Appendix 6: Transit New Zealand's Guidelines for the Management of Road Traffic Noise

- State Highway Improvements

CONTENTS

1. INTRODUCTION

Purpose

This appendix outlines Transit New Zealand's guidelines for designing for road traffic noise from State highway improvements on nearby noise-sensitive activities. The application of these guidelines is subject to relevant statutory procedures.

State highway planning and the relationship between the road network and surrounding activities with respect to road traffic noise are discussed in section 2.5.2 of this manual.

Scope

The guidelines on the right hand pages outline:

- road traffic noise design criteria and their application,
- methods for measuring and predicting road traffic noise, and
- options for road traffic noise reduction.

Explanatory comments are provided in italics on the left hand pages.

Background

In recent years the community has become increasingly aware of the impact of pollutants on the social and physical environment. In this context, road traffic noise has aroused significant concern and attention.

High levels of road traffic noise can cause annoyance and fatigue, and interferes with communication, sleep, and leisure activities (see Appendix A).

Resource Management Act 1991

In the Resource Management Act 1991, best practicable option in relation to an emission of noise, means:

"the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to -

The nature of the … emission and the sensitivity of the receiving environment to adverse effects; and

The financial implications, and the effects on the environment, of that option when compared with other options; and

The current state of technical knowledge and the likelihood that the option can be successfully applied."

Responsibility for Controlling Road Traffic Noise

Managing road traffic noise is a responsibility of:

- roading authorities,
- local authorities,
- land owners and developers,
- vehicle manufacturers,
- vehicle owners, and
- statutory agencies.

Transit New Zealand recognises that it has a particular responsibility to consider reasonably practicable road traffic noise reduction options which result from increases in levels of road traffic noise emitted from State highway improvements.

Resource Management Act 1991

The Resource Management Act 1991 points to the duty to avoid unreasonable noise. In particular, the Act:

- provides for local and consent authorities to prescribe noise emission standards in plans made, or in resource consents granted, and
- requires occupiers of land to adopt the best practicable option to ensure that the emission of noise does not exceed a reasonable level.

Practicability of Criteria

The criteria specified in these guidelines are the minimum which Transit New Zealand will aim to meet where practicable.

Review Process

Transit New Zealand will review these guidelines on a regular basis to take into account community responses, technological advances, research results, and any changes to statutory provisions.

2. TRANSIT NEW ZEALAND'S ROAD TRAFFIC NOISE DESIGN CRITERIA

Policy Statement

Transit New Zealand's aim is for State highway improvements *which require a new designation* to meet the road traffic noise criteria specified in these guidelines. The *implementation* of these criteria is dependent on the practicability and cost effectiveness of any noise reduction measures.

Design Criteria

These road traffic noise design criteria comprise:

- average design criteria, and
- a single event design criterion.

Both the average design criteria and the single event design criterion are to be satisfied, where practicable. Noise reduction measures are to be effected, if practicable, so that all criteria are complied with.

The average design criteria have been set to take account of the overall disturbing effects of road traffic noise. The single event design criterion has been set to take account of sleep disruption.

Application of Criteria to State Highway Improvements

These road traffic noise criteria apply to *noise sensitive facilities adjacent to* new State highway alignments, and any other improvements which require a new designation.

State highways form a network of national arterial routes and often carry high traffic volumes. Road traffic noise within the vicinity of these roads should be expected.

Noise Sensitive Facilities To Be Protected

The most serious effects of road traffic noise are sleep disturbance, particularly of a long-term nature, and speech interference. As a result, it is considered a priority to protect residences, particularly long-term sleeping accommodation, and teaching environments. Opportunities exist though the Resource Management Act 1991 procedures for consideration of effect in other activities.

Residential Activities: *The criteria apply to existing residential buildings, in residential areas, which are used for long-term sleeping accommodation and general residential activities.*

Residential accommodation in buildings which have other uses, such as residential accommodation in retail premises and office buildings is excluded. This type of accommodation is usually designed to ensure a quiet internal environment. Further, it would be costly, relative to the benefits, to protect this type of accommodation if noise insulation was not already in place.

Where residential buildings need to be insulated to meet the internal noise criterion, rather than the external noise criterion, living rooms (including kitchens) and bedrooms should be protected. Other rooms such as bathrooms, toilets, and laundries do not require protection.

Facilities or areas with short-term accommodation, such as hotels, motels and caravan parks which are adjacent to State highways are excluded. Hotels, motels and caravan parks are usually adjacent to State highways to attract business and it is considered reasonable that the owners should have the responsibility to protect their customers from unreasonable noise.

Exclusion of Existing State Highways

These guidelines do not apply to existing State highways other than as listed above.

Noise Sensitive Facilities To Be Protected

These road traffic noise criteria apply to the following types of existing facilities adjacent to State highway improvements:

- residential buildings, excluding:
  - garages and other ancillary buildings,
  - short-term accommodation (such as hotels, motels, hospitals and caravan parks) adjacent to existing State highways (but, not on new State highway alignments), and
  - residential accommodation in buildings which have other uses (such as residential accommodation in commercial buildings),
- teaching areas in educational facilities.

Where facilities with short-term accommodation are already located in low noise areas away from State highways it is considered they should be protected.

Hospitals are generally designed for closed windows and with air conditioning. These features ensure a quiet internal environment. Where hospitals have not been designed with adequate noise insulation they should be treated on a case-by-case basis.

Educational Activities: As teaching areas are primarily established to promote learning, which is acquired largely by word of mouth and by listening, good intelligibility of speech is of primary importance.

Teaching areas such as classrooms require protection. However, non-teaching areas such as offices, staff rooms and storerooms, where these can be differentiated from teaching areas, do not warrant protection.

Facilities/Activities Excluded

Retail, Commercial & Industrial Activites: Protection of these activities is not generally a concern of roading authorities. While road traffic noise may be a problem to customers in retail areas, businesses often rely on high traffic volumes for custom. In line with overseas practice, it is considered that these activities should not be protected.

Recreational Activities & Open Spaces: Given the priority of reducing sleep disturbance and speech interference, it is not proposed that recreational activities and open spaces should be protected. This is in accordance with overseas practice.

Facilities/ Activities Excluded

These road traffic noise do not apply to other facilities/activities including:

- retail, commercial, and industrial building, and
- recreational areas and other open space.

