Proceedings of 20th International Congress on Acoustics, ICA 2010

23-27 August 2010, Sydney, Australia

Directivity of the CoRTN road traffic noise model

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PACS: 43.50.Lj

ABSTRACT

When predicting noise emissions from a road utilising the CoRTN model, including as implemented in SoundPlan software, unexpectedly high noise results can occur due to a receiver located on the outside of a curved section of road. This can impact on traffic noise barrier designs, and may result in unnecessarily high traffic noise barriers for a potentially unintended consequence of the CoRTN model. Reducing the search radius from the default distance in the SoundPlan calculation module can result in a significant decrease in the noise level predicted for these receivers. This paper presents a brief overview of the implementation of the CoRTN model and the results of measurements undertaken on vehicles travelling at 100 km/hr. It seeks to determine the difference in sound power level between cars travelling head-on versus side-on relative to a receiver. Furthermore, the results were used to determine an appropriate search radius to use when implementing the CoRTN model in SoundPlan software.

INTRODUCTION

The purpose of the study was to identify the directivity pattern of a vehicle travelling at 100 km/hr in order to verify the CoRTN acoustic model for a large road project that was being undertaken by AECOM's acoustic practice (Bassett Acoustics at the time).

Predictions using the CoRTN model were indicating that receivers located on the outside of a curved section of road were experiencing unexpectedly high noise results. This would vary significantly by altering the search radius utilised for the calculation (in SoundPlan the search radius determines the noise sources to be included in the calculation, in this case the road line segments, based on the radial distance from the receiver). This can impact on traffic noise barrier designs, and may result in unnecessarily high traffic noise barriers for a potentially unintended consequence of the CoRTN model. Therefore we were seeking to determine the directivity pattern of a vehicle travelling at 100 km/hr to compare noise emissions between vehicles travelling head-on versus side-on. At this stage the study has only seeked to determine if the effect is real, and if so determine an appropriate search radius to utilise for the calculations.

The directivity study was undertaken on a section of road in a semi-rural location near Mallala, South Australia. Three different vehicles were utilised for the study, these being (test vehicle images are presented in the appendix):

- 2001 Toyota Landcruiser Utility (4.2 litre turbocharged diesel)
- 1997 Mitsubishi Lancer (1.8 litre petrol)
- 2009 Holden Colorado (3.0 litre turbocharged diesel)

CORTN AND MODELLING RESULTS

In Australia, traffic noise predictions are generally carried out in accordance with the United Kingdom, Department of Environment / Transport (UKDOE), Welsh Office HMSO, 'Calculation of Road Traffic Noise' (CoRTN) manual published 1988. This method is an updated version of the 1975 version method.

CoRTN was issued in the UK as a means to standardise the assessment of entitlements under the "Noise Insulation Regulations". The method uses a series of charts and equations to apply corrections to a base noise emission level for different situations. The CoRTN model has been accepted by many regulatory authorities in Australia as the basic model to be used for the prediction of traffic noise and the design of acoustic barriers, with industry accepted corrections for "Australian conditions" generally applied.

CoRTN implements a segment–by–segment calculation method for each road segment input. Calculation of propagation is undertaken by applying the following corrections to the base noise emission level:

- Distance correction
- Ground attenuation
- View angle correction
- Screening
- Reflection correction.

For the purpose of this investigation, the ground attenuation has been set to soft ground, and the screening and reflection corrections not included.

Figure 1 shows a grid noise output at 1.2 metres above ground level from SoundPlan for a basic CoRTN model for a flat road, which was input with:

- 12 000 vehicles for the 18 hour period 6am to 10pm
- no commercial vehicles
- 100 km/hr speed limit
- no road surface corrections (i.e. Dense Graded Asphalt).

The output (18 hour L_{10}) demonstrates the “beaming” characteristics of the CoRTN propagation model (“beaming” refers to the directivity where there is a distinct increase in emission levels directly in front of the road line segment). This is due to the fact that CoRTN uses the shortest perpendicular distance to the road segment in conjunction with the view angle correction. Where the receiver is in front of the road segment, the CoRTN model extends the road segment with an imaginary line to calculate the shortest perpendicular distance.

