommended on the basis of openable windows being opened sufficiently to provide adequate ventilation (refer to Building Code of Australia for additional information). For most residences this equates to a minimum of 20% of the window area left open.

3 Applying the criteria

3.1 Points to consider

It is clear that to apply the road traffic noise criteria successfully we will need an integrated management approach, involving a number of strategies administered by a number of agencies, over both the short and longer terms. Some measures should be adopted across the board; others need to be pursued in the context of individual road projects.

The non-mandatory nature of the criteria implies a process that needs to be followed to derive achievable noise levels for specific projects. That process commences with the criteria providing the target level that should be sought to be met and then incorporates considerations of cost, feasibility, equity and community preferences. Where it can be demonstrated that the target is not practicable, feasible or reasonable to achieve within the project planning, design and implementation for justifable reasons, then the criteria should be approached as closely as possible, with the aim of adopting broader supporting strategies for achieving the criteria in the longer term.

In this context, feasibility relates to engineering considerations and what can practically be built (for example, whether the type of building would allow acoustic treatment of the facade, or whether a particular road design is possible given the available road corridor site constraints).

Reasonableness relates to the application of judgement, taking into account the following factors:

- noise mitigation benefits—amount of noise reduction provided, number of people protected
- cost of mitigation—total cost and cost variation with benefit provided
- community views—aesthetic impacts and community wishes
- noise levels for affected land uses—existing and future levels, and changes in noise levels
- benefits arising from the development.

Although the criteria are non-mandatory, they provide the basis for establishing appropriate noise levels that can be incorporated into conditions in development consents issued by consent authorities (such as local authorities and DUAP) and into licences issued by the EPA. Where noise level conditions are set, they would result from starting with the noise criteria as the targets and then applying all feasible and reasonable measures. Noise levels higher than the criteria may need to be applied as a condition of consent where it is demonstrated that the criteria cannot be met by applying all feasible and reasonable mitigation measures.

3.2 Existing roads not subject to redevelopment

For existing roads (where no redevelopment is taking place), the primary role of the policy is to provide a basis for measuring and defining the extent of any existing traffic noise impacts.

The targets for existing roads not subject to redevelopment are:

- for existing freeway / arterial:

$L_{Aeq(15hr)}$	60 dB(A)	day
$L_{Aeq(9hr)}$	55 dB(A)	night

- for existing collector roads:

$L_{Aeq(1hr)}$	60 dB(A)	day
$L_{Aeq(1hr)}$	55 dB(A)	night

- for existing local roads:

$L_{Aeq(1hr)}$	55 dB(A)	day
$L_{Aeq(1hr)}$	50 dB(A)	night.

Resources are generally limited for noise control on existing roads, and strategies need to take into account what is reasonable and feasible; in many cases noise levels will have increased incrementally over long periods of time, allowing for a degree of habituation to noise.

Retrofitting of engineering-type noise controls is generally not recommended as a suitable strategy for addressing existing undesirable levels of road traffic noise impact where no upgrading or redevelopment is occurring. The reasons for this include:

- relatively large urban areas are already subjected to undesirable levels of road traffic noise, and the benefits from retrofitting noise controls are usually limited to relatively small areas. To be effective, any strategy needs to be able to address the widespread nature of the impacts

- there are often high costs and practical difficulties associated with retrofitting noise controls.

The retrofitting of engineering-type noise controls to existing roads where no upgrading or redevelopment is occurring should be limited to situations where there are acute noise impacts that require prompt attention.

The Noise Abatement Strategy that has been developed and implemented by the RTA on a priority basis for State-owned roads is an appropriate response for addressing acute existing traffic noise impacts. This strategy directs resources to receivers experiencing the highest road traffic noise impacts.

The preferred approach to addressing existing (and potential) traffic noise impacts are through State-wide or region-wide strategies, such as: progressive reduction of vehicle noise emission standards; in-service inspections to ensure vehicle mufflers are well maintained; driver education; traffic management (including limited access area for heavy vehicles); regulation of exhaust brakes; the integration of transportation and land use planning; and the promotion of design and construction of new housing alongside transport corridors to minimise noise impacts. These strategies offer the most promise in addressing existing (and potential) noise impacts in an overall fashion, rather than relying on piecemeal approaches such as the erection of noise barriers.

3.3 Individual road projects

Opportunities to improve road traffic noise levels arise when an existing road is redeveloped, and the appropriate criteria (see Table 1 and Table 2) and strategies should be applied. For new roads there is an even greater opportunity to ensure that noise criteria are met.

In arriving at the level of traffic noise that would occur in relation to any given road project, a technical and economic assessment would normally be done to establish feasible and reasonable options for noise mitigation. Such an assessment would include traffic noise criteria as a primary consideration. Other relevant factors—such as aesthetics, cost-effectiveness, engineering feasibility, equity issues and community preferences—would also be considered in the assessment process.

Where noise barriers are identified as the primary means of noise mitigation, then aesthetic considerations will include the protection of views, the presence of shadowing, and the design of the noise barriers.

Developing the details of the process to be followed in assessing noise mitigation for road developments is the job of road managers, who have both the responsibility for assessing the impacts of road developments and the relevant expertise in noise mitigation works. The assessment process for determining feasible and reasonable noise mitigation works for individual road projects needs to provide the community with a transparent decision-making process and to address what can be done in situations where the chosen noise mitigation works do not meet the noise targets.

For some transport corridors, the criteria would be readily met through judicious road corridor selection and road design. For more difficult situations, existing uses in the transport corridor may prevent the selection of a corridor that avoids impacts, and the use of more effective road design strategies may still mean that noise exceeds the criteria. In particular, there may be practical problems incorporating appropriate engineering solutions in existing road corridors. In these cases, the proponent would be expected to collaborate with land use authorities, and to identify the additional strategies needed to achieve the noise level criteria.

Where the existing traffic noise already exceeds the criteria, the marginal noise allowance of 0.5 dB (new road) or 2 dB (road redevelopment) should be applied only after all feasible mitigation measures have been assessed and all reasonable mitigation measures applied. Before applying the allowance, the following issues need to be considered:

- Identify how all feasible and reasonable measures have been considered in seeking to achieve the noise criteria.
- Identify how road traffic noise levels can be reduced over time, from a strategic perspective, by applying measures such as lower vehicle noise emission limits (ADRs), driver education (on issues such as exhaust brake use) and traffic management (for example, on defined truck routes).
- Where it is not possible to show that significant noise reductions would result from these strategic approaches for the project or location being considered, then feasibility and reasonableness of engineering options such as road surface treatments and other acoustic treatments needs to be assessed.
- Finally, where strategic and project-specific mitigation measures have been shown not to be feasible and reasonable, then a 0.5 dB (for new roads) or a 2 dB (for redeveloped roads and land use developments with potential to create additional traffic) increase in existing noise levels is allowed.

Information on maximum noise levels can be used to assess the relative impacts on sleep of different options for new roadway developments, and to rank maximum noise level impacts on residences so that noise control measures can be prioritised.

Note that the impact of noise on sleep relates to noise levels experienced inside the home[1] . On this basis, approaches used to control noise impacts on sleep can be different from those used to address annoyance.

The most promising strategies for limiting maximum noise levels are:

- reducing noise at the source through stricter noise emission requirements on new vehicles
- enforcing in-service noise emission limits
- improved land use planning
- improved noise design requirements for buildings near heavily trafficked roads
- management of traffic through heavy vehicle routes, with limited access to residential areas.

3.4 New residential developments affected by road traffic noise

New residential areas provide greater opportunities for noise mitigation than existing developments, because strategies can be implemented at both the planning stages of a development as well as at the individual allotment stage. In planning and designing a development it is important that noise be considered and balanced against other design considerations, such as solar access, privacy and security.

Noise mitigation measures for new residential developments would include:

1. Considering traffic noise impacts when planning the development of areas and incorporating suitable measures such as:
   —spatial separation between noisy activities and noise-sensitive areas through locating less noise-sensitive land uses (active recreation areas or access ways) in high noise areas
   —taking advantage of any natural topographic features that can be used to screen noise impacts when planning land use in an area
   —laying out subdivisions in ways that maximise the area shielded from noise
   —using intervening structures such as multi-level buildings to act as barriers. Buildings used as barriers should incorporate noise-quietening principles into their building design to ensure appropriate internal conditions.
2. Appropriate building design on development around roads to minimise noise impacts, for example by:
   —including acoustic design principles when

[1]Appendix B5 reviews the current level of knowledge and concludes that maximum internal noise levels below 50–55 dBA are unlikely to cause awakening reactions, and that one or two noise events per night with maximum internal noise levels of 65–70 dBA are not likely to affect health and wellbeing significantly.

planning landscaping for a site by examining the suitability of earth berms, walls or fences to act as barriers

—designing buildings to locate noise-insensitive areas such as the kitchen, storage areas and laundry towards the noise source; minimising the numbers and size of windows oriented towards the noise source; replacing a conventional roof design with eaves by a flat roof with parapets; and using the building structure to shield outdoor areas

—using construction techniques that pay good attention to sealing air gaps around doors and windows exposed to noise; using solid core doors; and using thicker window glass or double glazing.

