Assessing Risks Associated With Simple Algorithms For Calculating Effects Due To Partial Enclosure Of A Road

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Abstract

Partial enclosures have been used for the control of road traffic noise in Europe and have been considered for some road projects in Australia. However, the Calculation of Road Traffic Noise (CRTN) method has no algorithms for estimating the insertion loss of partial enclosures. In particular, CRTN does not consider the effect of multiple reflections within the enclosure. Also, environmental noise modelling software packages cannot always estimate the barrier attenuation as the edge of the enclosure is not necessarily between the noise source line and the receiver. This paper describes a simple modification to CRTN that can be implemented in a software package such as SoundPLAN which estimates effects. The risks associated with such a simple modification are estimated.

Introduction

Several new methods for the calculation of road traffic noise have been developed recently (Menge et al 1998; Kragh et al 2002). Modern computational methods have allowed these methods to incorporate significantly more complex algorithms than older, simpler methods. However, there is evidence that the more complex methods are not significantly more accurate than the older simpler methods (Austroads 2002).

The Calculation of Road Traffic Noise (CRTN) method (UK DoT 1988) is one such simple method which remains in common use in Australasia. Originally developed nearly 30 years ago, it is a simple method which uses basic formulae, charts and diagrams. In straightforward situations (such as flat terrain with a straight road) the charts and diagrams allow noise levels to be estimated without even using a slide-rule, let alone a computer.

In complex situations, computer software can be used to re-duce the geometric relationship between the road and the receiver into a number of simple vertical cross-sections. The noise level contribution is estimated for each cross-section and the contributions summed logarithmically to determine the total.

However, in the case of a partial enclosure of a road, some acoustic effects cannot be modelled. The CRTN method has no allowance for effects due to multiple reflections within the partial enclosure and most noise-modelling software such as SoundPLAN cannot estimate the path length difference over the diffracting edge of the enclosure.

Description of the Problem

Multiple reflections

Within the partial enclosure there will be some degree of multiple acoustic reflections present. However, there will be a very uneven distribution of reflections as there will be no re-flections from the ends of the enclosure and none from the opening beyond the diffracting edge.

To model such a situation accurately, computer ray models or physical scale modelling is preferred. However, in

$$L_{Prev} = L_w + 10\log\left(\frac{4}{R}\right)$$

this case we are looking for a simple modification to CRTN.

The simplest solution seemed to be to assume that a reverber-ant field is present. The simplicity of the statistical reverberant noise level formula makes it desirable to use in this application. However, its use introduces a level of risk additional to the usual risks associ-ated with CRTN.

Figure 1. *Photograph courtesy and copyright Transurban Limited*

Locating the diffracting edge

Despite the ability to handle complex terrain, there are some situations that software packages cannot model accurately. The case of a partial enclosure of a road is one case.

Figure 1 shows a partial enclosure on one of Melbourne's major roads. The enclosed portion is quite small in this case, but it is often the case that the diffracting edge of the enclosure is above the road. Entering such a configuration into noise modelling software such as SoundPLAN is likely to be problematic, as most software (including SoundPLAN) as-sumes that barriers are vertical. Thus, if a barrier were placed in the model at a location corresponding to the diffracting edge, it could be the case that the barrier would be placed somewhere in the middle of the road, so that one (or more) of the noise source

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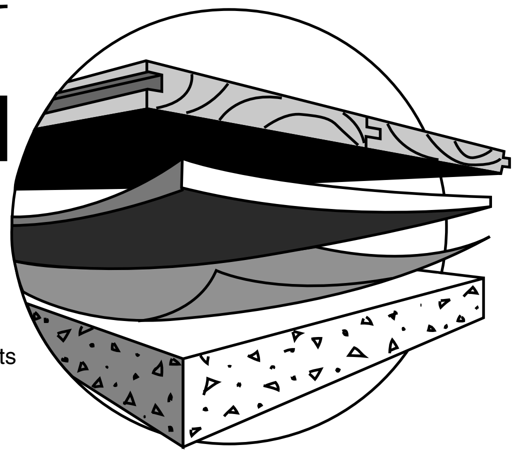
FLOOR ISOLATION



TYPICAL PERFORMANCE CHARACTERISTICS

The table below gives IIC ratings based on tests of various surface treatments Ref. ASTM E989 using an Impactamat resilient interface on a 100mm thick concrete structural floor.