Assessment Point

The most common assessment point worldwide is 1 metre from the most exposed facade of permanent buildings. Most outdoor activities occur on the rear portion of properties rather than the front. Therefore, it is considered a priority to protect the residential dwelling rather than the whole property.

Noise Buffer Strips

Noise buffer strips have the purpose of indicating to prospective developers that:

- *significant levels of road traffic noise can be expected from the adjacent State highway, and*
- *the developer must take responsibility for any noise reduction works, if required, within the noise buffer zone.*

Noise buffer strips should generally extend a minimum of 20 metres from the outer limit of designations in the case of residential land and 50 metres from the outer limit of designations in the case of rural land. In some situations, such as cuttings and screens, these minimum distances can be reduced.

As appropriate, designations for State highway improvements should be accompanied by noise buffer strips. For existing State highways territorial local authorities will be encouraged to include the concept of noise buffer strips, or something similar, as a rule in their district plans. This would allow for compatibility between the roading activities and noise sensitive facilities.

Assessment Point

The point at which noise levels are measured and/or assessed, and to which the design criteria apply, is 1 metre in front of the most exposed point on the facades of existing residential buildings or educational facilities, but otherwise in accordance with the provision of NZS 6801:1991 "Measurement of Sound: methods of measuring noise".

An exception is in the case of noise buffer zones, where the assessment point is the outer limit of the buffer zone (with provision for facade effect).

Noise Buffer *Strips*

Noise buffer strips are areas adjacent to a State highway designation where the road traffic noise design criteria will not apply, except to permanent buildings erected within (or partially within) the buffer strip before the creation of the buffer strip.

Noise Descriptor

Road traffic noise levels vary continually. However, where traffic volumes are above 2000 vehicles per day people generally react to the total level of traffic noise rather than to the noise of individual vehicles. For this reason traffic noise levels are generally measured for each hour on a percentile basis that weights the louder noise level, and then averaged over the relevant period of time.

More complex indices have been proposed to account for the intermittent or variable nature of noise. These indices, however, have not proved to be better correlated with annoyance due to traffic than the simpler single figure indices L_{10} and Leq.

Whilst L_{10} and Leq are used internationally, it has been general practice in New Zealand to use the L_{10} index.

There are, however, advantages to using the Leq descriptor. These are:

- *that Leq takes greater account of the high energy levels of trucks,*
- *its wider use throughout the world including its use by OECD and WHO, and*
- *its consistency with noise measurements for aircraft and train noise.*

For further information see Appendix B.

Time Period

It is important that the road traffic noise design levels apply for those time periods when noise sensitive activities are occurring in residential and educational facilities.

<u>Residential Activities:</u> In many residences, noise sensitive uses take place over most of the 24-hour period. These uses include general activities such as conversation and sleep.

Some overseas criteria specify both "day-time" and night-time criteria, for the reason that there is at least a 5 dB(A) difference between the acceptable noise level for normal day-time activities and sleep. Depending on the country the "day-time" criterion applies either to a 16 hour, 18 hour or 24 hour period.

3. AVERAGE DESIGN CRITERIA

Noise Descriptor

The noise descriptor used in these guidelines for average noise design levels is the A-frequency weighted time average, Leq.

Time Period

The time period over the day for which the average noise design levels apply for residential buildings and educational facilities is 24 hours.

Data from 40 urban and rural sites in New Zealand indicates that for urban areas, a 5 dB(A) difference in design levels between Leq (24 hour) and Leq (8 hour, night-time) would mean the Leq (24 hour) nearly always applies. For rural areas the difference between Leq (24 hour) and Leq (8 hour, night-time) is more varied. However, for rural areas the single event design criterion is considered more appropriate given that it takes account of individual vehicles.

<u>Educational Activities:</u> Educational facilities, which include schools, polytechnics, and universities can be in use from 8am to 9pm. However, for simplicity a design level to cover the same time period as for residential facilities has been set.

Average Noise Design Levels

International research on the subjective reaction to noise in the local environment indicates that it is not only the level of noise which determines the reaction, but it is also the opinions and attitudes associated with the noise being experienced that affect the overall response. Reviews of factors influencing the relationship between noise exposure and reaction have found that differences are related to non-physical responses variables such that reactions are intuitively linked to the respondent's opinions about the type of source creating the noise. The findings indicate that for a given level of exposure, aircraft noise causes more adverse reaction than road traffic noise which is greater than railway traffic noise. The reaction to industrial type sounds varies considerably, but it is generally more annoying than transportation noise. Caution should therefore be exercised when comparing relevant noise limit criteria for noise from different sources.

<u>Low Noise Areas:</u> The results of overseas research is that in low noise areas where the increase was 11-15 dB(A) the community reaction was moderate. The reaction intensified to strong above a 15 dB(A) increase. As a result of this research, RTA (NSW) considers that an increase of 12 dB(A) is acceptable and have adopted this figure in their guidelines.

No independent research has been conducted in New Zealand and accordingly the results of the RTA (NSW) research has been adopted for low noise areas in the meantime.

Achieving less than 55 dB(A) Leq (24 hour) is very difficult and likely to have significant cost implications for projects. Accordingly, it is considered that no action should be taken unless the predicted noise level is more than the average noise design levels given in Table 1.

Average Noise Design Levels

The average noise design levels for residential buildings and educational facilities at the assessment points are set out in Table 1 in:

- low noise areas (ambient noise level of less than 50 dB(A) Leq (24 hour))
- medium noise areas (ambient noise level 50-59 dB(A) Leq (24 hour))
- high noise areas (ambient noise level of more than 59 dB(A) Leq (24 hour))

Table 1 Average Noise Design Levels

NOISE AREA	NOISE DESCRIPTOR	AMBIENT NOISE LEVEL (dB(A))	AVERAGE NOISE DESIGN LEVEL (dB(A))
Low	Leq (24 Hour)	Less than 43	55
	"	43-50	Ambient + 12
Medium	"	50-59	62
High	"	59-67	Ambient + 3
	"	67-70	70
	"	More than 70	Ambient

Medium Noise Areas: *For residential buildings in medium noise areas:*

- *Dose-effect relationships indicate that road traffic noise in the range of 58 dB(A) Leq (24 hour) to 64 dB(A) Leq (24 hour) is generally acceptable.*
- *OECD/WHO guidelines establish 54 dB(A) Leq (24 hour) to 64 Leq (24 hour) as an acceptable range.*
- *Economic evaluations of a sample of New Zealand roading projects based on overseas house price surveys, indicate a noise design level of 62 dB(A) Leq (24 hour) is justified.*

For further information see Appendices C and D.