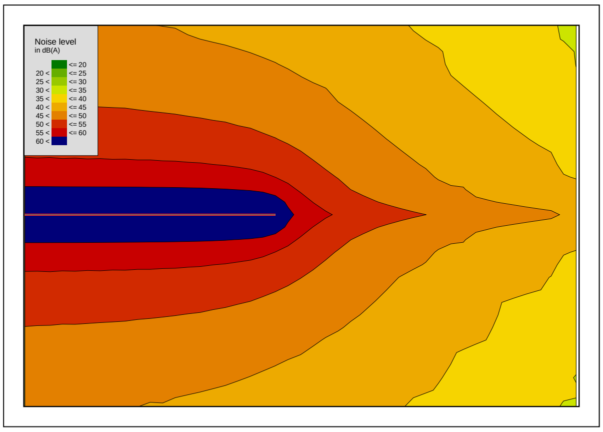

Figure 1. Output from basic CoRTN model

This output does not appear logical when considering a typical line source, which propagates more like a point source as the distance increases from the source. Figure 2 presents the grid noise output at 1.2 metres above ground level from SoundPlan for a line source. The line source output is an L_{eq} (note that this is not calibrated).

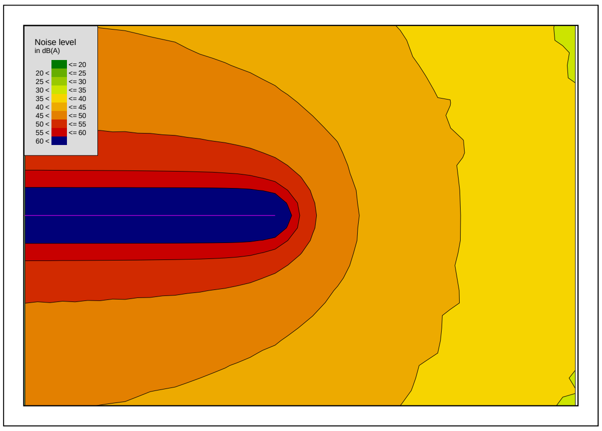

Figure 2. Output from basic line source model

The US Federal Highway Model FHWA model was also utilised to determine the grid noise output at 1.2 metres above ground level from SoundPlan for a flat road, which was input with:

- 12 000 vehicles for a 24 hour period
- no commercial vehicles
- 100 km/hr speed limit
- dense graded asphaltic concrete (DGAC) road surface.

The FHWA model output is a 24 hour L_{eq}. The results, presented in Figure 3, show a similar result to the CoRTN output.

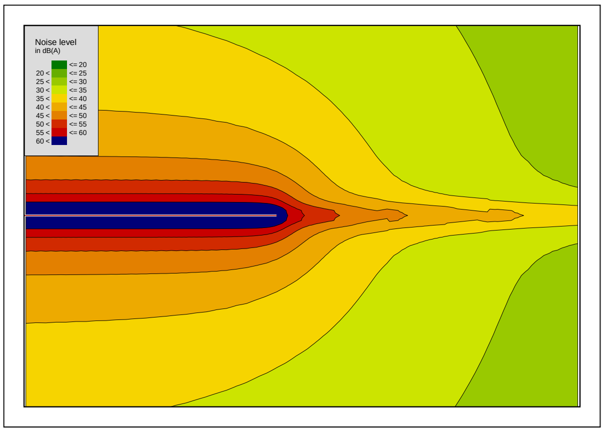

Figure 3. Output from basic FHWA model

TESTING METHODOLOGY

The testing was aimed at determining whether vehicle noise emissions behave more like the CoRTN and FHWA models as shown in Figures 1 and 3 or more like a line source as shown in Figure 2.

Site conditions

The directivity study was undertaken on a section of road which runs north–south, near Mallala, South Australia. This section of road was chosen as it is sealed, straight, and was not influenced by significant background noise. The test road surface was continuous “spray seal” bitumen.

The land adjacent to the road was agricultural on either side, with vast areas of grain crop. There were no houses, solid fences, or any other obvious objects that may have influenced the measurements anywhere near the road.