FLOOR SURFACE TREATMENT (Floating Floor Construction)	Impactamat			Overall IIC Rating	IIC Improvement over bare slab	Ref.fig.
	Construction	Type	Thickness			
Loose lay timber veneer flooring with thin foam bedding layer	full cover	750	5mm	47-50	18-20	1
Direct bond 19mm block parquetry	full cover	900	5mm	45-49	18-20	2
Direct bond 10mm ceramic tiles	full cover	750	5mm	44-46	13-15	2
Particle board or strip timber battens supported at nom. 450 x 450 centres with acoustic absorption	pads 75 x 50mm	750	10mm	52-60	21-30	3
Double layer bonded 12mm ply with bonded parquetry, supported at nom. 300 x 300 centres (sports floor)	pads 75 x 50mm	750	10mm	52-57	21-27	4
50mm reinforced concrete slab or 25 mm slab with 20mm bonded marble/slate/ceramic tile	full cover	750	10mm	58-63	27-32	6
50mm reinforced concrete slab	full cover	750	15mm	59-64	28-33	5
100mm reinforced concrete slab	full cover	750	15mm	60-65	29-34	5

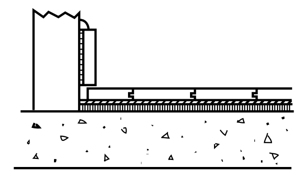


Fig. 1 Timber loose lay floating floor

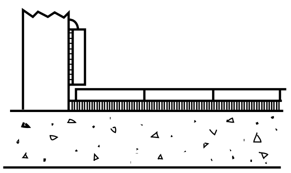


Fig. 2 Direct bond parquetry or ceramic tiles

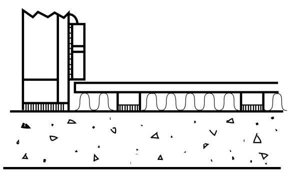


Fig. 3 Timber strip floor on battens with isolated frame wall

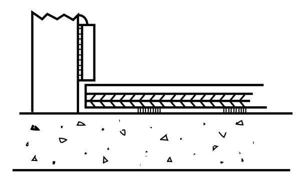


Fig. 4 Sports floor

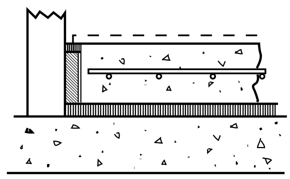


Fig. 5 Concrete slab

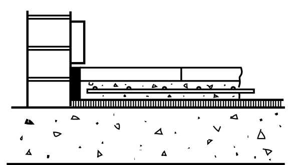


Fig. 6 Marble/slate ceramic tiles with thin reinforced slab

IMPACTAMAT by EMBELTON features two main environmental properties: it is recycled and it reduces noise pollution.
Indeed, it is made from 100% recycled natural rubber recovered from tyres, granulated and reconstituted as a solid mat (various sizes are available upon request).

IMPACTAMAT is a flexible material manufactured as a preformed sheet bound together with a flexible binder.
It is a low cost impact absorbing layer for covering hard earth or concrete in outdoor applications or as an underlay for in-situ cast or pre-cast concrete floors where noise isolation is required (rubber underlay, acoustic insulation, door mats, playground and sports surfaces, industrial floor tiles etc.).

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lines would be between the barrier and the receiver.

Noise Barrier Design Risks

Risks associated with the use of CRTN without a partial enclosure

In 1997–98, Marshall Day Acoustics undertook an extensive evaluation of the accuracy of the CRTN method for the Vic-torian State Road Authority, VicRoads (summarized in Aus-troads 2002). This is the only study in Australia that examined the accuracy of CRTN at actual residences. Most meas-urement locations used in a previous study (Saunders 1983) and in the more recent Queensland study (Batstone et al 2001), were close to the road (often within 20-30m) with no noise barriers. By contrast, measurement locations used in the VicRoads study were 20–120m from the road, with 15 out of 19 locations having noise barriers.