In teaching rooms of educational facilities, good intelligibility of speech is of primary importance.

Overseas research has shown a relationship between acceptable background level and the reverberation time, where a higher background noise can be tolerated if the reverberation time is short. Maximum recommended internal background levels from different studies, however, range between 40 dB(A) Leq and 50 dB(A) Leq.

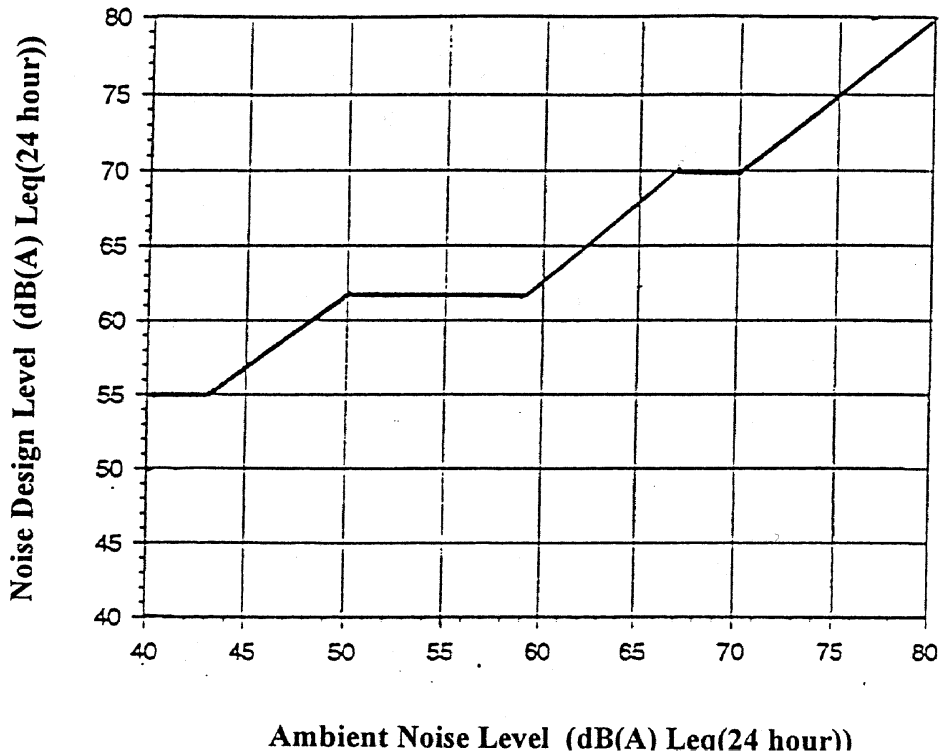
By way of comparison, the Australian Standard AS2107:1987 recommends a day-time indoor maximum level of 45 dB(A) which approximates to an external level of 62 dB(A) Leq (24 hour).

Based on the research, it is considered that 62 dB(A) Leq (24 hour) at the assessment point is acceptable. This approximates to a day-time indoor level of 45 dB(A) Leq given that the exposed windows can generally be closed.

High Noise Areas: *To achieve the same design levels as those for medium noise areas would be impractical in some circumstances and potentially very expensive. Therefore, the liability of roading authorities should be limited to not making the noise levels perceptibly different from existing levels. That is, the noise level should not increase by more than 3 dB(A) above the ambient noise level.*

Based on overseas research, at levels above 70 dB(A) Leq (24 hour) more than 20 per cent of people are likely to be highly annoyed with the road traffic noise levels. Therefore, at above 70 dB(A) Leq (24 hour) the criteria is to maintain the ambient noise level.

Figure 1 Average Noise Design Levels



Design Year

In most areas, traffic volumes are constantly increasing due to changing mobility patterns and redevelopment. As a result, the criteria need to take account of predicted traffic flows in the medium-term future.

In deciding a suitable design year there needs to be a balance between protecting those people immediately affected by a roading change and establishing a limit on the liability of the roading authority to those people who buy into an affected area <u>*after*</u> *the roading change has occurred. Establishing the design year is an arbitrary decision and overseas practice ranges from year 5 to year 20. It is likely that Australian states will adopt 10 years, and it is considered that this design year should also be adopted for New Zealand.*

Internal Noise Level

While in New Zealand houses windows are frequently open, it is not practical to reduce internal noise levels with windows on the exposed wall open. Internal noise levels are assessed on the basis of windows on the exposed walls being closed.

For New Zealand conditions, internal noise levels are on average 20 dB(A) less than external noise levels when the windows are closed. Therefore, the internal criterion is the external criterion as given in Table 1 less 20 dB(A), with a lower limit of 40 dB(A) Leq (24 hour). This lower limit is generally equivalent to a night-time internal level of 35 dB(A) which is recommended by WHO to prevent sleep disturbance. Reducing internal noise levels below the lower limit produces no significant extra benefits.

As with residences the internal noise level in teaching areas is generally 20 dB(A) less than external noise levels when the windows are closed. Therefore, the internal criterion is the external criterion as given in Table 1 less 20 dB(A), with a lower limit of 45 dB(A) Leq (24 hour). This lower limit is within the range of acceptable internal noise levels in teaching areas. Reducing internal noise levels below the lower limit produces no significant extra benefits.

Design Year

The assessed average noise levels are to be based on forecasts of traffic flows 10 years after the completion of the State highway improvement.

Internal Noise Level

If it is not practicable, including not cost effective, to meet the average design noise criterion given in Table 1 at the assessment point, then an internal noise design criterion will apply, if practicable, to all living rooms (including kitchens) and bedrooms in residential buildings, or teaching areas in educational facilities, with windows closed.

In these circumstances, the internal noise level criterion is the level given in Table 1 minus 20 dB(A), or 40 dB(A) Leq (24 hour) for residential buildings and 45 dB(A) Leq (24 hour) for educational facilities, whichever is the higher.