Weather conditions

Meteorological conditions for the time of the testing were obtained from the closest weather station at Roseworthy, approximately 25–30 km south-east from the test location.

For the initial testing, the temperature varied between 21–22°C and the wind was a light breeze (approximately 2–4 m/s) from a south–westerly direction.

For the additional testing, the temperature was 11°C and the wind was a light breeze (approximately 1 m/s) from a northerly direction.

Initial pass-by testing

The testing was undertaken between 1.00 am and 2.30 am. Background noise in the area at the time was very low i.e. less than 20 dB(A).

The testing was initially undertaken with the 2001 Toyota Landcruiser Utility and the 1997 Mitsubishi Lancer. The testing was conducted with two sound level meters situated at a 6 metre and 50 metre sideline distance from the centreline of the road. The sound level meters were set up to continuously record the equivalent noise level at 1 second intervals.

Each test vehicle drove past the test location at a constant speed of 100 km/hr, for a total distance of 4 km (2 km either side of the test location). The test vehicle then turned around and drove back past from the other direction. This process was repeated again so that each vehicle drove past the test location a total of four times (two times from each direction). The test vehicle drove on the centreline of the road so that the distance to the sound level meters was the same for each pass-by direction.

Six pass-bys were then obtained with two vehicles driving past the test location together. The two vehicles were spaced by approximately two–three car lengths, with the Landcruiser leading for three of the pass-bys and the Lancer leading for the following three pass-bys.

Additional pass-by testing

Additional testing was undertaken between 12.30 am and 1.30 am. Background noise in the area at the time again, was very low i.e. less than 20 dB(A).

Additional testing was undertaken following the analysis and review of the initial results. Based on the results of the initial testing, it was determined that only one vehicle was required for the additional testing, this being the 2010 Holden Colorado. The same procedure was used as that for the initial testing.

The purpose of the additional testing was to:

- Reduce the sample rate time period from 1 second to 0.1 seconds to increase the number of data points for the determination of the sound power level vs angle
- Include an additional receiver at a 300 metre sideline distance from the centreline of the road to gain a better understanding of what is happening at greater distances from the road.

TESTING RESULTS

Initial pass-by testing

The time trace of the vehicle pass-bys are presented in Figures 4 and 5. The traces have been averaged for each vehicle and each direction. Figure 4 presents the pass-bys for the sound level meter at the 6 metre sideline distance, and Figure 5 presents the pass-bys for the 50 metre sideline distance. The “North” and “South” presented in the legends of each figure represents the direction from which the vehicle is travelling.

The sound pressure level vs time plots do not show significant variation between each vehicle. In addition, the results for two vehicles do not show a significant difference to one. The greatest variation is a result of the wind direction, which can be seen in the groupings for each pass-by direction.

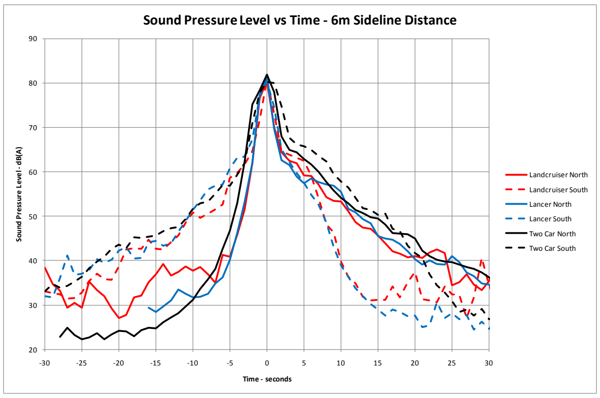

Figure 4. SPL vs time for 6 m sideline distance

The sound power level, which was calculated using geometric spreading, has been plotted against the angle to the vehicle, where the line projected directly in front of the vehicle is 0° and the line directly behind is 180°. The results are presented in Figures 6 and 7.