Under such realistic conditions, noise levels predicted using CRTN were higher than the measured noise levels by 4.4 dBA on average with a standard deviation of 2.7 dBA. In other words, CRTN had an average extent of over-design of 4.4 dBA with an uncertainty of ±5.4 dBA. The 5.4 dBA figure is based on the fact that, for a normal distribution, the 95% confidence interval corresponds with approximately 2 standard deviations.

The assumption that the accuracy of CRTN could be modelled as a normal distribution was tested and was found to be acceptable. This implies that it is also likely to be acceptable to assume that the accuracy of a method for estimating acoustic effects due to partial enclosure of a road would also be normally distributed. This assumption is used as the basis of this risk analysis.

Extent of over-design	
Mean	SD
4.4dBA	2.7dBA
Risk of under-design	
By more than 1dBA	At all
2%	5%
Risk of over-design	
By more than 3dBA	By more than 6dBA
70%	28%

Table 1. Risks associated with use of CRTN

Based on the results of the VicRoads study, Table 1 shows the risks of various degrees of under-design and over-design associated with the use of CRTN.

In other words, on average:

- Measured noise levels can be expected to be higher than predicted noise levels 5% of the time
- Measured noise levels can be expected to be at least 1 dBA higher than predicted noise levels 2% of the time
- Measured noise levels can be expected to be at least 3 dBA lower than predicted noise levels 70% of the time
- Measured noise levels can be expected to be at least 6 dBA lower than predicted noise levels 28% of the time.

Risks associated with the reverberant field assumption in a partial enclosure

It is difficult to assess whether the assumption of a reverberant field is conservative. Assuming a reverberant field may over-estimate the noise due to reflections, as it effectively models the partial enclosure as a fully enclosed space, which may result in a greater build-up of sound than is actually the case. Alternatively, assuming a reverberant field may under-estimate the noise due to reflections, as it may over-estimate the amount of sound energy that is being absorbed.

A comparison was undertaken of statistical theory with simple ray-tracing and image-source models. Both the ray-tracing and image-source models were basic and would not be more accurate than the reverberant field model. However, a comparison of the three models has provided an indication of the variation between approaches.

The comparison was for a partial enclosure having highly absorptive walls (α = 0.8). The ray-tracing model (constructed using ODEON room acoustics modelling software) gave a noise level for reflections that was less than that given by the reverberant field model. The image-source model (constructed in a spreadsheet) gave a noise level for reflections that was greater than that given by the reverberant field model.

This comparison indicated that the reverberant noise level calculated using classical statistical theory is similar to the noise level due to reflections calculated using ray-tracing and image-source models. However, the difference could be as much as ±3 dBA.

The ±3 dBA figure is likely to be a good estimate of the un-certainty in the noise level due to the semi-reverberant field in the partial enclosure. However, as discussed below, this com-ponent is significant compared to other components due to the near carriageway. Given that this is a critical component, it may be preferable to conservatively assume an uncertainty of ±5 dBA.

Modelling Partial Enclosures

Figure 2 shows the base configuration used in this study. Q1 and Q2 are the line noise sources corresponding to each car-riageway. Although dimensions are given, variations in the extent and height of the overhang were investigated. Note that Q is the symbol used in CRTN for traffic volume.

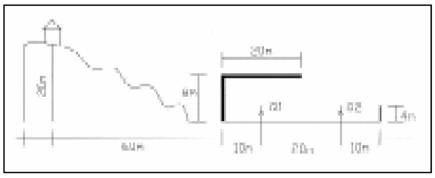

Figure 2

For clarity, it was assumed that only the near carriageway (Q1) is under the enclosure. In fact, the formula derived below can be modified easily to apply to a situation where both Q1 and Q2 are under the enclosure roof.