There are a number of documents that provide advice on planning and building design options to mitigate road traffic noise, including:

- A *Guide for Homeowners, Designers and Builders—Reducing Traffic Noise,* available from the RTA, dated August 1991.
- *Traffic Noise and Your Next Home*—brochure available from the RTA
- *AMCORD—A National Resource Document for Residential Development*, published by the former Commonwealth Department of Housing and Regional Development
- *Better Urban Living,* 'Acoustic Privacy' section, pages 33–4, published by DUAP and the Government Architect
- *NSW Model Code* published by DUAP.

3.5 Land use developments that create traffic

Land use developments may have the potential to create additional traffic and affect existing residential or other noise-sensitive land uses.

The criteria contemplate accepting an increase in levels of existing traffic noise only after all feasible and reasonable mitigation measures have been applied. The intent is to limit any additional traffic noise impacts as far as practicable. In practice, the application of the 2 dB(A) allowance would need to take into account the prevailing circumstances. For example, a development will not be able to obtain multiple use of the 2 dB(A) allowance simply by dividing a large development into small segments. However, where a single development covers a large area and separate changes are expected to increase traffic noise to two widely separated areas around the site (so as not to have any cumulative noise impact), then the 2 dB(A) allowance may be applied for each area. This, of course, would need to be assessed on a case-by-case basis. Where several separate developments are proposed in an area, and each is expected to contribute to an overall cumulative noise impact, then as far as possible these developments should be considered both individually and as a group for the purposes of assessing impacts and deciding mitigation measures.

For developments that create additional traffic, there may be situations where it is reasonable and necessary to vary the standard time periods applied to the day and night periods. For example, there will be instances where the noise levels in an area begin to rise earlier than 7 am (the standard time delineating day and night) due to normal early morning activity from the general community. For these situations 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. In these situations, appropriate noise level targets for the 'shoulder periods' may be negotiated with the determining or regulatory authority on a case-by-case basis.

3.6 General strategies

These strategies cover the three approaches to noise control; that is, control of the source, control in transmission, and control at the receiver. Solutions to the traffic noise problem can rarely be found through any single strategy. Any real gain will generally depend on a combination of strategies.

The strategies listed in Table 3 are considered to be areas of high priority.

Table 3. General traffic noise management strategies and responsible organisations

GENERAL TRAFFIC NOISE MANAGEMENT STRATEGIES	RESPONSIBLE ORGANISATIONS
HEAVY VEHICLE NOISE CONTROL This includes engine/exhaust brakes, development/implementation of new Australian Design Rules, identification and policing of heavy vehicle preferred routes, and in-service enforcement.	**RTA**, EPA, local councils
PLANNING, DEVELOPMENT CONTROL AND TRANSPORTATION PLANNING This includes: DUAP and local councils developing formal mechanisms for ensuring that new development and redevelopment activities take into account noise from existing and proposed road developments; the inclusion of traffic noise amelioration provisions for residential areas in AMCORD—Australian Model Code for Residential Development; and the development of a Model Development Control Code.	**DUAP**, local councils, RTA, EPA
NOISE ABATEMENT STRATEGY A priority ranking scheme and a range of mitigation measures have been developed and implemented for noise abatement on existing State-owned roads.	**RTA**
COMMUNITY EDUCATION ON VEHICLE USE AND NOISE MITIGATION Develop education campaigns targeted at:	
• vehicle repairers and heavy vehicle users	**RTA,** EPA
• the housing development industry and local councils.	**DUAP**, EPA, local councils
Ongoing encouragement for the community to use public transport and to increase the numbers of passengers travelling per vehicle.	**EPA, DUAP, RTA**
IN-SERVICE ENFORCEMENT Strategies include programs to monitor and regulate noisy vehicles on the roads through in-service enforcement, and regulating against modifications to motor vehicle noise control equipment that increase noise emissions.	**RTA**, EPA, police

Note: Organisations holding prime responsibility for the strategies are shown in bold.

Appendix A: A history of road traffic noise criteria in NSW

A1 Early EPA traffic noise guidelines

The first formal expression of traffic noise policy by a regulatory authority in NSW was in the *Environmental Noise Control Manual*, published by the (then) State Pollution Control Commission (SPCC) in 1985. This recommended a traffic noise level goal of 60 dB(A), $L_{10(18hr)}$ for major arterial roads. It also recommended levels of 58 dB(A) $L_{10(18hr)}$ for non-arterial roads, and 55 dB(A) L_{eq} for intermittently-used roads.

Some concern was expressed at that time that achieving the 60 dB(A) goal for arterial roads would involve significant and unjustifiable additional costs for housing and road construction. As a result of subsequent interdepartmental consultation, it was concluded that a noise level of 63 dB(A) $L_{10(18hr)}$ should be adopted as a provisional working objective for arterial road design and residential area planning. This traffic noise level was adopted as the objective for major roads, with lower noise levels set for minor roads and rural areas (see Table A.1).

A2 Use of TNL noise descriptor for new freeways

Another significant influence in the development of traffic noise policy within the SPCC was the realisation that night-time noise levels (and particularly noise levels from heavy vehicles) were significant in determining the reaction of residents to traffic noise. Evidence for this came both from the results of Australian and overseas research and from practical experience, notably following the opening of the F3 freeway. Noise from this section of road generated considerable public reaction, as a result of which the previously-designed noise mitigation measures were significantly (and expensively) upgraded by the Roads and Traffic Authority. This experience was considered to be sub-optimal from both the economic and environmental perspectives.

In preparing its submission to the Commission of Inquiry into the proposed F2 freeway in 1992, the EPA suggested the use of a noise level goal for new freeways and similar roads, determined as the level at which about 10% of the population would be highly annoyed by traffic noise. (Research literature provided a basis for the choice of a 10% highly annoyed figure.) On the basis of a re-analysis of research performed by Hede, a noise descriptor referred to as the TNL (traffic noise level) was proposed. This descriptor is given by

$$TNL = L_{eq(24hr)} + 0.1\ MNH$$

where $L_{eq(24hr)}$ represents the L_{eq} noise level over a 24-hour period and MNH represents the mean number of heavy vehicles per hour between 10 pm and 7 am. Hede's research suggested that a level of TNL 55 corresponds approximately with 10% of residents being highly annoyed by traffic noise.

The EPA emphasised at the F2 Commission of Inquiry that it understood the practical problems of constructing a new freeway to meet TNL 55 at all residences, but recommended that efforts be made to approach that level, subject to cost and technical restraints. A TNL level of 55 was regarded as an environmental goal, with the RTA being the appropriate body to propose and evaluate the best practicable means to meet or approach the environmental criteria for specific individual circumstances.

With the incorporation of this measure, the EPA's previously recommended traffic noise criteria changed to the criteria set out in Table A1.

In cases where the noise levels in Table A1 were already exceeded, the guideline recommended that new developments should not increase existing levels by more than 2 dB.

Table A1 Old EPA road traffic noise guidelines

ROAD TYPE	DESCRIPTOR	ENVIRONMENTAL GOAL*
Freeways, tollways, etc.	TNL	55 dB(A)
Arterial—urban and rural	$L_{10(18hrs)}$	63 dB(A)
Non-arterial—urban and rural	$L_{10(18hrs)}$	58 dB(A)
Intermittent or low traffic flow, suburban	$L_{eq(1hr)}$	55 dB(A) (new) 60 dB(A) (existing)
Low traffic flow, rural	$L_{eq(1hr)}$	50 dB(A) (new) 55 dB(A) (existing)

* measured within 1 m of a residential facade or other noise-sensitive location

Appendix B: Technical background to the road traffic noise criteria

B1 Overseas criteria

In considering appropriate guidelines for road traffic noise, it is important to look at the criteria used in other countries, as a guide to the noise levels considered appropriate in residential areas. Table B1 shows criteria currently in place in a number of countries (Lambert & Vallet 1993). Most countries have a variety of criteria, depending on the zoning of the area receiving noise. Table B1 compares criteria in residential areas.

The noise descriptor used by most countries to define noise criteria is L_{eq}. Where L_{eq} is not used, usually a descriptor such as L_{10} or L_{50} is used. Lambert and Vallet (1993) point out that the descriptor L_{dn}, used in the USA, is insensitive to night-time noise level variations, and state that for this reason it is an inappropriate descriptor to use in setting a criterion. They also comment that L_{eq} is easy to calculate, but it is not liked by residents, who find it hard to understand. They state that residents prefer L_{10}, as it is perceived as better at taking traffic noise peaks into account. For continuous traffic noise, L_{eq} and L_{10} are strongly correlated, L_{10} being approximately 3 dB higher than L_{eq}.

Daytime noise criteria range from 55 to 75 dB(A) L_{eq}, while night-time criteria range from 45 to 65 dB(A) L_{eq}. Many countries place a more stringent limit on the night-time L_{eq} level from road traffic noise than on the daytime level. L_{eq} is measured or calculated over a variety of periods, from 24 hours (NSW RTA daytime criterion) to a single peak-hour value (USA), with some countries (including France, Britain and America) assuming that a single criterion will assure that both daytime and night-time noise levels will be satisfactory. The period over which the night-time L_{eq} is to be calculated also varies considerably from country to country, and sometimes between regions in one country. This may partly be explained by a difference in normal sleeping hours from one country to the next.