Single Event Noise Design Level

Some overseas studies have suggested that peak levels of 60dB(A) should not occur more than 16 times per night, or peak levels of 50dB(A) no more than 64 times in a night. Other studies have suggested more stringent criteria.

Given closed windows on the most exposed façade this indicates and external Lmax design level of between 70 and 80 dB(A). On this basis, a design level of 75dB(A) (without façade effect) or 78 dB(A) (with façade effect) at the assessment point has been adopted. These criteria are also in keeping with NZS6802:1991 "Assessment of Environmental Sound: assessment of noise in the environment"

Given that the Lmax of vehicles varies greatly and that roading authorities have no control over the noise emitted by individual vehicles, a typical Lmax level emitted by vehicles, and in particular trucks, has been assessed at 82dB(A) at 7.5m from the carriageway.

Therefore, to achieve the criterion of 78dB(A)Lmax, the assessment point would need to be at least 12m from the nearside edge of the traffic lane.

Noise Reduction Required

No noise measurements are required, however it is necessary to reduce noise levels by the prescribed amounts for noise-sensitive activities within 15 metres of the nearside edge of the traffic lane.

It should generally be possible to achieve the required noise reductions by using road surfacing options.

4. SINGLE EVENT DESIGN CRITERION

Single Event Noise Design Level

The minimum distance to meet the single event noise design level is 12 metres from the nearside edge of the traffic lane to the nearest assessment point for residential buildings and educational facilities.

Noise Reduction Required

Where the nearest assessment point is within the 12 metres, a noise reduction of 3 dB(A*)* is required at the assessment point.

5. MEASUREMENT& PREDICTION METHODS

Measurement Method

Equipment and methods used for the measurement of noise are to comply with NZS 6801:1991 “Measurement of Sound: Methods of measuring noise”.

AADT Prediction Method

Traffic volumes used for noise predictions are normally to be based on the AADT for the base year and the traffic flow growth forecasts given by local transport studies. Where such local data is unavailable the traffic flow growth forecasts given in Appendix A4 of Transfund New Zealand's Project Evaluation Manual are to be used.

Road Traffic Noise Prediction Method

Prediction of road traffic noise is to be carried out using the United Kingdom "Calculation of Road Traffic Noise" (1988) method, calibrated to New Zealand conditions (refer to TNZ Research Report No. 28 "Traffic Noise From Uninterrupted Traffic Flows" (1994)) and converted to the appropriate Leq index.

The conversion formulae to calculate Leq values from the L_{10} values derived from the U.K. "Calculation of Road Traffic Noise" (1988) method are:

$$\text{Leq (24 hour)} = L_{10}\text{ (18 hour)} - 3\text{ dB(A)}$$

$$\text{Leq (1 hour)} = L_{10}\text{ (1 hour)} - 3\text{ dB(A)}$$

6. NOISE REDUCTION OPTIONS

Introduction

There are various options to reduce road traffic noise for State highway improvements.

Options

The noise reduction options are:

- Noise Buffer Zones
- Distance from Traffic Lane
- Barriers
- Alternative Road Surfaces
- Vegetation
- Building Insulation

For further information see Appendix E.

7. DEFINITIONS

Ambient The totally encompassing sound in a given situation at a given time, usually composed of sound from all sources near and far.

DB(A) An abbreviation for the A frequency weighted decibel as per IEC651, a scale of sound measurement which emulates human auditory response. The decibel is a measure of sound pressure level.

Facade Effect The effect of noise reflecting off the wall of a structure.

Leq

An abbreviation for the time average level, that is an energy average of varying sound levels, over the measurement period. Leq is given by the formula:

$$\text{Leq(T)} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{P_A{}^2(t)}{Po^2} dt \right]$$

where

t_2-t_1 is the period T over which the average is taken starting at t_1 and ending at t_2,
p_A is the A-weighted sound pressure in pascals, and
p_o is the reference sound pressure of 20 micropascals

Leq (24 hour) The inverse logarithmic average of the hourly Leq values taken over the 24-hour period of a full day.

$$\text{Leq (24 hour)} = 10 \times \log 1/24 \{ \sum_1^{24} 10^{Leq/10} \} \text{ dB(A)}$$

Lmax The maximum sound level as defined by NZS6801:1991 “Measurement of Sound: Methods of measuring noise”.