It has also been assumed that only Q1 contributes to the "re-verberant" field. This assumption can be justified on the basis that while it is true that some fraction of the sound from Q2 will enter the enclosure, it is also true that some fraction of the sound from Q1 would escape the enclosure without being reflected and hence without contributing to the 'reverberant' field.

Sound transmitted through the enclosure wall has been ne-glected.

The contributions to be considered are:

- Direct sound from the near

carriageway diffracted over the edge of the enclosure $L_{dir,1}$

- Direct sound from the far carriageway diffracted over the edge of the enclosure $L_{dir,2}$
- Reverberant sound from within the enclosure diffracted over the edge of the enclosure $L_{rev,1}$.

CRTN has algorithms for calculating distance effects, ground effects and – provided the sound path difference can be calculated – diffraction (barrier) effects. However, in this case, the sound path difference cannot always be calculated by the modelling software. Also, the reverberant field strength estimate is not a part of CRTN.

Table 2 lists the effects that must be calculated external to the software.

Contribution	Additional effects
$L_{dir,1}$	Diffraction over the edge of the enclosure
$L_{dir,2}$	No additional effects, provided the diffracting edge can be properly located
$L_{rev,1}$	Reverberant noise level; Diffraction of the reverberant noise over the edge of the enclosure

Table 2. Additional effects

It is proposed to model each of these contributions as an in-dividual line source and then sum the contributions to obtain the total noise level. In CRTN, the noise level at a reference distance (rBNL, say) of 13.5m is called the basic noise level (BNL).

Calculation method

It was decided that the simplest way to structure the calculation would be to calculate the various components outlined above and then logarithmically add them to obtain the total noise level. This approach could be implemented in noise modelling software, either at specific receiver locations or on a grid prior to deriving contours. This method would also provide good clarity, as the relative significance of the various components can be seen easily.

Calculation of the various components was undertaken in a spreadsheet using methods that could be implemented in noise modelling software. For comparison, the spreadsheet was also used to manually calculate the "actual" barrier effect by determining the actual sound path difference for the direct sound from the near carriageway.

Relative magnitude of the various components

Use of a partial enclosure will only be considered when sig-nificant noise reductions of at least (say) 15 dBA are required. At this level of attenuation, it was determined that direct diffracted noise from the far carriageway (Q_2) would dominate.

So, in practice, the sensible way to model the total noise level would be to optimise a barrier design based on the noise from the far carriageway alone and then examine how the noise from the near carriageway contributes. One approach using noise modelling software would be to:

- Turn on the far carriageway (and remove the near car-riageway)
- Decide on an enclosure height (say, 8 m)
- Locate the edge of the enclosure laterally as far from the far carriageway (i.e. reduce the amount of overhang) as possible without exceeding the relevant noise limit less some safety factor (say 2 dBA), and then
- Add in the effects due to noise from the near carriageway and check that the relevant noise limit is not exceeded.

Diffraction of direct sound from the near carriage-way

Diffraction of direct sound from the near carriageway could be estimated by manually calculating the actual sound path difference and entering the value into the CRTN barrier effect formula. However, such a method would be extremely difficult to implement in noise modelling software.

A number of methods were reviewed, one of which was to simply neglect this component. This method would be acceptable provided the extent of under-prediction of the total noise level could be estimated.

The manual spreadsheet calculation was used to compare the total direct noise level (i.e. not including the reverberant con-tribution) calculated using the actual sound path difference with the total noise level calculated by simply neglecting Ldir,1. The under-prediction due to neglecting $L_{dir,1}$ was estimated for a range of overhangs and (realistic) receiver positions.

It was found that the under-prediction was 0 to 2 dBA for a range of overhangs of 7 to 30 m, with an enclosure height of 8 m and the two carriageways located as in Figure 2.

Thus it was determined that a simple, conservative approach would be to neglect the direct diffracted component from the near carriageway and correct by adding 2 dBA to the result.

