

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

The simplest solution seemed to be to assume that a reverberant field is present. The simplicity of the statistical reverberant noise level formula

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

makes it desirable to use in this application. However, its use introduces a level of risk additional to the usual risks associated with CRTN.

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.



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Figure 1

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 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 Victorian State Road Authority, VicRoads (summarized in Austroads 2002). This is the only study in Australia that examined the accuracy of CRTN at actual residences. Most measurement 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 4.4dBA on average with a standard deviation of 2.7dBA. In other words, CRTN had an average extent of over-design of 4.4dBA with an uncertainty of ± 5.4 dBA. The 5.4dBA 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.

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.

Table 1. Risks associated with use of CRTN

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%

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 1dBA higher than predicted noise levels 2% of the time
- Measured noise levels can be expected to be at least 3dBA lower than predicted noise levels 70% of the time
- Measured noise levels can be expected to be at least 6dBA 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 underestimate 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 ($\alpha = 0.8$). 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 uncertainty in the noise level due to the semi-reverberant field in the partial enclosure. However, as discussed below, this component 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. Q_1 and Q_2 are the line noise sources corresponding to each carriageway. 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.

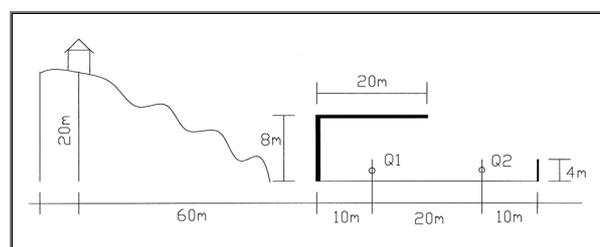


Figure 2

For clarity, it was assumed that only the near carriageway (Q_1) is under the enclosure. In fact, the formula derived below can be modified easily to apply to a situation where both Q_1 and Q_2 are under the enclosure roof.

It has also been assumed that only Q_1 contributes to the "reverberant" field. This assumption can be justified on the basis that while it is true that some fraction of the sound from Q_2 will enter the enclosure, it is also true that some fraction of the sound from Q_1 would escape the enclosure without

being reflected and hence without contributing to the ‘reverberant’ field.

Sound transmitted through the enclosure wall has been neglected.

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.

Table 2. Additional effects

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

It is proposed to model each of these contributions as an individual line source and then sum the contributions to obtain the total noise level. In CRTN, the noise level at a reference distance (r_{BNL} , 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 significant noise reductions of at least (say) 15dBA 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 carriageway)
- Decide on an enclosure height (say, 8m)
- 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 2dBA), 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 carriageway

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 contribution) calculated using the actual sound path difference with the total noise level calculated by simply neglecting $L_{dir,1}$. 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 2dBA for a range of overhangs of 7 to 30m, with an enclosure height of 8m 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 2dBA 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 1dBA 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 $1m^2$ (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

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

$$\Rightarrow L_{P_{rev}} = 10 \log \left(\frac{4 \pi r_{BNL} I_{BNL} L}{R w_{ref}} \right) \quad (1)$$

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

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

This gives the reverberant field level inside the partial enclosure.

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

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

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

$$L_{w,rad} = L_{P_{rev}} - 6 + 10 \log(Lh) \quad (3)$$

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

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

Combining equations (1) and (3) gives:

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

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

$$\Rightarrow 10 \log \left(\frac{I_{rad}}{w_{ref}} \right) = 10 \log \left(\frac{I_{BNL} L h}{R w_{ref}} \right)$$

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

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:

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

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 13.5m (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 Q_{rev} 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 10-15dBA would be appropriate.

For the risk analysis, this correction has been modelled as a normally-distributed random variable having a mean value of 12dBA 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.

Table 3. Calculation of the total noise level

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 (± 1 dBA) 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	

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.

Table 4. Additional uncertainties

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

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 80dBA for each of the two carriageways, a reverberant noise level L_{Prev} of 83dBA 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.

Table 5. Example calculation – absorptive enclosure

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	

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.

Table 6. Effect of uncertainties on L_{Total}

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

Note that even though the uncertainty in L_{Prev} and D is significant, 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 1dBA uncertainty in L_{dir} has been carried over into L_{Total} .

The standard deviations shown in Table 6 are minor compared to the 2.7dBA 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.

Table 7. Example calculation – reflective enclosure

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	

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

Also, in Table 5, the total noise level is 1dBA greater than the direct diffracted component due to the far carriageway alone, while in Table 7, it is 3dBA 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 enclosure is absorptive, add 1dBA; if it is reflective, add 3dBA.

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

Table 8. Effect of uncertainties on L_{Total}

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

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.

Table 9. Risks – reflective enclosure

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%

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 carriageway 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.

Table 10. Example – both carriageways below overhang

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	

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.

Table 11. Effect of uncertainties on L_{Total}

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

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.

Table 12. Risks – both carriageways below overhang

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%

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 acceptable 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 2dBA safety factor is used.

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

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%

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 carriageway, 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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