A planning level of 50 to 55 dB(A) L_{eq} appears to be the most widely used night-time criterion, with a daytime criterion, also measured in L_{eq}, set 10 dB above this. In many countries, variations in the criteria are used in order to allow higher noise levels on existing roads or roads in industrial areas, and lower noise levels on rural roads or roads near noise-sensitive land uses such as hospitals.

Table B1 Comparison of residential traffic noise criteria

COUNTRY	DAYTIME CRITERIA	NIGHT-TIME CRITERIA	COMMENTS
France	60–70 dB(A) L_{eq} (8 am–8 pm)	Not normally set	Daytime criterion considered acceptable, unless $L_{eq(day)}–L_{eq(night)}<6$ dB(A).
Germany	62–70 dB(A) $L_{eq(15h)}$; in practice 55 dB(A) is used.	52–60 dB(A) $L_{eq(9h)}$; in practice 45 dB(A) is used.	Federal law
Greece	Interior levels of 30–35 dB(A) in new buildings (all noise sources)		Criteria on traffic noise are being developed. L_{eq} traffic noise criterion is likely to be used in future.
The Netherlands	60–75 dB(A) $L_{eq(7am–7pm)}$	50–65 dB(A) $L_{eq(11pm–7am)}$	60 criteria to choose from, depending on zoning and stage of construction of road and residences
Italy	55 dB(A) $L_{eq(15h)}$	45 dB(A) $L_{eq(9h)}$	National law
Japan	60 dB(A) L_{50}	50 dB(A) L_{50} 55dB(A) L_{50} early am / late pm	Criteria increase if more than one road is nearby. L_{50} and L_{eq} are correlated.
Spain	Proposed criteria of 55–75 dB(A) L_{eq}	Proposed criteria of 45–65 dB(A) L_{eq}	No fixed laws—awaiting an EEC directive.
Switzerland	60 dB(A) $L_{eq(15h)}$ reference level	50 dB(A) $L_{eq(9h)}$ reference level	Planning levels 5 dB below these criteria.
UK	68 dB(A) $L_{10(18h)}$	Not set	Equivalent to a criterion of 65 dB(A) L_{eq}. Proposed future planning criterion is 55 dB(A) L_{eq}.
USA	55 dB(A) $L_{eq(peak\ hour)}$ is 'interference level'; 67 dB(A) $L_{eq(peak\ hour)}$ is 'intervention level'.		Criterion of L_{dn} = 65 dB(A) is also sometimes used.

B2 Reaction to road traffic noise

Noise reaction is a term used to describe the emotional response that is evoked by a loud noise. For most people, this response can be described as annoyance, but for some people other responses are evoked. For example, people may choose words related to annoyance to describe their reaction (such as ‘annoyed’, ‘irritated’, ‘bothered’), but some may choose words related to fear (‘nervous’, ‘scared’, ‘edgy’) or anger (‘cranky’, ‘angry’). All these types of responses are included in the term ‘noise reaction’.

The only way that has been found reliably to assess the strength of an individual’s noise reaction is through a social survey. Typically, the purpose of the survey would initially be disguised, to allow respondents to rate their reaction to traffic noise in the context of other environmental or neighbourhood issues. Later, respondents would be asked questions relating specifically to reaction to traffic noise. Noise social surveys consistently focus on residents as being the group potentially most affected by environmental noise.

In surveys, it is consistently found that measured noise exposure explains only a small proportion of the variation in individuals’ noise reaction. Typically between 10% and 25% of the total variation in noise reaction is explained by variation in noise exposure. The remaining variation appears to be due to individual differences in sensitivity to noise in general, or to traffic noise in particular.

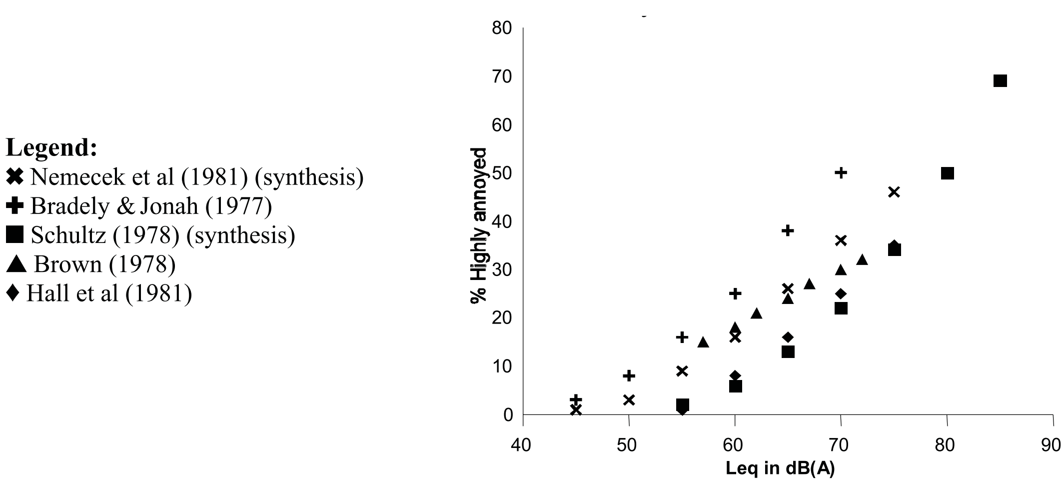
However, the average reaction of a group of people, or the proportion of people showing a high level of reaction, can be predicted relatively accurately from the noise exposure. One useful measure of noise reaction for a group of people is the proportion of those people who are ‘highly annoyed’ by the noise. This term may have a specific meaning in the context of an individual survey, but in general it is used to describe people who would choose the designation ’highly annoyed’ from a list of categories to describe their annoyance.

The proportion of residents found to be seriously and moderately affected by road traffic noise is shown in Figure B1, plotted against noise exposure as measured by the daytime L_{eq} noise level. Data in this figure are drawn from a number of international studies, including one conducted in Brisbane, Sydney and Melbourne (Brown 1978).

From Figure B1, 55 dB(A) L_{eq} corresponds to approximately 10% of residents highly annoyed, and 60 dB(A) L_{eq} corresponds to approximately 18 % of residents highly annoyed.

Based on research findings, the practice has developed that environmental objectives for transportation-related noise sources be set approximately at the point at which 10 % of residents are highly annoyed by the noise. This is the case, for example, with aircraft noise, where the 20 Australian Noise Exposure Forecast (ANEF) noise contour (below which the construction of new residences is considered ‘acceptable’) represents approximately the

Figure B1 Percentage of people highly annoyed by road traffic noise



point at which 10 % of residents are highly annoyed.

This would indicate that, for road traffic noise, such objectives should be set at approximately 55 dB(A) L_{eq} for daytime noise exposure. However, other factors also influence the choice of a criterion, including the practicality of achieving the criterion in high-noise areas and the additional impact of the introduction of a new noise source to a relatively quiet environment. The latter factor is discussed in Section B4.

B3 Sleep disturbance due to traffic noise—results of recent research

In addition to causing annoyance, traffic noise can also significantly disturb specific activities within residences. Among these are:

- conversation, either in person or on the telephone
- watching and listening to television
- sleeping
- relaxing, listening to music, reading and other passive indoor activities.

In general, studies of reaction to environmental noise indicate that the activity that most people would like to have free from noise disturbance is watching television. However, if only those people who are seriously affected by the noise are considered, the most important disturbance for these people is to sleeping.

Disturbance to sleep as a result of environmental noise is a particularly emotive issue, raising the possibility of effects on health, and other effects of which a resident may not be fully aware. For this reason, most researchers have preferred experimental methodologies to study the degree of sleep disturbance caused by noise, rather than social surveys. The sleep disturbance can be assessed by subjectively-reported sleep quality, number of awakenings during the night (either self-reported or as assessed with an electroencephalograph) or number of changes in sleep state.

The present review of results from this research includes studies of single noise events other than motor vehicle passbys, such as individual train and aircraft passbys. The effects of these various noises on sleep are assumed to be similar, for the same noise level, so that results from the various studies can be compared.

A number of experimental studies have concluded that the use of the L_{eq} noise level alone does not provide an adequate measure of the sleep disturbance produced by noise, and that a better measure would be one that also takes account of the level and number of individual noise events, or noise 'peaks'. For example, Brown and Rutherford (1991), in their assessment of several published studies of the effects of noise on sleep, conclude that, for continuous traffic noise conditions, L_{eq} appears to provide an appropriate measure of sleep disturbance, but that in cases where traffic noise is intermittent (which is often the case at night) sleep disturbance is affected more by the number of individual noise events exceeding a particular level. They point out that various studies indicate that it is the emergence of a noise event above the background that tends to lead to sleep disturbance, rather than the actual peak noise level of the event.