For the risk analysis, this correction to the total direct noise level L_{dir} has been modelled as a normally-distributed random variable having a mean value of 1 dBA with a 95% confidence interval of ±1 dBA.

Reverberant noise level

This section provides an outline of the derivation of the formula for the reverberant noise level. Note that the derivation has been simplified for clarity's sake. For example, the mean square pressure should be used rather than intensity and terms having the value 1 m^2 (such as w_{ref}/I_{ref}) have not been shown.

Let Q_1 be a line source of w_0 watts/m. Then the total sound power will be w_0L for an enclosure of length L.

If we ignore the ends of the enclosure and assume the noise source is on the ground, the noise will be radiating through a surface of area πrL at a distance of r from the source.

The sound intensity at a distance r would be:

$$I = \frac{w_0 L}{\pi r L} = \frac{w_0}{\pi r}$$

At the CRTN reference distance r_{BNL}, the intensity is

$$I_{BNL} = \frac{w_0}{\pi r_{BNL}}$$

$$\Rightarrow w_0 = \pi r_{BNL} I_{BNL}$$

$$\Rightarrow \frac{w_0 L}{w_{ref}} = \frac{\pi r_{BNL} I_{BNL} L}{w_{ref}}$$

$$\Rightarrow L_w = 10\log\left(\frac{\pi r_{BNL} I_{BNL} L}{w_{ref}}\right)$$

For a reverberant space

$$L_{Prev} = L_w + 10log\left(\frac{4}{R}\right)$$

$$\Rightarrow L_{Prev} = 10log\left(\frac{4\pi\pi_{BNL} I_{BNL} L}{Rw_{ref}}\right) \qquad (1)$$

$$\Rightarrow L_{Prev} = 10\log\left(\frac{I_{BNL}}{w_{ref}}\right) + 10\log\left(\frac{L}{R}\right) + 10\log(4\pi r_{BNL})$$

$$\Rightarrow L_{Prev} = BNL + 10\log\left(\frac{L}{R}\right) + 22 \qquad (2)$$

This gives the reverberant field level inside the partial enclosure.

In a reverberant-to-free-field situation, the sound power radi-ated by a surface of area S is

$$L_{w,rad} = L_{Prev} - 6 + 10log(S) - TL$$

For the case of sound exiting the partial enclosure via the opening, the transmission loss TL = 0. If we assume we can model the radiating area as a surface extending from the edge of the enclosure down to the road surface, then S = Lh where h is the height of the enclosure. This gives

$$L_{w,rad} = L_{Prev} - 6 + 10\log(Lh) \qquad (3)$$

We wish to model the radiated noise due to the reverberant field as a line source having a BNL of Lrad. If such a source has a sound power of wrad watts/metre, then we can define:

$$I_{rad} = \frac{w_{rad}}{\pi r_{BNL}}$$

Combining equations (1) and (3) gives:

$$10log\left(\frac{w_{rad}L}{w_{ref}}\right) = 10log\left(\frac{4\pi\pi_{BNL} I_{BNL} L}{Rw_{ref}}\right) - 6 + 10log(Lh$$

$$\Rightarrow 10log\left(\frac{I_{rad}\pi r_{BNL} L}{w_{ref}}\right)$$

$$= 10log\left(\frac{\pi r_{BNL} I_{BNL} L^2 h}{Rw_{ref}}\right)$$

$$\Rightarrow 10log\left(\frac{I_{rad}}{w_{ref}}\right) = 10log\left(\frac{I_{BNL} Lh}{Rw_{ref}}\right)$$

$$\Rightarrow L_{rad} = BNL + 10log\left(\frac{Lh}{R}\right)$$

where BNL is the BNL of the direct noise due to the left-hand carriageway.