APPENDIX A

EFFECTS OF ROAD TRAFFIC NOISE ON PEOPLE

Sound and Noise

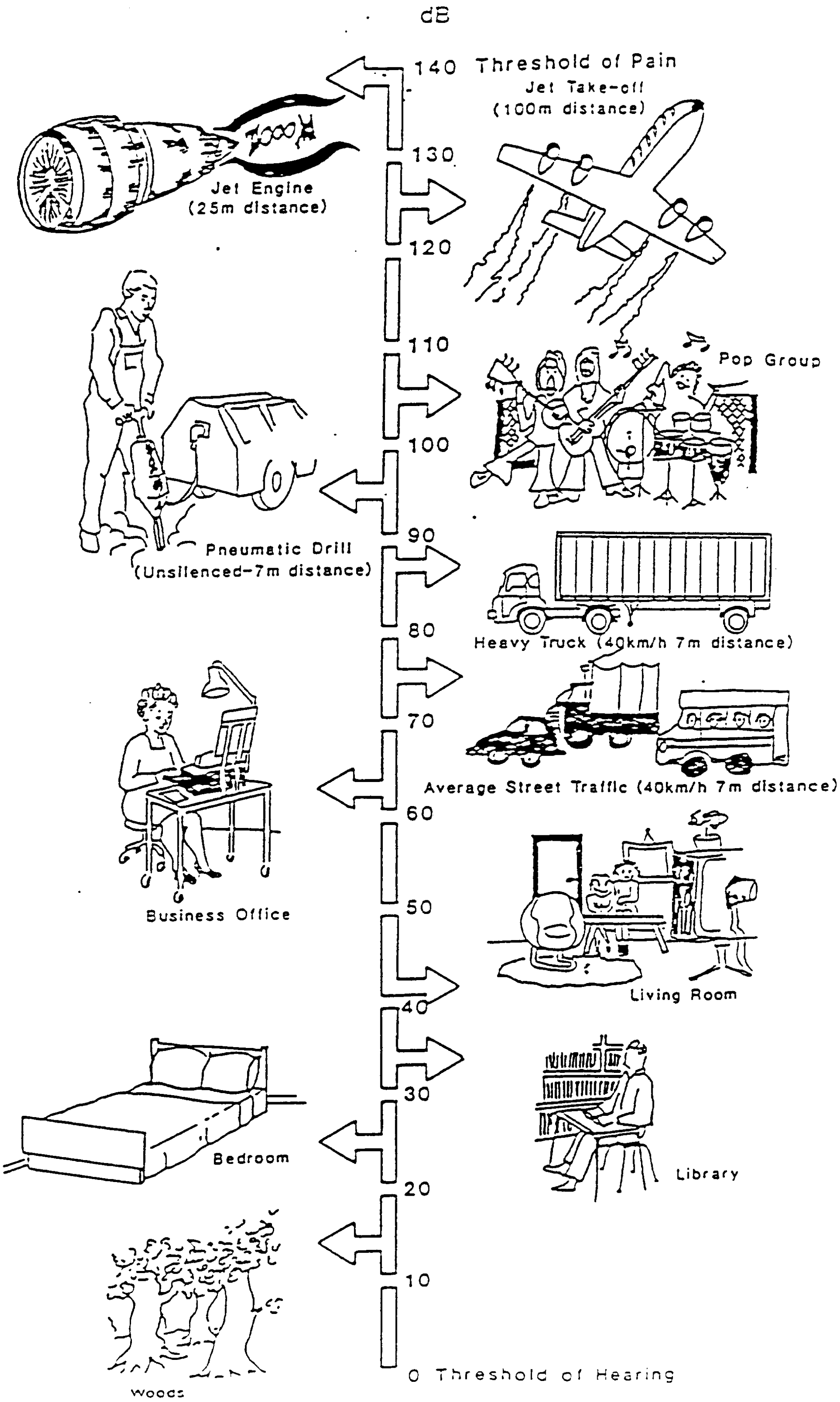
Noise has often been defined as "unwanted sound". For the purpose of this document, noise is taken to be the perceived sound emitted by road traffic.

Sound is measured in terms of its energy content relative to the smallest reference level, that is, "threshold of hearing", or zero decibels (dB). The ear also responds in different ways to sounds at different frequencies; therefore the measured sound level is adjusted to give more weight to some frequencies than others. The weighting found to give the best correlation between "perceived" and "actual" loudness is the "A" weighting. "A" weighted readings are expressed in terms of dB(A).

As a rough guide, an increase (or decrease) of 10 dB(A) represents a doubling (or halving) of loudness. For example, a noise measured as 80 dB(A) will sound twice as loud as one which registers 70 dB(A). Some examples of typical sound levels in dB(A) are shown in Figure A1.

In general, the untrained ear will not detect level differences of 3 dB or less. However this "rule-of-thumb" may not apply in relation to road traffic noise in all conditions, and should be treated with caution. To increase the noise level by 3 dB would require a doubling of the traffic volume.

Figure A1 The Level of Common Sounds (after Department of Main Roads, New South Wales 1987)



Speech Interference

Speech interference by high levels of road traffic noise can cause serious problems in schools, homes and work places.

With respect to schools, in particular, Australian Standard AS2107:1987 recommends as satisfactory a day-time indoor level of 40 dB (A) Leq for classrooms, with 45 dB (A) Leq as a maximum.

Annoyance

A widespread problem caused by road traffic noise is the general annoyance and related stress suffered by communities adjacent to major roads. In the WHO report "Environmental Health Criteria – Noise" (1980) it is stated that "annoyance may be defined as a feeling of displeasure associated with any agent or condition known or believed by an individual or group to be adversely affecting them". The annoyance caused by road traffic noise arises primarily from the disturbance it causes to activities such as sleeping, listening to music, watching TV, reading, studying, relaxing and entertaining.

Effects on Behaviour

In addition to the psychological reaction of annoyance, excessive noise can lead to a variety of changes in behaviour. One study showed that as road traffic noise levels increase, so does the percentage of people who:

- close windows to prevent activity disturbance,
- transfer activities to quieter rooms,
- insulate their dwellings against noise,
- give consideration to moving house,
- use sleeping tablets, and
- resort to formal complaint.

OECD Position

The OECD position is summarised in a report put out by OECD's Environment Committee Group on the State of the Environment – Transport, dated December 1989, as follows:

> "Noise disrupts activity, disturbs sleep and hinders people carrying out their work….It had been seen that noise impedes the learning process (particularly in school), psychological development, social activity and verbal communication and imparts job performance and safety in the workplace and in transport.
>
> Noise also generates stress….It also has a very considerable impact on how the individual functions physiologically, psychologically and socially, both because of the effort required to adjust to noise and because of the frustration resulting from the deterioration in the quality of life and sleep."

APPENDIX B

NOISE DESCRIPTIONS

Background	There is a plethora of units for the measurement of noise. Half a century ago the A, B and C scales were established to take into account the non-linear behaviour of the human ear with respect to both frequency and sound intensity. The A scale remains in use and over the last quarter of a century has become widely accepted as a measure of environmental noise. For the levels of sound caused by road traffic, the A weighted scale best simulates the frequency responses of the human ear. Using the A weighted scale several single figure indices have been derived, such as L_{10}, Leq and Ldn, to describe noise levels over any period of time, such as 24 hours.
L_{10}	L_{10} is the sound pressure level which is equalled to or exceeded for 10 percent of the measurement period. L_{10} (18 hour) is, for the purpose of road traffic noise measurement, the arithmetic average of hourly L_{10} values taken over the 18 hour period from 6am to midnight.
Leq	Leq is the time average sound pressure level, ie an energy average of varying sound levels, over the measurement period. Leq (24 hour) is the inverse logarithmic average of the hourly Leq values taken over the 24 hour period of a full day. Leq has been adopted by some European countries and is the basis of Ldn proposed by the United States Environmental Protection Agency.
Ldn	The Ldn (or DNL) which is a day/night equivalent sound level, is the Leq inverse logarithmic average of the hourly Leq values but with a 10 dB penalty for night period, the night period being defined as from 2200 to 0700.
Relationship Between L_{10}/Leq	It is generally accepted that, under New Zealand free traffic flow conditions, a given L_{10} (1 hour) value will exceed the corresponding Leq (1 hour) by about 3 dB.

mathematical models have been developed that can with reasonable accuracy (± 2 dB(A) at 95 per cent confidence limits) predict the road traffic noise level at a particular location under a given set of conditions. These models have been calibrated for New Zealand conditions. One advantage of the L_{10} index is its use in the comprehensive prediction method described in "Calculation of Road Traffic Noise" (CRTN) Department of Transport, UK, 1988.