Eberhardt (1988) and Eberhardt et al. (1987) state that the results of their studies indicate that in cases of intermittent traffic flow L_{eq} is an inadequate descriptor of sleep disturbance, and needs to be complemented with some measure of noise peaks. Eberhardt states that the emergence of noise events from the background—rather than the absolute noise level of such events—determines the frequency of sleep disturbance. Eberhardt also states that high continuous traffic noise levels have an undesirable effect on REM sleep.

Vallet et al. (1983) conclude that it is possible to use L_{eq} as a single noise index to measure sleep disturbance due to continuous traffic flow. Vallet states that both L_{eq} and L_{max} are important in assessing sleep disturbance, but that for continuous traffic flow these two levels are correlated; therefore L_{eq} alone can be used as an index. On the other hand, for intermittent traffic flow where the emergence of a noise event, the number of noise events and the intervals between them become important, the use of L_{eq} is not considered adequate, although Vallet does postulate an approach whereby the L_{eq} levels of individual noise events are used to characterise intermittent traffic noise. It is difficult to see how this could be done in practice for road traffic noise.

Vernet (1979) finds that sleep disturbance is related to both L_{eq} and L_{max}, as well as to signal emergence. However, because in his results the L_{max} and emergence were strongly correlated, he comments that it is difficult to discriminate between their effects. Vernet (1983) also finds that in quiet areas it is emergence that is most closely related to sleep disturbance, but that in noisier areas it is the noise duration and peak level that are the more dominant factors.

Griefahn and Muzet (1978) find that the greater the difference between the peak level of noise and the ambient noise (that is, the greater the emergence of a noise event) the greater the level of sleep disturbance. Griefahn (1992) also finds that people are generally more disturbed by intermittent than by continuous noises, and he suggests that this indicates that L_{eq} alone is not generally suitable for the prediction of sleep disturbance.

Ohrstrom and Bjorkman (1988), and Ohrstrom and Rylander (1982), state that intermittent noise was found to have a significantly more noticeable effect on sleep quality than continuous noise at the same L_{eq} level; they suggest that these results imply that peak noise levels should be taken into account when setting criteria for nocturnal noise. In one set of studies, Ohrstrom concludes that the L_{eq} noise level was totally unrelated to sleep disturbance effects.

Horonjeff et al. (1982) conclude that the maximum level, duration and signal-to-noise ratio of a noise event are all closely related to the probability of awakening. They suggest that awakening may be more closely related to signal detectability (emergence) than to absolute level.

Griefahn and Muzet (1978) note that although the number of awakenings increases with the number of noise events, this relationship is not a linear one, with less awakenings per event occurring as the number of events increases. Similarly, Ohrstrom and Rylander (1990) indicate that the number of awakenings from 64 events per night was four times the number from eight events, rather than eight times as expected. However, Vernet (1979) concludes that the number of noise events is closely related to the number of disturbances to sleep.

In summary, the current literature concerning sleep disturbance due to noise indicates that the main noise characteristics that influence sleep disturbance are the number of noisy events heard distinctly above the background level, and the peak level and emergence of these events. The L_{eq}, which is the energy average level of the noise signal, takes some account of the number and level of the louder events in a signal, due to the high amount of energy such events carry. However, the consensus is that L_{eq} by itself is an inadequate predictor of the potential of a noise signal to disturb sleep. For continuous traffic flow, L_{eq} appears to be acceptably correlated with sleep disturbance, since under these conditions there are few emergent noise events above the main hum of the traffic. However, for intermittent traffic flow, which often occurs at night, some other measure that takes into account the emergence, peak level and number of noise events is required.

B4 Response to a change in noise level

The data presented above are based on the responses of people living in residences that have been exposed to road traffic noise for some time. However, the level of reaction to a newly introduced noise may not be directly predictable from these results. In simple terms, while people may express a certain level of acceptance of their existing noise environment, they may feel strongly about any increase in noise.

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 (reported in Schultz 1979), conducted in Japan, compared the reaction to noise near a newly-opened Shinkansen (fast 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_{eq}). The difference in reported awakenings from sleep was equivalent to a difference of 7dB in maximum noise levels.

An Australian study (Brown 1987) considered reaction to a sudden increase in road traffic noise levels. It was found that while reported reaction to traffic noise was consistent with other studies before the change in exposure, after the change it was higher than would have been predicted from studies performed under conditions of constant exposure. The difference was equivalent to a difference of between 3 and 15 dB in noise exposure, this variation reflecting the uncertainty in predicting reaction for a given exposure under steady conditions.

In addition, one study (Geoplan Resource Planning 1992) investigated reaction to traffic noise in residents living near the newly opened F3 freeway. The level of reaction was compared with that of residents living near the Pacific Highway, before the opening of the freeway, who were exposed to similar noise levels. The reaction of residents near the F3 freeway was found to be higher than that of residents near the Pacific Highway for the same noise level, the difference being equivalent to a difference of approximately 9 dB in noise level.

The results of these studies are consistent, and indicate that where noise exposure is suddenly and substantially increased, reaction is higher than would be predicted from studies of steady conditions. Converse findings have been reported for the case of reaction to a sudden decrease in exposure, that is, the reaction to the altered situation is lower than would have been predicted from the reaction to steady conditions.

On the other hand, very small increases (or decreases) in noise exposure can be assumed to result in only minor changes in noise reaction. The minimum detectable change in a constant noise level is approximately 1 dB under ideal conditions, or 2 dB under field conditions. Given the fact that a change of this magnitude is likely not to be noticed by residents experiencing it, it can be assumed that the significant increase in noise reaction described above would not apply to changes in noise exposure of 2 dB or less.

B5 Potential noise level descriptors for assessing the impact of road traffic noise on sleep

The first step in determining a practical noise level goal for limiting sleep disturbance due to road traffic noise is to determine the units in which the goal is to be expressed.

From the discussion in Appendix B3, the characteristics of a noise signal that are most strongly related to sleep disturbance are:

- the peak level of noise events, described by L_{max}
- the emergence of noise events above the general noise level, described by measures such as (L_{max} – L_{eq}) or (L_{max} – L_{90})
- the number of such noise events occurring during the sleeping period.

Ideally, any night-time noise assessment methodology should take each of these factors into account if it is to provide effective protection against sleep disturbance. The use of single level indicators, such as L_{eq}, which is widely used to define night-time noise criteria, does not take full account of all these factors.

In the light of studies such as Horonjeff et al. (1982), the SPCC incorporated a guideline in its *Environmental Noise Control Manual* (1985) aimed at limiting the level of sleep disturbance due to environmental noise—namely that the L_1 level of any noise should not exceed the ambient L_{90} noise level by more than 15 dB. This criterion takes into account the emergence of noise events, but does not directly limit the number of such events or their peak level, which are also found to affect sleep disturbance.

The use of an indicator such as L_1 may appear favourable, in that it represents the higher noise levels experienced, and also takes some account of the number of events. However, L_1 also depends on other characteristics of the noise (notably the duration of events) that are not strongly correlated with sleep disturbance. In addition, the value of this index is very difficult to predict using standard traffic noise prediction methodologies.

Ultimately, a descriptor used to assess the impact of road traffic noise on sleep should be able to predict the level of sleep disturbance directly, as is possible for annoyance using the daytime L_{eq} level (Figure B1). This would necessarily involve a relatively complex methodology, taking into account the distribution of numbers of noise events by noise level, as well as the emergence of noise events. Such a methodology has not yet been adequately demonstrated or tested.

There is a large difference in the level of effects of noise on sleep between studies conducted in the

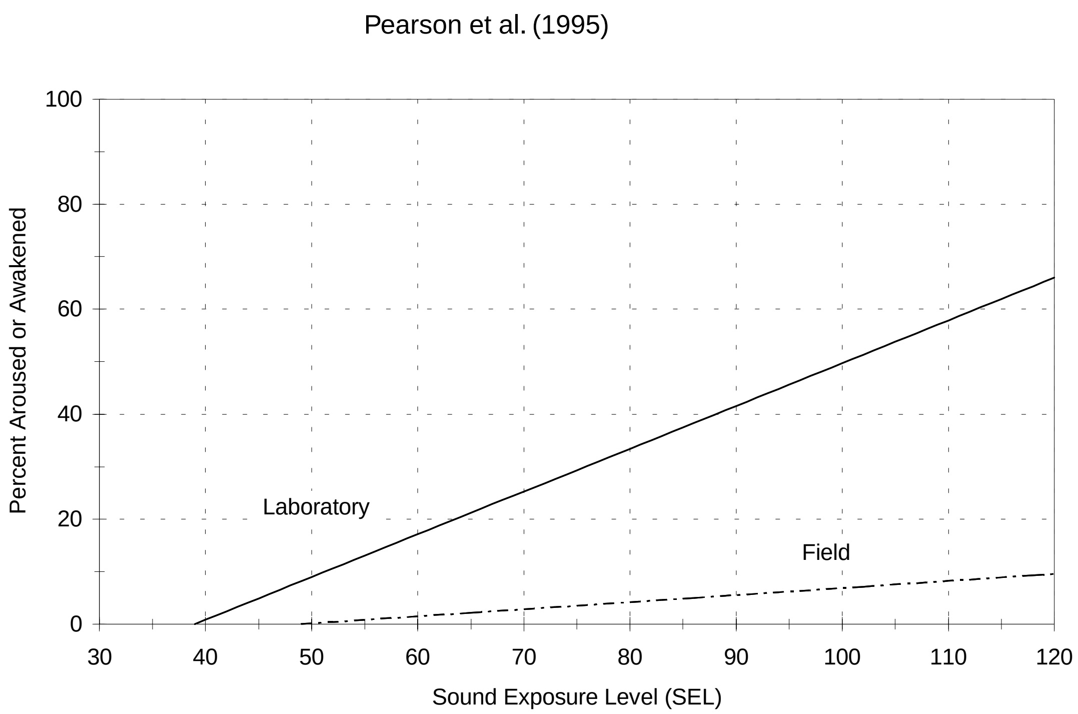


Figure B2 Example of the different effects of noise on sleep in the laboratory and in the field (Pearson et al. 1995)

laboratory and those conducted in the field. Laboratory studies usually show much greater levels of sleep disturbance than for field studies at a given noise level. The reason for such large variations has not been fully explained, but is probably due to the difference in sleeping environments between the field and laboratory studies.