Diffraction of the reverberant noise over the edge of the enclosure

Let D be the correction for diffraction of the reverberant noise around the edge of the enclosure. Note that this could also be considered as the directivity of a plane source facing away from the receiver. Then

$$L_{rev,1} = L_{rad} + D$$

This gives:

$$L_{rev,1} = BNL + 10log\left(\frac{Lh}{R}\right) + D$$

This formula can be entered into noise modelling software as a source having a traffic volume

$$Q_{rev} = \frac{Lh}{R} Q_1 \times 10^{\left(\frac{D}{10}\right)}$$

Q_{rev} is the traffic volume of a source line having an $L_{10,18hr}$ at 13.5 m (ie BNL) equal to the radiated noise level due to the reverberant field after diffraction around the edge of the partial enclosure. Thus, it should be located at the edge of the partial enclosure.

The speed and %HV for Qrev are as for Q_1.

Note that if both Q_1 and Q_2 are under the enclosure, this formula can still be used to calculate the reverberant component by setting Q_1 equal to the total two-way traffic volume.

Estimating D

The reverberant noise will not be

diffracted in the same way as the direct noise as it will be arriving at the edge of the enclosure from a variety of directions.

It is common practice in acoustics engineering to simply apply a directivity correction when calculating noise levels in a reverberant-to-free-field situation. A review of various engineering texts suggests that a correction in the range 10-15 dBA would be appropriate.

For the risk analysis, this correction has been modelled as a normally-distributed random variable having a mean value of 12 dBA with a 95% confidence interval of ±4 dBA.

Risk Analysis

The total noise level L_{Total} will be a combination of direct diffracted sound L_{dir} from the two carriageways and the reflected ("reverberant") sound from within the enclosure $L_{rev,1}$. As outlined in Table 2, a number of effects must be estimated. Table 3 provides further detail concerning the quantities that must be calculated in order to estimate the total noise level and shows which other quantities are relied on as part of the calculation. Also shown are the assumptions or approximations behind the calculation.

Quantity	Assumption or approximation	Quantities relied on
L_{Total}	See below	L_{dir}, $L_{rev,1}$
L_{dir}	That the direct noise from the near carriageway can be neglected provided that 1dBA (±1dBA) is added to the noise level from the far carriageway	$L_{dir,2}$
$L_{dir,1}$	Neglected	
$L_{dir,2}$	None	
$L_{rev,1}$	See below	L_{Prev}
		D
L_{Prev}	That the reflected noise can be modelled as reverberant noise	
D	That "reverberant" noise is reduced by 10-15dBA when it is diffracted around the edge of the enclosure	

Table 3. Calculation of the total noise level

Of course, the quantities used in a standard CRTN calculation are relied on, such as the traffic volume and traffic speed, but the uncertainties in these quantities are included in the overall uncertainties shown in Table 1.

The additional uncertainties due to the various assumptions and approximations shown in Table 3 have been quantified above. These are summarised in Table 4.

Quantity	Calculated using	95% confidence interval (dBA)
L_{dir}	$L_{dir,2}$ + 1	1
L_{Prev}	Equation (2)	5
D	Constant	4

Table 4. Additional uncertainties

Although L_{dir} has a narrow confidence interval, it is the most significant component and may significantly affect the overall uncertainty (i.e., the uncertainty in the estimate of L_{Total}). The following example illustrates how the uncertainties in Table 4 can affect the uncertainty in L_{Total}.

Example Calculations

Example 1 – Absorptive enclosure surfaces

Using the base configuration shown in Figure 2 and an assumed BNL of 80 dBA for each of the two carriageways, a reverberant noise level L_{Prev} of 83 dBA was found, despite assigning a reasonably high absorption coefficient (0.8 at mid-to-high frequencies) to the inside of the enclosure.

Table 5 shows the total noise level at the receiver, together with the various components.

Quantity	Near carriageway	Far carriageway
Basic Noise Level (BNL)	80	80
Direct diffracted component	43	55
Reverb diffracted component	48	
Sub-total	50	55
Total	56	

Table 5. Example calculation – absorptive enclosure

It can be seen that the noise from the far carriageway is dominant. Note also the diffracted reverberant component is the most significant component due to the near carriageway.

Using the values shown in Table 5, the effect on L_{Total} of the uncertainties shown in Table 4 is shown in Table 6.