APPENDIX C

DETERMINING THE DESIGN CRITERION FOR MEDIUM NOISE RESIDENTIAL AREAS

Alternative Methods

The design criterion for medium noise areas has been established by applying the following methods:

- dose-effect relationships,
- OECD/WHO recommendations, and
- economic evaluation

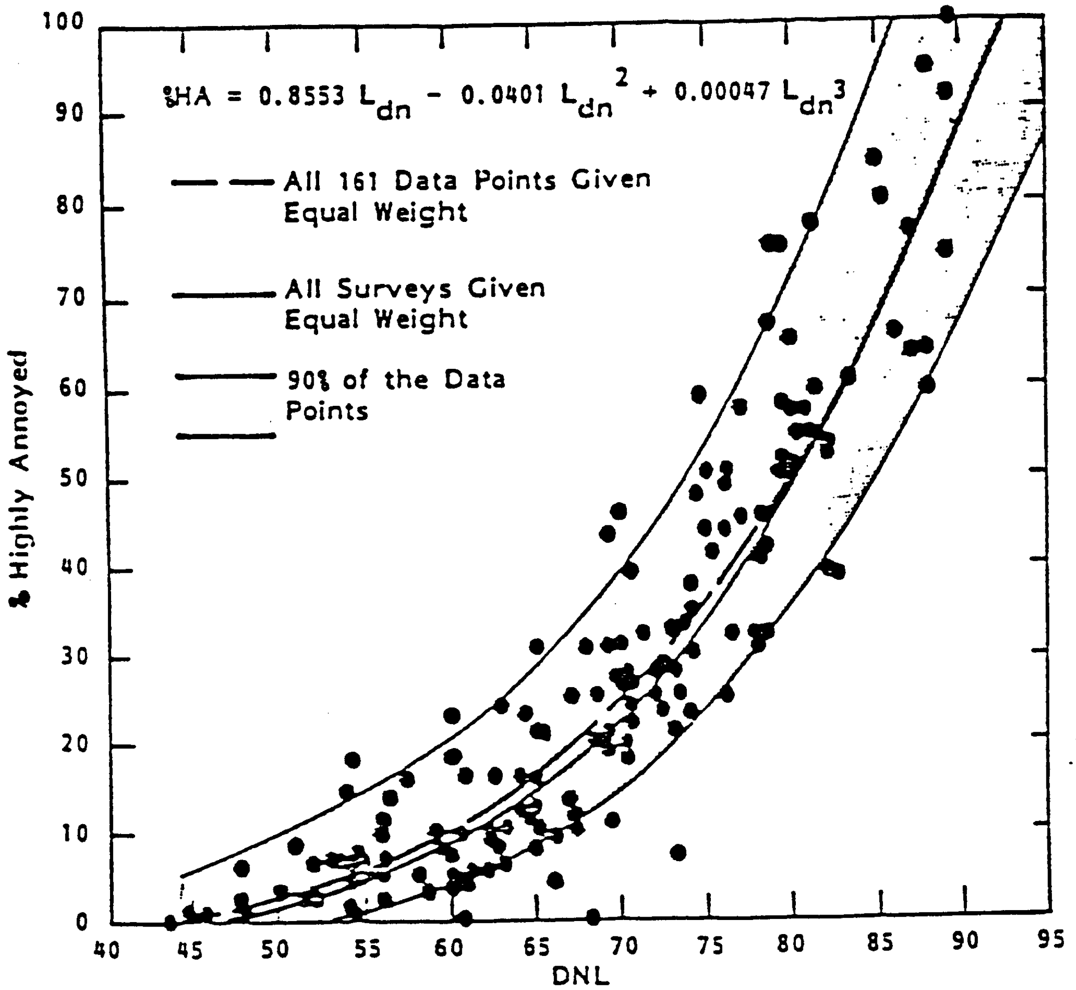
Dose-Effect Relationships

The dose-effect relationships method is based on a survey of the perceived annoyance level arising from road traffic noise within residential properties. At the same time, the actual road traffic noise levels are measured at a standard point outside the residences. From this information, a relationship is determined between the percentage of people annoyed and the actual road traffic noise level.

Standard references on dose-effect relationships are Schultz, Fidell and Fields from the United Stares, Langdon and Griffiths from the UK, and Hede from Australia. The most comprehensive study of dose-effect relationships was undertaken by Schultz in 1978 and updated by Fidell and Green in 1989.

In these surveys, annoyance was expressed as the percentage of the community that claimed to be annoyed to a high degree by noise exposure. The individual data points seen in Figure C1 represent the findings of these surveys which were undertaken in different places, at different times, by different methods and reported in different units. Despite this, Job (1988) in an extensive review of previous surveys concluded that, across measurement techniques and cultures, dose-effect relationships show a remarkable similarity.

Figure C1 Empirical Data on Prevalence of Annoyance of Transport Derived From Social Surveys (Schultz, 1978)



Note that DNL= Ldn = 1.16 Leq(24 hr) - 6.8
(60 Ldn = 59 Leq (24hr))

Overseas organisations have accepted that 100 per cent acceptance of noise levels is not possible and that generally a 10-20 per cent highly annoyed rate is a reasonable target. On this basis, acceptable road traffic noise for residential buildings is within the range of 58 dB(A) Leq (24 hour) to 64 dB(A) Leq (24 hour).

OECD/WHO Recommendations

Based on the results of research conducted in OECD member countries on the effect of noise and more generally its impact on behaviour and human activities, the OECD has concluded that:

- Below 54 dB (A) Leq (24 hour), adverse effects due to noise are very slight and most noise sensitive activities can be carried out normally.

- Between 54 and 59 dB (A) Leq (24 hour), noise impact remains limited but some disturbance is likely to more sensitive individuals, in particular older persons.

- Between 59 and 64 dB (A) Leq (24 hour), the adverse effects of noise increases very appreciably.

- Above 64 dB (A) Leq (24 hour), constrained behaviour patterns arise, symptomatic of serious damage caused by noise.