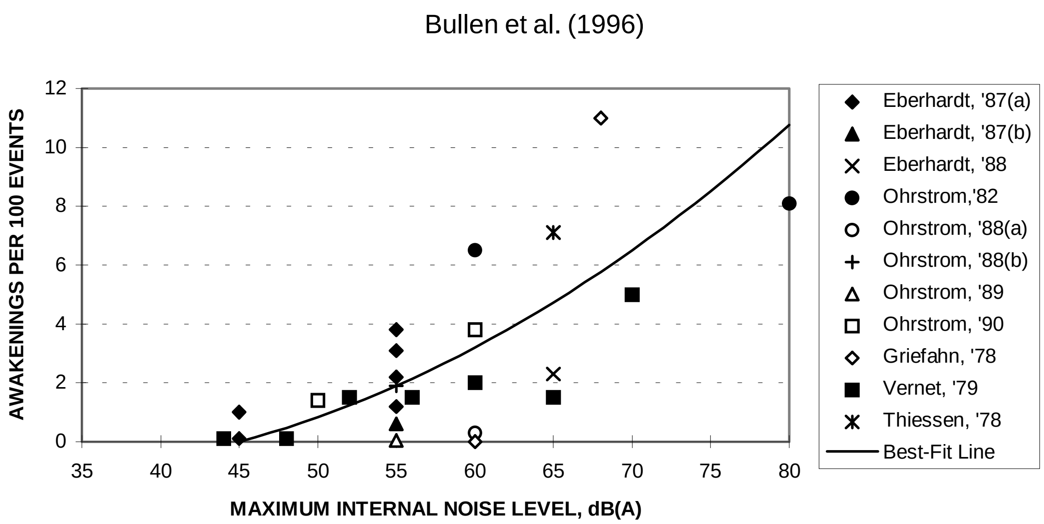
Figure B2, extracted from Pearson et al. (1995), demonstrates the difference between laboratory and field studies.

A number of researchers have produced results designed to allow an assessment of noisy events on sleep. The following examples provide a perspective of the approaches and their results.

Figure B3, produced by Bullen et al. 1996, synthesises a number of studies that have been conducted into sleep disturbance due to noise.

This graph demonstrates the problems in using the current level of understanding of the effects of

Figure B3 Awakenings due to noise (compiled from various studies)



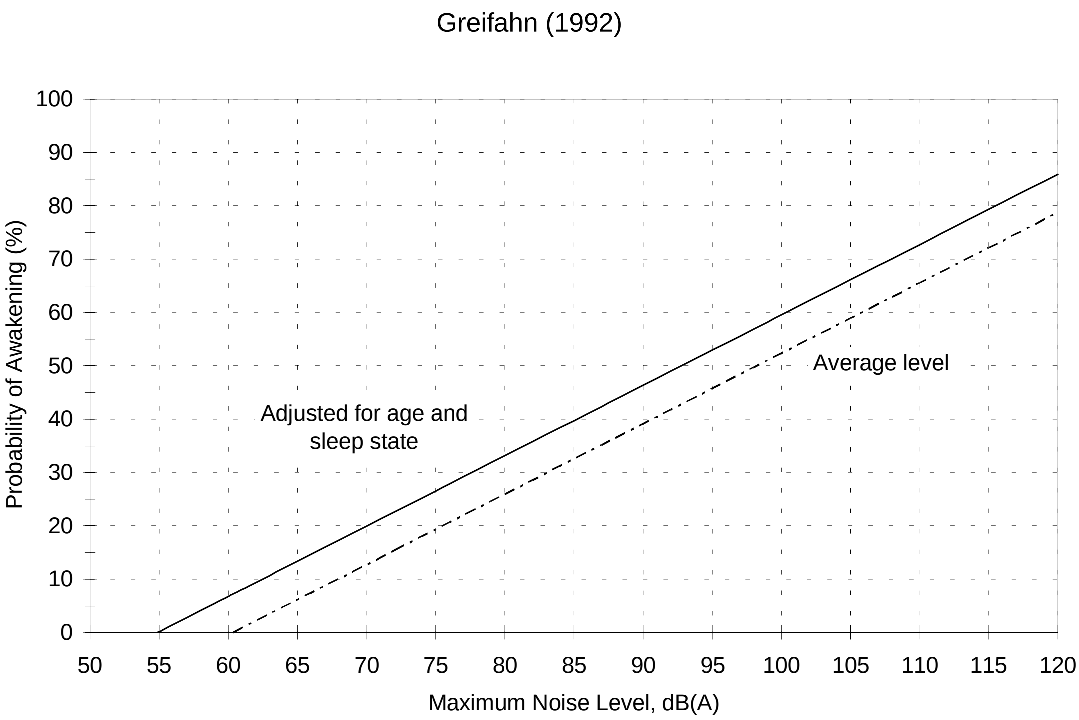


Figure B4 Probability of awakening related to age and sleep state (Griefahn 1992)

noise on sleep to predict awakenings. For instance, the same probability of sleep disturbance is given for one event of 70 dB(A), ten events of 49 dB(A) and thirty events of 46 dB(A). However, it is unlikely that even a relatively high number of noise events at a low noise level would cause awakening reactions.

Figure B4 is adapted from Griefahn (1992). It shows two lines: one derived from survey results, and a second line adjusted to incorporate the increased reaction to noise with age and adjusted to show awakening reaction in the most sensitive sleep state.

Griefahn's results show a very different level of awakening reaction from that in Bullen's figure B3.

Figure B5 is from Finegold et al. (1994), and presents percentage awakenings compared with noise events expressed in ASEL (A-weighted sound exposure level). The authors acknowledge the problem with differences between laboratory and field data and the need for further research. They present their graph as a possible interim means of evaluating awakening reactions from general transportation.

Again, the results presented in this graph bear little relationship to those in the previous two graphs. To allow for a rough comparison, if it can be assumed that the ASEL levels presented in figure B5 correspond to maximum noise levels of about 10 dB lower, then it is clear that Finegold's results indicate a much higher level of reaction than the synthesis presented by either Bullen or Griefahn.

Considering all of the foregoing information the following conclusions can be drawn:

- Maximum internal noise levels below 50–55 dBA are unlikely to cause awakening reactions.
- One or two noise events per night, with maximum internal noise levels of 65–70 dBA, are not likely to affect health and wellbeing significantly.

More work is required to answer two essential questions:

- What is the cause–effect relationship between noisy events and awakening reactions in the home?

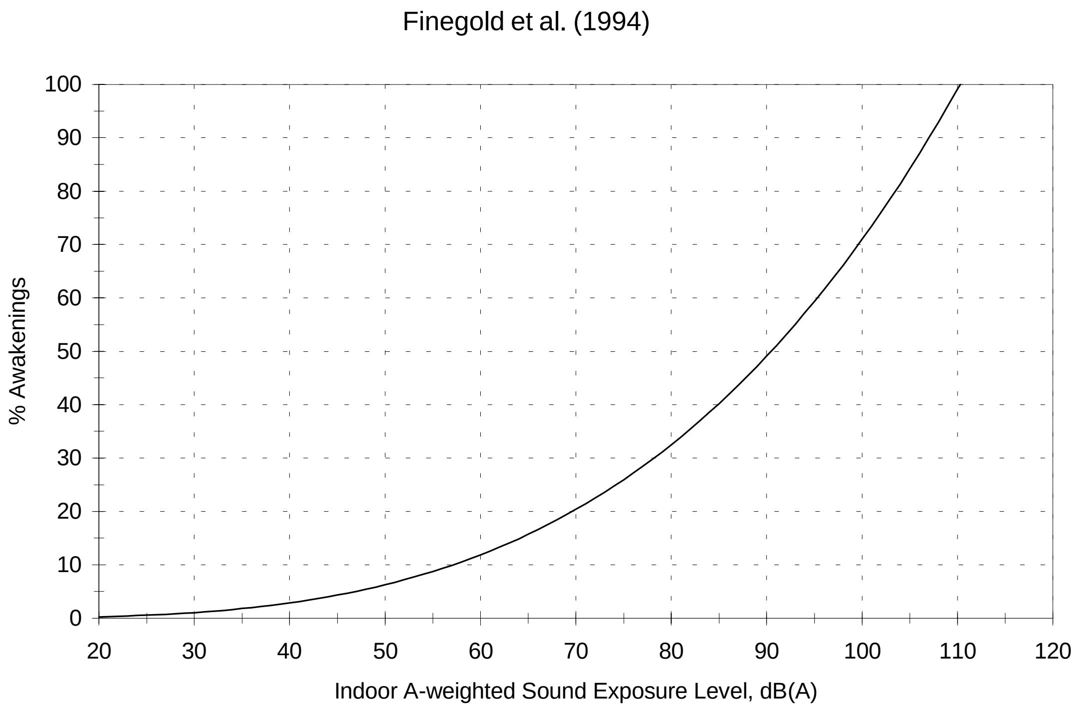


Figure B5 Percentage awakenings from noise events expressed as ASEL (Finegold et al. 1994)

- At what level do awakenings affect our health and wellbeing?