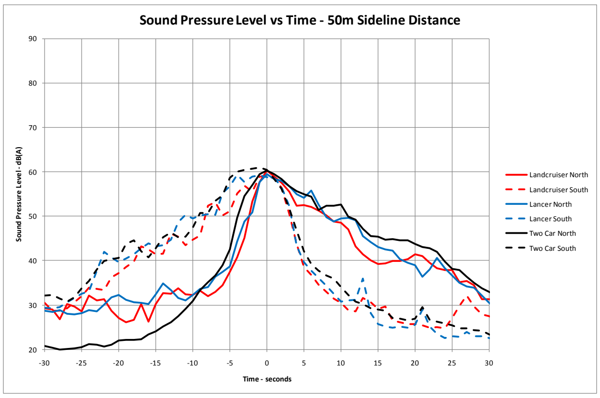

Figure 5. SPL vs time for 50 m sideline distance

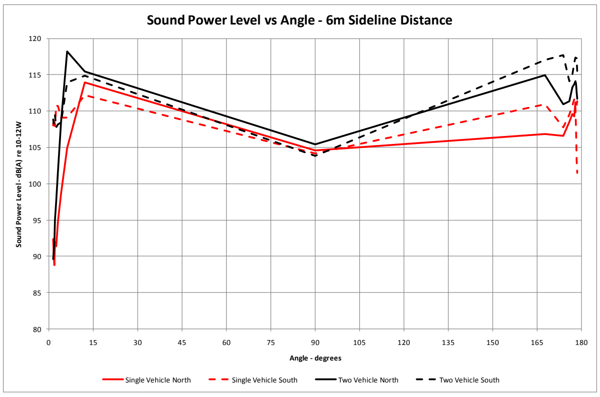

Figure 6. Sound power vs angle for 6 m sideline distance

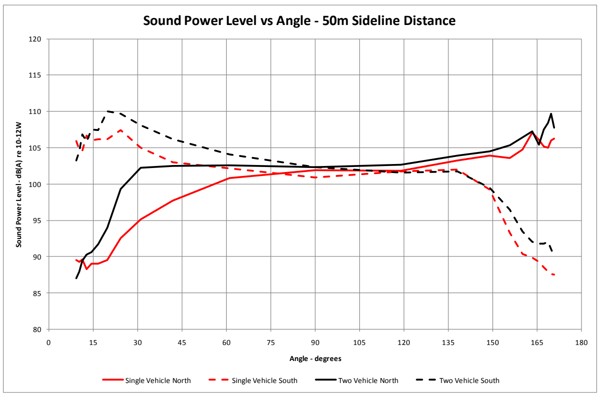

Figure 7. Sound power vs angle for 50 m sideline distance

Due to the sampling period being one second, there are very few data points around 90°. However, the results at the 6 metre sideline distance show distinct beaming, which is not heavily influenced by the direction of the wind. The results at the 50 metre sideline distance do exhibit beaming characteristics; however the influence of the wind can be seen close to 0° and 180° when the vehicle is downwind of the measurement location. This is due to the larger distances (and greater meteorological effects) involved at these angles, and also the effects of soft ground which are not present for the 6 metre sideline distance.

The total sound energy (SEL) is shown against the radial distance from the measurement location in Figure 8. An indication of an appropriate search radius that could be used when modelling traffic noise, in programs such as SoundPlan, can be determined by reading off the radial distance at which the limit of sound energy is reached. Based on Figure 8, this would be approximately 300 metres for receivers within 50 metres of the road corridor; beyond this distance the additional energy added is less than 0.2 dB(A).

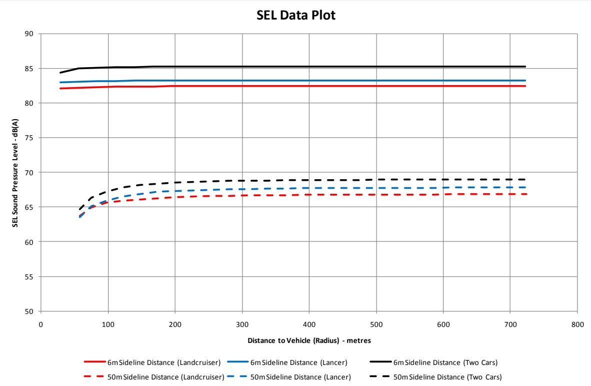

Figure 8. Sound energy vs distance

Additional pass-by testing

The additional testing was undertaken with one vehicle near the original test location on the same stretch of road. The purpose of this testing was to introduce an additional receiver at a 300 metre sideline distance and to increase the sampling rate so that the sound power level vs angle plot has better resolution around 90°. The sound pressure level vs time plots are presented for all sideline distances in Figure 9.