These conclusions have led the OECD to recommend that in order to comply with desirable limits for well-being indoors, the outdoor level should not exceed 64 dB(A) Leq (24 hour). In the case of new residential ares, it is recommended that the outdoor level should not exceed 54 dB(A) Leq (24 hour).

WHO's report "Environmental Health Criteria 12 – Noise" (1980) states that "for good speech intelligibility indoors, background noise levels of less than 45 dB(A) Leq are required. At night, sleep disturbance is the main consideration and available data suggest a bedroom noise limit of 35 dB(A) Leq.

Data from surveys of community noise annoyance lead to the recommendation that general daytime noise levels of less than 55 dB(A) Leq are desirable to present any significant community annoyance. This is consistent with speech communication requirements. At night, a lower level is desirable to meet sleep criteria: depending upon local housing conditions and other factors this would be in the order of 45 dB(A) Leq."

Caution needs to be taken with the WHO recommendations because technology and economic limitations make these recommendations impracticable, at present, for many existing urban areas.

Economic Measures

The main method used overseas to value the benefits of noise reduction has been studies of “house price differentials” (or “hedonic pricing”). Studies have been carried out in Australia, North America, and Europe on the price differences between similar houses exposed to varying road traffic noise levels. These take the difference in house prices as a proxy for willingness to pay for peace and quiet.

A summary is given by Nelson (1982) reviewing nine empirical studies covering fourteen different housing markets in Canada and the United States. All studies contain various shortcomings. The small number of empirical studies, repeated use of the same areas, and the inherent diversity and difficulties encountered lead to problems of variability and interpretation. However, the estimates are fairly consistent and suggest house price differentials in the range of 0.16 to 0.63 per cent per decibel with a mean of 0.4 per cent per decibel. Based on this study and others, the OECD has recommended 0.5 per cent per decibel.

In a more recent review which included Nelson’s work, the Australian Resource Assessment Commission (1990) determined a range of 0.08 to 1.26 percent per decibel but recommended no single figure. The Roads and Traffic Authority (RTA)(NSW) recommends 0.9 percent per decibel based on one case study in Sydney while VICROADS has adopted an implied depreciation index of about 0.75 percent per decibel based on three case studies. The higher depreciation indices used in Australia have been based on only a small number of case studies.

In New Zealand, there have been no specific hedonic pricing studies carried out to determine the benefits of noise reduction. In the absence of such studies the OECD recommendation of 0.5 percent per decibel has been used. This is because the OECD recommendation is based on a relatively wide range of studies compared with small number of studies undertaken in Australia.

Overseas Criteria

By applying some or all of the above methods, road traffic noise standards and objectives recommended by various overseas agencies are generally between 57 to 62 dB (A) Leq (24 hour). These are set out in more detail in Appendix D.

APPENDIX D

OVERSEAS CRITERIA

This appendix outlines the criteria adopted by other countries for limiting road traffic noise. All noise units used have been converted to the Leq (24 hour) description using the following conversions, except where otherwise indicated:

Leq (24 hour)	=	L_{10} (18 hour)	-	3dB (A)
Leq (16 hour)	=	L_{10} (16 hour)	-	3dB (A)
Leq (8 hour)	=	L_{10} (8 hour)	-	3dB (A)

United States

The American Environmental Protection Agency has suggested that 55 dB (A) is the level at which no adverse effects on public health can be found.

The Federal Inter-Agency Committee on Urban Noise suggests in its “Guidelines for Considering Noise in Land Use Planning and Control” that 58 dB (A) is a goal for outdoors in residential areas for protecting the public with an adequate margin of safety.

Meanwhile the US Dept of Housing considers the range 55 to 63 dB (A) “acceptable” and in the range 63 to 72 dB (A) “normally acceptable”.

Canada

Ontario Ministry of Transportation and Communication has set an objective for noise from new roads at 55 dB (A).

Action is considered when levels exceed 5 dB (A) above the pre-existing noise level.

United Kingdom

Road construction authorities are required under the Noise Insulation Regulations to offer insulation to occupiers of eligible properties. Properties are eligible if the additional traffic within 15 years on a new or altered highway causes the noise level to increase by at least 1 dB (A) so that the level of 65 dB (A) is reached or exceeded.

Finland and Sweden

These countries have “desirable” standards that apply both inside and outside buildings such as residences, schools, offices and recreational facilities. In addition, there are no exceptions to which high acceptable limits apply. These exceptions include new routes in existing areas, upgrading of existing routes and redevelopment of existing areas.

	Finland (dB(A)	**Sweden (dB(A)**
Residential (desirable) indoors outdoors	 35 55	 30 55
Exception 1 (new route in existing area) indoors outdoors	35 60	35 60
Exception 2 (new route in existing area) indoors outdoors	40 65	40 70
Exception 3 (redevelopment of existing route) indoors outdoors	35 70	30 70

Denmark

The objective is to reduce road traffic noise to 55 dB (A). This is not considered achievable in some urban areas.

France

The criteria is 65 dB (A) with the objective of reducing this to 60 dB (A).

Switzerland

Switzerland has a desirable road traffic noise level of 60 dB (A) Leq (16 hour) between 6am and 10pm and 47 dB (A) Leq (8 hour) between 10pm and 6am. However maximum permitted levels are 70 dB (A) Leq (day) and 65 dB (A) Leq (night).

Netherlands

A three tiered system applies to the road or dwelling under consideration together with maximum exemptions in urban areas. Road authorities may be exempted if the level is at or below the maximum, depending on the situation in question.

Road	Dwelling	Guideline	Maximum Exemption
Planned	Planned Under Construction Existing	55 55 55	65 70 70
Under Construction	Planned Under Construction Existing	55 60 60	65 70 75
Existing	Planned Under Construction Existing	55 60 65	70 70 75

Australia

In **Victoria** an interim guideline is used by VICROADS under which the roading authority installs noise barriers along roads when the noise levels are predicted to exceed 60 dB (A) 10 years after the opening of a new facility. Installation of noise barriers has been undertaken on existing motorways where the 65 dB (A) level is exceeded.

In **New South Wales**, the Road and Traffic Authority has adopted interim traffic noise guidelines. The objectives are 60 dB (A) Leq (24 hour) and 55 dB (A) Leq (8 hour) between 10pm-6am in residential areas for new roading projects. Action is also considered if the level rises by at least 12 dB (A) above the preconstruction level.