Until more definitive information becomes available, it will not be possible to develop noise level criteria for sleep disturbance that would have the equivalent level of confidence as those noise criteria used for annoyance reactions.

The EPA will continue to review research on sleep disturbance as it becomes available. A more complete review exploring the two essential issues raised above is planned.

Appendix C: Measuring traffic noise and preparing a noise impact statement

This appendix gives detailed guidance on measuring and predicting traffic noise levels and preparing a noise impact statement. Three situations are considered—a new road, a new road use and a new development near an existing road. Details are also given of the procedures required for monitoring existing noise levels, and of specific requirements in noise calculation.

C1 Traffic noise assessment for a new road

This section applies to assessments of traffic noise from new roads, road bridges and freeways where a new road corridor is proposed, or to changes in noise levels due to substantial realignments of existing roads.

1 Determine land uses and area classifications, as set out in Tables 1 and 2 in section 2 of this document, along the length of the new or upgraded road. (This is not necessary for a freeway or main arterial in Table 1, where a single noise level criterion applies.)

2 Determine environmental noise level criteria for each section of the road, using the levels given in Tables 1 and 2 for each land use.

3 Conduct noise monitoring to determine whether existing traffic noise levels already exceed the noise level criteria for some locations. Measurement procedures are described in section C4. In cases where non-traffic noise constitutes an important part of the ambient noise in an area, monitoring needs to be supplemented by calculation of the traffic noise component, carried out as described in section C5.

Note that all noise descriptors that will be used in the assessment should be monitored. This may include $L_{Aeq(1hr)}$, $L_{Aeq(15h)}$, $L_{Aeq(9h)}$ and maximum noise levels, depending on the area classification and types of land use involved.

For the purpose of determining environmental noise level criteria, the monitoring program needs only to define areas where these criteria may already be exceeded or are likely to be exceeded; only limited monitoring would be required in areas with low existing traffic noise, where criteria are unlikely to be exceeded. However, if traffic noise levels from existing roads are close to the noise level goal, they could have an influence on the total traffic noise level after road construction. Note that in such cases any change in traffic volume on these existing roads, resulting from construction of the new road, would also need to be taken into account.

4 Identify every potentially affected receiver along the length of the proposed road, and assign a noise level criterion to each one.

5 Obtain accurate data on:

—the alignment of the proposed road, including gradient and heights of cuttings and fill

—projected traffic speeds

—projected traffic volumes immediately after opening and for a time ten years after opening. (Break this down at least into the periods 7 am–10 pm and 10 pm–7 am, and specify the proportion of heavy vehicles for each period. Preferably, obtain projected volumes for each hour and use average weekday volumes.)

6 Calculate noise levels, expressed in terms of the required descriptors, for each receiver, as described in section C5, assuming no noise amelioration measures are introduced. Calculated levels should include noise from traffic on the new road, and on any other roads, which may influence the total traffic noise level at the receiver.

7 Where the calculated noise level exceeds the environmental noise level criteria for any receiver, investigate the following ameliorative measures:

—use of alternative transport modes, or other methods of avoiding the new road construction

—alternative road alignments

—control of traffic (for example, limiting times of access or speed limitations)

—use of a quiet road surface

—use of noise barriers or bunds

—for non-residential buildings or residential buildings where the night-time criteria are the major concern, treatment of the facade to reduce internal noise levels.

8 If appropriate, re-calculate noise levels to include the effect of the proposed ameliorative measures. If noise levels still exceed the environmental level criteria, repeat the process.

9 In cases where (after the levels are calculated as set out above and ameliorative measures evaluated) it is considered impractical to meet the required environmental noise level criteria, provide an assessment that ad dresses cost-versus-equity considerations, community preferences and actions that could achieve the criteria in the long term.

10 Include the following details in the acoustic report:

—diagrams showing the road alignment, land uses along the proposed road and noise measurement locations. These should be to a scale big enough to delineate individual residential blocks.

—details of the environmental noise level criteria at each potentially affected receiver

—details of noise monitoring procedures and / or calculations of existing noise levels. This should include raw measurement data from each site, and assumptions made in calculations, including assumed traffic volumes and proportions of heavy vehicles, as well as details of the calculation procedure

—details of assumed data for the new road, including traffic volumes and percentage of heavy vehicles by time of day; and details of the calculation process, including assumed noise source heights for vehicles

—if required, a description of the ameliorative measures considered, reasons for inclusion or exclusion, and procedures for calculating noise levels, including ameliorative measures

—a diagram showing noise level contours, or other methods of determining the calculated noise level at each receiver, both with and without ameliorative measures

—if necessary, discussion of any potential problems associated with the proposed ameliorative measures, such as overshadowing effects.

—where the environmental noise level criteria set out in Tables 1 and 2 have not been met, a socioeconomic assessment of the proposal or the relevant part of the proposal, as discussed in point 9 under section C1.

C2 Traffic noise assessment for a new road use

This section applies to assessments of traffic noise from redeveloping an existing road and road bridge, and for land use developments with the potential to create additional traffic on existing local or collector roads.

1 Determine land uses and area classifications, as set out in Tables 1 and 2 in section 2 of this document, along the affected section of the road. (This is not necessary for a freeway or main arterial in Table 1, where a single noise level criterion applies.)

2 Determine environmental noise level criteria for each section of the road, using the levels given in Tables 1 and 2 for each land use.

3 Conduct noise monitoring to determine whether existing traffic noise levels already exceed the environmental noise level criteria at some locations. Measurement procedures are described in section C4. In cases where non-traffic noise constitutes an important part of the ambient noise in an area, monitoring needs to be supplemented by calculation of the traffic noise component, carried out as described in section C5. Note that all those noise descriptors that will be used in the assessment should be monitored. This may include $L_{Aeq(1hr)}$, $L_{Aeq(15h)}$, $L_{Aeq(9h)}$ and

maximum noise levels, depending on the area classification and types of land use involved.

Monitoring would generally be done only at receivers located near the existing road, to define areas where these criteria might already be exceeded.

4 Identify every potentially affected receiver along the affected section of the road, and assign an environmental noise level criterion to each one.

5 Obtain accurate data on the alignment of the proposed road redevelopment (including gradient and heights of cuttings and fill), and on the projected volume and speed of traffic to be introduced, broken down at least into the periods 7 am–10 pm and 10 pm–7 am. Specify the proportion of heavy vehicles for each period. Preferably, obtain projected volumes for each hour, and use average weekday volumes. Obtain similar data for existing traffic on the road, since calculated levels represent the total traffic noise level from the road.

6 Calculate noise levels (expressed in terms of the required descriptors) for each receiver, assuming no new noise amelioration measures are introduced. Calculations may be done as described in section C5, or may be based on existing measured noise levels, with a correction for the variation in traffic conditions.

7 Where the calculated noise level exceeds the environmental noise level criteria for any receiver, investigate the following ameliorative measures:

—use of alternative transportation modes, alternative routes, or other methods of avoiding the new road use

—control of traffic (for example, limiting times of access or speed limitations)

—resurfacing of the road using a quiet surface

—use of (additional) noise barriers or bunds

—for non-residential buildings or residential buildings where the night-time criteria are the major concern, treatment of the facade to reduce internal noise levels.

8 If appropriate, re-calculate noise levels to include the effect of the proposed ameliorative measures. If noise levels still exceed the noise level criteria, repeat the process.

9 In cases where, after levels are calculated as set out above, it is considered impractical to meet the required environmental noise level criteria, provide an assessment that addresses cost-versus-equity considerations, community preferences and actions that could achieve the criteria in the long term.

10 Include the following details in the acoustic report:

—for projects with a significant potential impact, diagrams showing the road alignment, land uses along the proposed road, and noise measurement locations. These should be to a scale big enough to delineate individual residential blocks.

—details of the environmental noise level criteria at each potentially affected receiver

—details of noise monitoring procedures and / or calculations of existing noise levels. Include raw measurement data from each site and the assumptions made in the calculations, including assumed traffic volumes and proportion of heavy vehicles, as well as details of the calculation procedure.