Quantity	95% confidence interval (dBA)		SD (dBA)
	Quantity	L_{Total}	L_{Total}
L_{dir}	1	0.8	0.4
L_{Prev}	5	1.2	0.6
D	4	1.0	0.5

Table 6. Effect of uncertainties on L_{Total}

Note that even though the uncertainty in L_{Prev} and D is sig-nificant, the effect on L_{Total} is relatively minor. This is because, in this example at least, the direct noise is dominant. This can also be seen in the effect on L_{Total} of the uncertainty in L_{dir} – almost the whole of the 1 dBA uncertainty in L_{dir} has been carried over into L_{Total}.

The standard deviations shown in Table 6 are minor compared to the 2.7 dBA standard deviation for CRTN without a partial enclosure shown in Table 1. As standard deviations add in quadrature, the uncertainties shown in Table 6 do not significantly affect the overall uncertainty.

Example 2 – Reflective enclosure surfaces

Constructing the enclosure of concrete or a similarly reflective material would result in the noise levels shown in Table 7.

Quantity	Near carriageway	Far carriageway
Basic Noise Level (BNL)	80	80
Direct diffracted component	43	55
Reverb diffracted component	55	
Sub-total	55	55
Total	58	

Table 7. Example calculation – reflective enclosure

Note that the diffracted reverberant component is now more significant, but still not dominant.

Also, in Table 5, the total noise level is 1 dBA greater than the direct diffracted component due to the far carriageway alone, while in Table 7, it is 3 dBA greater. This suggests that a simple rule of thumb relating total noise level to the direct diffracted component due to the far carriageway: if the enclo-sure is absorptive, add 1 dBA; if it is reflective, add 3 dBA.

Using the values shown in Table 7, the effect on L_{Total} of the uncertainties shown in Table 4 is shown in Table 8.

Quantity	95% confidence interval (dBA)		SD (dBA)
	Quantity	L_{Total}	L_{Total}
L_{dir}	1	0.6	0.3
L_{Prev}	5	2.4	1.2
D	4	2.0	1.0

Table 8. Effect of uncertainties on L_{Total}

A comparison with Table 6 shows that the uncertainty in L_{Prev} and D is now more significant. Table 9 shows the risks of various degrees of under-design and over-design associated with this example calculation.

Extent of over-design	
Mean	SD
4.4dBA	3.1dBA
Risk of under-design	
By more than 1dBA	At all
4%	8%
Risk of over-design	
By more than 3dBA	By more than 6dBA
67%	30%

Table 9. Risks – reflective enclosure

A comparison with Table 1 shows that the risk of under-design has approximately doubled. However, this risk is still low. There is no significant difference in the risk of over-design.

Example 3 – Both carriageways below the overhang

For the case where both carriageways are under the enclosure overhang it is no longer possible to rely on the dominance of the noise from the far carriageway. Although such a configuration is unlikely to occur in practice, it is interesting to see what the implications are for the process outlined in this paper.

As discussed above, the equations derived above can be used to estimate the reverberant component in this situation, but it is likely that it will be necessary to estimate both of the direct diffracted components (rather than neglect the near carriage-way component).

However, assuming the effect of diffraction on the direct sound can be estimated, the resultant noise levels for the reflective enclosure situation would be similar to those shown in Table 10.

Note that the diffracted reverberant component is now clearly dominant. Using the values shown in Table 10, the effect on L_{Total} of the uncertainties shown in Table 4 is shown in Table 11.

The uncertainty in L_{Prev} and D is now significant. Table 12 shows the risks of various degrees of under-design and over-design associated with this example calculation.