In **Queensland**, the Queensland Department of Transport has adopted interim guidelines for road traffic noise amelioration. The objective is 60 dB (A) Leq (24 hour) for new access controlled roads. Ameliorative measures will be considered when upgrading existing access controlled roads and the noise level is 65 dB(A) Leq (24 hour) or greater.

The **Tasmanian** Department of Main Roads has set an objective to reduce the noise level on new and upgraded roads to 60 dB(A) at the road boundary. The Department acknowledges that with large traffic flows this is not always feasible.

APPENDIX E

NOISE REDUCTION OPTIONS

Introduction

There are various ways to reduce road traffic noise for state highway improvements. Indicative information is given on the effectiveness and costs of various reduction methods. All costs are in 1992 dollars.

Options

The noise reduction options are:

- Noise Buffer Zones
- Distance from Traffic Lane
- Barriers
- Alternative Road Surfaces
- Vegetation
- Building Insulation

Noise Buffer Zones

Noise buffer zones can be created as part of planning new road designations, or as part of the plans of local and consent authorities. The intent of these zones is not to prevent development but to ensure a reasonable distance, and therefore noise reduction, between busy state highways and noise sensitive facilities.

Distance from Traffic Lane

Increasing the distance between traffic and buildings reduces noise, providing a reduction of 3-5 dB (A) per doubling of distance. Table E1 gives an example of road traffic noise attenuation as a function of distance.

Table E1: Traffic Noise Attenuation as a Function of Distance from Roadway (20,000 vpd, 10 per cent Heavy Vehicles, Receiver Height 1.5m, Soft Ground

Distance (m)	10	15	20	25	30	35	40
Leq (24 hour)	68	66	64	62	61	60	59

Barriers

Barriers may take the form of walls, solid fences, or earth mounds. Noise reduction can be up to 10-12 dB(A) provided barriers have no holes or gaps and prevent a direct line of sight between the noise source and the receiver. Table E2 gives indicative costs for different types of barrier.

Table E2 Indicative Net Costs for different Types of Barrier (excluding land costs).

Barrier Types	Costs/Linear metre (1.8m high)	Costs/Linear metre (3m high)	Costs Linear metre (5m high)
Timber	$80-100	$150-200	$350-450
Concrete	$300-500	$400-700	$800-1200
Glass Reinforced Cement			
- Absorptive	$1000	$1500	$2200
- Dispersive	$600	$900	$1400
Earth Mound (1:2 Slope)	$0-150	$0-200	$0-300

In practice, barrier effectiveness is greatly influenced by site topography and barrier design. The use of barriers may also be limited by engineering considerations, safety requirements and aesthetics, as well as costs. Extra reserve width may be necessary in some instances to allow construction to barriers.

If noise barriers are considered appropriate, the height and location of these should be established after consultation with owners of adjoining properties

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Alternative Road Surface

The selection of road surface type can have a noticeable effect on road traffic noise levels. Table E3 shows the effect of different surface types as compared with dense asphalt and Table E4 gives indicative costs.

Table E3: Indicative Changes in Road Traffic Noise Due to Road Surface/Tyre Interaction as Compared with Dense Graded Asphalt (assuming traffic speed 80 km/h)

Road Surface Type	**Indicative Changes in Road Traffic Noise Level dB(A)**
New Chip seal	
14 to 20mm chip	plus 4
10 to 14mm chip	plus 3
7 to 10 mm chip	plus 3
Open Graded Asphalt (Friction Course)	minus 3

Table E4 Indicative Costs of Various Road Surfaces

Road Surface Type	Cost per sq. m	Total Cost per km for a 3.5m lane	Design Life (20,000 to 50,000 vpd)
Chip Seal	$3.00	$10,500	8 years
Dense Graded Asphalt	$10.00	$35,000	15 years
Open Graded Friction Course	$9.00	$31,500	8 years

Also of significance is the change in noise frequencies, as determined by a frequency analysis, between chip seals and open or dense-graded asphalts. This explains, in part, the greater reduction than might be expected from the reduced noise level in the number of people annoyed when an asphalt replaces a chip seal.

Transit's Surfacing Strategy

AADT Variable	Weighting
0 - 500	0.60
500 - 1000	0.70
1000 - 2500	0.80
2500 - 5000	0.90
5000 - 7500	0.95
> 7500	1.00

Speed Variable	Weighting
50	1.00
70	0.95
80	0.90
LSZ	0.85
100	0.80

Population Variable	Weighting
< 150	0.50
150 - 250	0.60
250 - 500	0.70
500 - 1000	0.80
1000 - 2500	0.90
2500 - 5000	0.95
> 5000	1.00

Land Use Variable	Weighting
Industrial	0.85
Residential	1.00

The seal type proposed for each combined weighting of the variables considered is as follows:

Seal Type	Combined Weighting Range
Asphaltic Concrete (AC)	1.00
Friction Course (FC)	0.85 - 1.00
Slurry Seal (SS)	0.70 - 0.85
Grade 5 Chip Seal (G5)	0.55 - 0.70
Grade 4 Chip Seal (G4)	0.40 - 0.55
Grade 3 Chip Seal (G3)	0.25 - 0.40

Allowance can therefore be made for changes in land use, traffic volumes, speed values and population when determining proposed treatments.

Vegetation (Trees and Shrubs)

Sound reduction by vegetation is frequently overestimated. Only very dense vegetation, of more than 10 metres in depth, will significantly reduce road traffic noise. However, vegetation provides some psychoacoustical benefits (what you don’t see you don’t hear) and aesthetic appeal.

Building Insulation

Where external noise at a residence cannot be achieved, interior levels can be minimised by noise insulation of the building facade and roof.

The average difference in noise levels between the outside and inside of residences is 20 dB(A) with windows closed and 10-12 dB(A) with windows open.

Insulation can consist of upgrading windows and doors and improving their seals, and installing mechanical ventilation. These measures have the potential to reduce noise levels by about 10dB(A) compared with noise levels with conventional windows and doors. In New Zealand, an indicative cost for noise insulation is around $10,000 per house for sealed windows and doors, as well as air conditioning (excluding air conditioning running costs).