—details of assumed data for the new road use, including traffic volumes and percentage heavy vehicles by time of day; details of the calculation process

—if required, a description of the ameliorative measures considered, reasons for inclusion or exclusion, and procedures for calculating noise levels, including ameliorative measures

—for projects with a significant potential impact, a diagram showing noise level contours, or other methods of determining the calculated noise level at each receiver, both with and without ameliorative measures

—if necessary, a discussion of any potential problems associated with the proposed ameliorative measures, such as overshadowing effects.

—where the environmental noise level criteria set out in Table 1 have not been met, a socioeconomic assessment of the proposal or the relevant part of the proposal, as discussed in point 9 of section C1.

C3 Traffic noise assessment for a new residential or sensitive land use development near an existing freeway/arterial or other road where traffic noise is likely to be a significant concern

This section applies to assessments of traffic noise at proposed new residential or noise-sensitive developments adjacent to existing freeways, tollways, heavy vehicle routes or major arterials; or near other existing roads and bridges where it is likely that noise from traffic will be a significant concern.

1 Determine the land use and area classification for the proposed development, as set out in Tables 1 and 2 in section 2 of the policy.

2 Determine the environmental noise level criteria, using the levels given in Tables 1 and 2.

3 Conduct noise monitoring to determine whether traffic noise levels exceed the noise level criteria at the relevant location. Measurement procedures are described in section C4. In cases where non-traffic noise constitutes an important part of the ambient noise in an area, monitoring needs to be supplemented by calculation of the traffic noise component, carried out as described in section C5.

Note that all noise descriptors that will be used in the assessment should be monitored. This may include $L_{Aeq(1hr)}$, $L_{Aeq(15h)}$, $L_{Aeq(9h)}$ and maximum noise levels, depending on the area classification and the types of land use involved.

For large potential developments, noise measurements may be supplemented by calculations to determine noise levels at various locations.

4 Where the measured and / or calculated noise level exceeds the noise level criteria for any receiver, the site would not normally be considered appropriate for the land use in question. However, it may be possible to use a number of ameliorative measures, including:

—redesigning or reorienting the building to minimise or eliminate the noise emission to noise-sensitive areas within the building and to external areas at the rear of the building

—treatment of the building or its facade to reduce internal noise levels

—using noise barriers or bunds

—re-surfacing the existing road using a quiet road surface, at the developer's expense.

5 If treatment of the façade is being considered to reduce internal noise levels, it is necessary to include requirements for ventilation. For residential and other proposed development where the noise level criteria are expressed in terms of external noise levels, it is desirable that internal noise level criteria be 10 dB below the relevant external criteria cited in this document.

6 Include the following details in the acoustic report:

—a diagram showing the proposed development in relation to the road alignment

—the environmental noise level criteria that are determined

—details of noise monitoring procedures and / or calculations of existing noise levels. This should include raw measurement data from each site, and assumptions made in calculations, including assumed traffic volumes.

—the proportion of heavy vehicles, as well as details of the calculation procedure

—a description of the ameliorative measures considered, reasons for inclusion or exclusion, and the procedures for calculating noise levels, including ameliorative measures

—if necessary, discussion of any potential problems associated with the proposed ameliorative measures, such as overshadowing effects.

C4 Noise monitoring procedures

This section describes the procedures used to gather the noise information needed to apply this document. This section is not intended to provide a complete description of the procedures required to undertake a comprehensive noise-monitoring program. These procedures are documented elsewhere, and are a part of general acoustic practice.

To measure the range of noise levels specified in this document, any noise monitoring program must be carefully designed. Select sites to cover the range of traffic noise conditions encountered in the area of interest. Avoid locations with significant sources of noise other than road traffic. If this is not possible, document these other sources and estimate their contribution to the measured noise level. Remember that in the application of this document it is only levels of road traffic noise that are of importance.

L_{Aeq} noise levels can be measured with noise monitors or appropriate sound level metres, using conventional techniques. Measuring systems may be staffed or unstaffed, depending on the requirements of the specific project.

- $\mathbf{L_{Aeq(15hr)}}$ is the L_{Aeq} noise level for the period 7 am to 10 pm. It is recommended that the L_{Aeq} be measured on a 15-minute basis. $L_{Aeq(15hr)}$ = logarithmic average of all the individual $L_{Aeq,15\ min}$ values from 7 am to 10 pm, with the first reading taken at 7:15 am and the last at 10:00 pm. Logarithmic average = $10 \times \log_{10}((\Sigma_{i=1\ to\ n}\ 10^{(LAeq,15\ min,i/10)})/n)$ where n = number of $L_{Aeq,15\ min}$ values in each assessment period over the measurement period.

- $\mathbf{L_{Aeq\ (9hr)}}$ is the L_{Aeq} noise level for the period 10 pm to 7 am. It is recommended that the L_{Aeq} be measured on a 15-minute basis. $L_{Aeq(9hr)}$ = logarithmic average of all the individual $L_{Aeq,15\ min}$ values from 10pm to 7am, with the first reading taken at 10:15 pm and the last at 7:00 am. Logarithmic average = $10 \times \log_{10}((\Sigma_{i=1\ to\ n}\ 10^{(LAeq,15\ min,i/10)})/n)$, where n = number of $L_{Aeq,15\ min}$ values in each assessment period over the measurement period.

- $\mathbf{L_{Aeq(1hr)}}$ is the L_{Aeq} noise level for a specific one-hour period. $L_{Aeq(1hr)}$ represents the highest tenth percentile hourly L_{Aeq} noise level (or, if this cannot be accurately defined, the L_{Aeq} noise level for the noisiest hour) during the period 7 am to 10 pm or the period 10 pm to 7 am, as relevant. It is recommended that the L_{Aeq} be measured on a 15-minute basis. Logarithmic average = $10 \times \log_{10}((\Sigma_{i=1\ to\ n}\ 10^{(LAeq,15\ min,i/10)})/n)$, where n = number of $L_{Aeq,15\ min}$ values in each assessment period over the measurement period.

The most appropriate currently available methods of determining maximum noise levels as required for this document are:

- the use of a chart recorder, or
- electronic storage of instantaneous sound pressure levels at intervals of about 1/4 second.

In either case, 'fast' speed rectification should be used. Storage of longer-period noise levels, such as 1–second L_{eq} levels, may be appropriate, but should be justified on the basis that shorter-term fluctuations in noise levels are unlikely in the circumstances involved.

For unstaffed monitoring, the arrangement of instruments would normally involve a standard noise logger with a signal output to the storage device. With a chart recorder, and possibly also with electronic storage, the data have to be retrieved after each monitoring night.

Maximum noise levels during the night-time period (10 pm–7 am) should be assessed to analyse possible affects on sleep. The assessment should encompass the likely maximum noise levels due to road traffic, the extent to which these maximum noise levels exceed ambient noise levels, and the number of noise events from road traffic during the night on an hourly basis for a 'typical' night.

Noise levels that are attributable to sources other than road traffic, including sirens on emergency vehicles, should be discarded.

When describing the measurement and analysis procedures used in any monitoring program, give details of the method used to determine maximum noise levels.

C5 Noise calculation procedures

The calculation of traffic noise levels may be based on one or more of a number of modelling procedures, each of which has its advantages and disadvantages. The three models generally used in Australia are:

- 'Calculation of Road Traffic Noise'—the CORTN model. This has the advantage of having been specifically validated under Australian conditions, and specific corrections can be included to account for the results of this validation study. It is also relatively simple to use, and for this reason may be the most appropriate method for relatively small projects. However, the method provides only relatively simplistic corrections for percentage of heavy vehicles and distance from the roadway. In addition, results are in terms of $L_{10(18hr)}$ and require corrections to give predicted levels for other noise descriptors. Source of model: UK Department of Transport or UK Department of Environment.

- 'Federal Highway Administration Model—the FHWA model. This has the advantage of allowing direct calculation of L_{Aeq} noise levels, based on stated assumptions regarding the noise emission levels of various classes of vehicles. Where the noise emission levels differ from those assumed, adjustment to the model is relatively easy. Furthermore, the calculation algorithms are generally considered to be mathematically more rigorous than those of the CORTN method, leading to greater accuracy and a wider range of validity at low traffic flows. Source of model: US Federal Highway Administration / US Department of Transport.

- Environment Noise Model—the ENM model. This model incorporates a more sophisticated ground effect correction, and may be the most appropriate model for calculating noise levels at large distances from a road. However, the model is relatively complex to set up and use. Source of model: RTA Technology Pty Ltd.

For more information on the models see the following references: Brown (1989), Hede (1995) and UK DoT (1988).

The use of one or more of the above models, or any other procedure, should be justified according to the circumstances of the particular project.

A point that should be taken into account in any traffic noise calculation is the effective vehicle height. This can be crucial in determining the predicted attenuation from barriers. The effective height of light vehicles is generally taken as 0.5 metres, and this appears to give acceptable results. However, for heavy vehicles there are often two distinct sources, representing the engine and the exhaust, with different noise emission levels and different heights. The recommended practice is to model heavy vehicles as two sources, calculating the barrier attenuation for each and adding the final result. The procedure used in any specific case should be documented and justified in the report.