Quantity	Near carriageway	Far carriageway
Basic Noise Level (BNL)	80	80
Direct diffracted component	43	50
Reverb diffracted component	58	
Sub-total	58	50
Total	58	

Table 10. Example – both carriageways below overhang

Quantity	95% confidence interval (dBA)	SD (dBA)
Quantity	L_{Total}	L_{Total}
L_{dir}	$0^{(1)}$	0	0
L_{Prev}	5	3.6	1.8
D	4	2.8	1.4

Note (1): it is assumed that no additional assumptions or approximations are required to estimate the direct component

Table 11. Effect of uncertainties on L_{Total}

Extent of over-design	
Mean	SD
4.4dBA	3.5dBA
Risk of under-design	
By more than 1dBA	At all
6%	11%
Risk of over-design	
By more than 3dBA	By more than 6dBA
65%	33%

Table 12. Risks – both carriageways below overhang

A comparison with Table 1 shows there is no significant difference in the risk of over-design. However, the risk of under-design has approximately tripled and may be even higher if estimation of the direct diffracted component requires additional assumptions or approximations.

While Marshall Day Acoustics has, in the past, undertaken noise barrier designs at risk levels higher than this with ac-ceptable outcomes, it may be desirable to add a safety factor to the total noise level to reduce the risk of under-design. Table 13 shows the risks if a 2 dBA safety factor is used.

Extent of over-design	
Mean	SD
6.4dBA	3.5dBA
Risk of under-design	
By more than 1dBA	At all
2%	4%
Risk of over-design	
By more than 3dBA	By more than 6dBA
83%	55%

Table 13. Risks – both carriageways below overhang – 2 dBA safety factor

A comparison with Table 1 shows that the risk of under-design has been restored to that of CRTN without a partial enclosure. However, the risk of over-design is somewhat higher.

Summary

A method for roughly estimating the noise level contribution due to reflected noise within a partial enclosure of a road has been developed based on statistical room acoustics theory.

The method suggests that the simplest design approach would be to simply neglect noise from within the enclosure (both direct and reflected) and add 1-3dBA to the direct diffracted noise from the far carriageway. For the case where only the near carriageway is under the enclosure overhang, the direct diffracted noise from the far carriageway can be calculated by noise-modelling software such as SoundPLAN providing the edge of the enclosure is correctly positioned.

For the case where both carriageways are below the overhang, the risks become significant, as the assumptions and approximations have a greater role in the estimation of the total noise level.

Symbols

BNL Basic noise level. Used in CRTN to define noise emission.

D Correction due to diffraction of reverberant noise over the edge of the enclosure. Assumed to be 12±4 dBA.

h Height of the enclosure.

L Length of the enclosure.

L_{dir} BNL of a line source having a noise emission level equal to the direct noise from both carriageways, corrected for diffraction over the edge of the enclosure.

$L_{dir,1}$ BNL of a line source having a noise emission level equal to the direct noise from the near carriageway, corrected for diffraction over the edge of the enclosure.

$L_{dir,2}$ BNL of a line source having a noise emission level equal to the direct noise from the far carriageway, corrected for diffraction over the edge of the enclosure.

$L_{rev,1}$ BNL of a line source having a noise emission level equal to the reverberant noise from the near car-riageway, corrected for diffraction over the edge of the enclosure.

L_{Prev} BNL of a line source having a noise emission level equal to the reverberant noise level within the enclosure.

L_{rad} BNL of a line source having a noise emission level equal to the reverberant noise radiated from the enclosure.

L_{Total} Total noise level due to all components.

Q_1 Traffic volume on the near carriageway.

Q_2 Traffic volume on the far carriageway.

R Room constant.

r_{BNL} CRTN reference distance of 13.5m.

TL Transmission loss.

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NOISE CONTROL IN ACTION...

A Noise Control Officer appeared before St. Peter at the Pearly Gates.

“Have you ever done anything of particular merit?” St. Peter asked.

“Well, I can think of one thing,” the man offered. “Once, while working in the suburbs of Auckland, I came upon a group of boy racers, who were creating unacceptable levels of noise and upsetting the neighbourhood. I directed them to stop their racket, but they wouldn’t listen.

So, I approached the largest and most heavily tattooed amongst them, and smacked him in his face, kicked his car door in, ripped out his nose ring, and threw it on the ground. I yelled, “Now, cut that noise out!! Or I’ll kick the CRAP out of all of you!”

St. Peter was impressed, “When did this happen?”

“Just a couple of minutes ago...”