The prediction of maximum noise levels during the night-time period involves consideration of the likely sources of these noise maxima. They will generally be due to heavy vehicle movements, and in most cases the number of these movements will be sufficiently low that noise events can be identified with the passing of a single vehicle.

Because the maximum noise levels from individual heavy vehicles vary, the distribution of noise levels from these vehicles may need to be taken into account in order to determine the representative values for maximum noise levels; the extent to which the maximum noise levels exceed the ambient noise levels; and the number of noise events. The decision as to the level of detail to be adopted in calculations will depend on the size and potential impact of specific projects, and on the level of detail needed for noise amelioration design requirements.

Where there are very high numbers of heavy vehicle movements at night, it may become difficult or impractical to identify noise level maxima with the passing of a single heavy vehicle. However, in these cases, experience indicates that the difference between maximum and L_{Aeq} noise levels will be less than 15 dB. Under these circumstances the design of noise control measures will generally be governed by the night-time L_{Aeq} criterion.

Of the models described above, only ENM can directly predict maximum noise levels from an individual source. However, the algorithm used in the FHWA method can be adapted to do this and other methods may be available.

Figure C1 compares the noise levels emitted from some common sources.

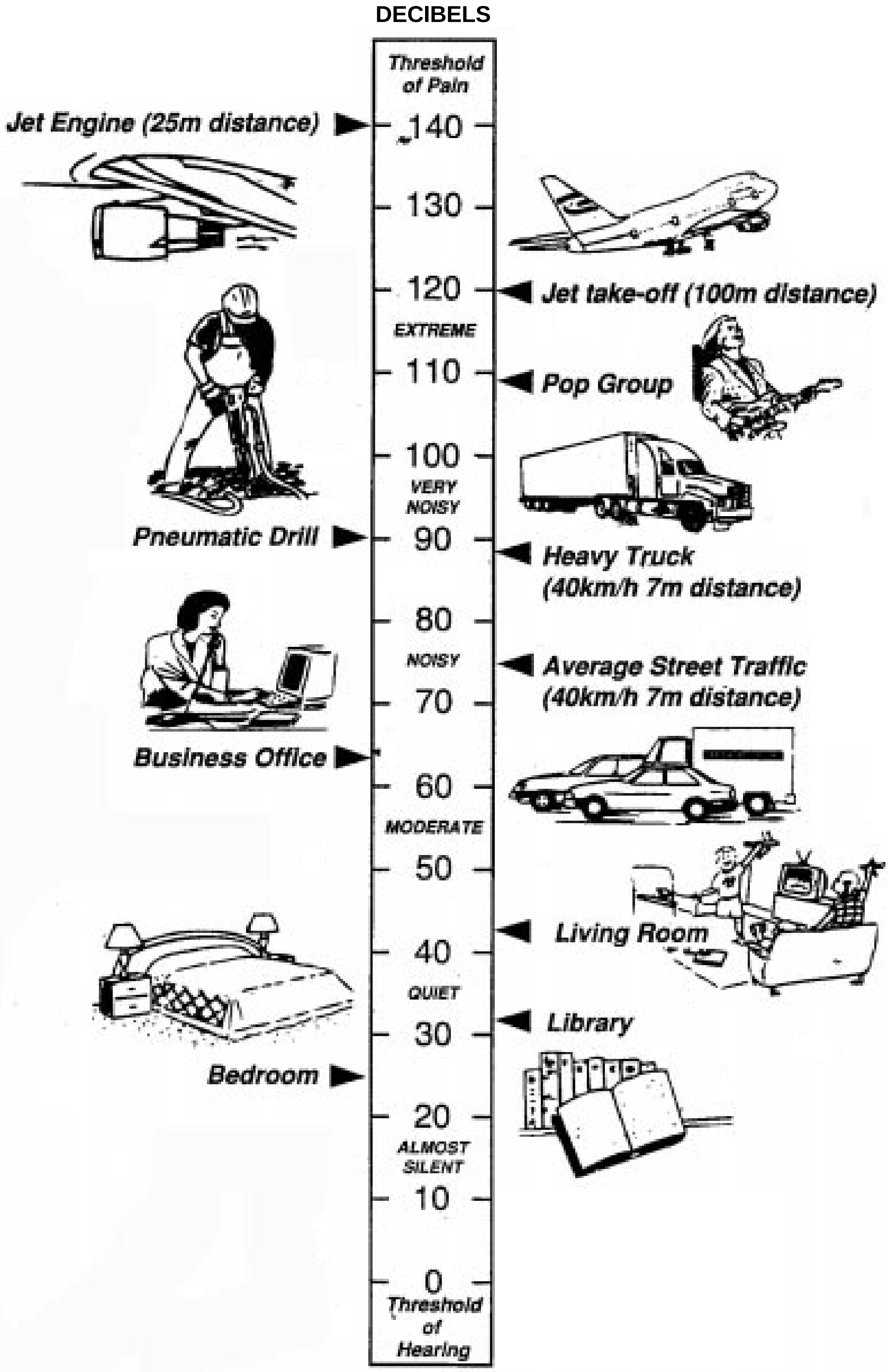


Figure C1. An illustrated comparison of common noise sources

Source: Road Traffic Noise Task Force Final Report

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Glossary

ADR Australian Design Rules

ambient noise The general environmental noise at any specific location, being a composite of sounds from many sources, both near and far.

ANEF Australian Noise Exposure Forecast

annoyance The most common type of reaction felt by residents towards traffic noise. The degree of annoyance felt by an individual may be assessed using social survey techniques.

A–weighting An adjustment made to sound level measurement, by means of an electronic filter, to approximate the response of the human ear.

barrier—noise Any natural or artificial physical barrier to the propagation of noise (from a roadway), but generally referring to acoustically reflective or absorbent fences, walls or mounds (or combinations thereof) constructed beside a roadway.

buffer An area of land between a roadway and a noise-sensitive land use, used as open space or for some other noise-tolerant land use.

dB Decibel, which is 10 times the logarithm (base 10) of the ratio of a given sound pressure to a reference pressure; used as a unit of sound.

dB(A) Unit used to measure 'A–weighted' sound pressure levels.

DUAP Department of Urban Affairs and Planning

EPA Environment Protection Authority

grade (road) The line or slope of a road—that is, the angle of a road to the horizontal plane, expressed as a percentage.

greenfield sites Sites that do not accommodate existing roads

heavy vehicle A truck, transport or other vehicle with a gross vehicle weight above a specified level (for example: over 8 tonnes)

highly annoyed An individual is generally referred to as being 'highly annoyed' by a specific type of noise if in a social survey they choose 'highly annoyed' from a list of possible descriptions of their reaction (such as 'highly, moderately, slightly, or not at all annoyed'), or if they rate their annoyance as at least eight on a ten point scale.

L_1 The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.

L_{10} The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.

$L_{10\,(1hr)}$ The L_{10} level measured over a 1-hour period.

$L_{10(18hr)}$ The arithmetic average of the $L_{10(1hr)}$ levels for the 18-hour period between 0600 and 2400 hours on a normal working day. It is a common traffic noise descriptor.

L_{Aeq}	Equivalent sound pressure level—the steady sound level that, over a specified period of time, would produce the same energy equivalence as the fluctuating sound level actually occurring.
$L_{Aeq(15hr)}$	The L_{Aeq} noise level for the period 7 am to 10 pm
$L_{Aeq (9hr)}$	The L_{Aeq} noise level for the period 10 pm to 7 am
$L_{Aeq(1hr)}$	The L_{Aeq} noise level for a one-hour period. In the context of this policy it represents the highest tenth percentile hourly A-weighted L_{eq} during the period 7 am to 10 pm, or 10 pm to 7 am (whichever is relevant). If this cannot be defined accurately, use the highest A-weighted L_{eq} noise level.
maximum noise level	Maximum level value of sound pressure, measured at a given location over a specified time interval.
mound	A type of noise control barrier consisting of an artificial earthen embankment or knoll constructed between a roadway and a noise receptor area.
noise impact statement	A document setting out the existing noise impacts at a specific location, and, generally, the expected change in noise impacts that would result from a proposed development; includes strategies and controls to mitigate noise impacts.
noise level (goal)	A noise level that should be adopted for planning purposes as the highest acceptable noise level for the specific area, land use and time of day.
noise reaction	The response evoked in a listener by a noise. For traffic noise, this can usually be described as 'annoyance', but may also include fear, anger and other reactions.
noise-tolerant (land use)	Types of land use that are not generally regarded as being sensitive to relatively high noise levels—in the range 60–80 dB(A)—for example, open space, pasture / grazing, industrial, port facilities).
RTA	Roads and Traffic Authority
sound pressure level	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 the noise.
set-back	The distance between the building alignment or face and the corresponding land boundaries of a property, minima for which are controlled through planning regulation
threshold	The lowest sound pressure level that produces a detectable response (in an instrument / person).
traffic noise	The total noise resulting from road traffic, including both light and heavy vehicles, steady and intermittent traffic flow and specific events such as the use of engine brakes.
WHO	World Health Organisation