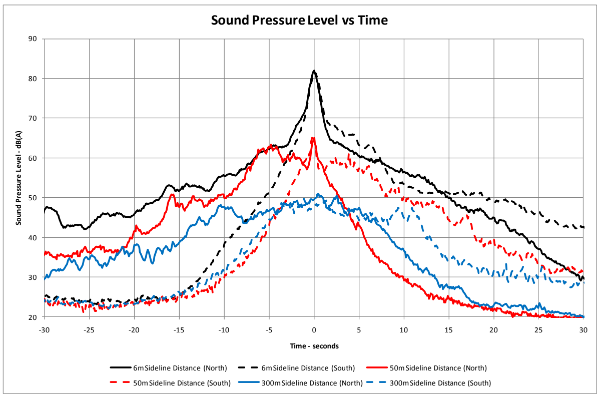

Figure 9. SPL vs time for all sideline distances

The updated sound power level vs angle plots are presented for the 6 metre, 50 metre and 300 metre sideline distances in Figures 10, 11 and 12 respectively.

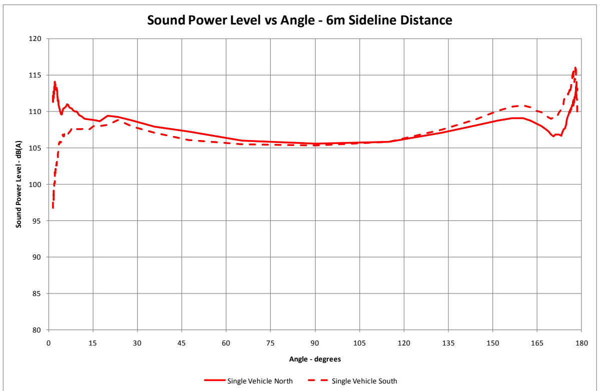

Figure 10. Sound power vs angle for 6 m sideline distance

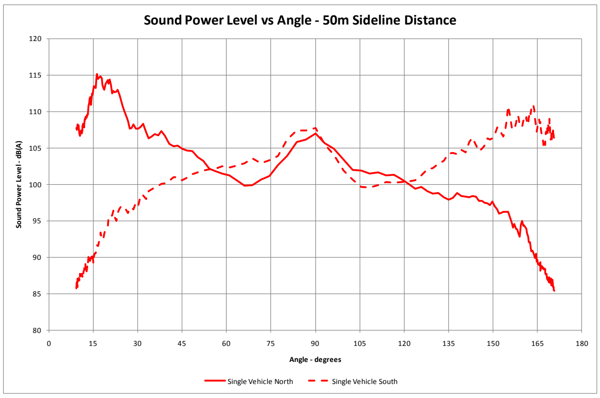

Figure 11. Sound power vs angle for 50 m sideline distance

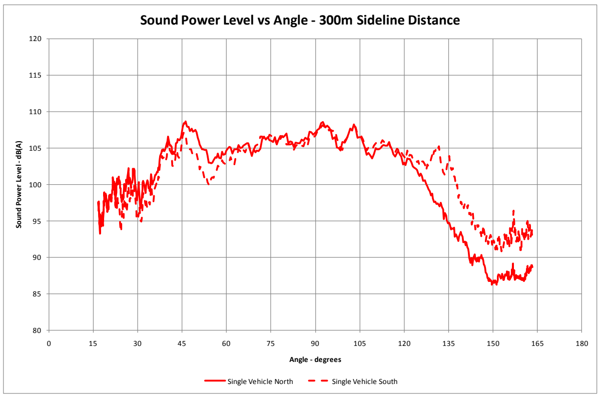

Figure 12. Sound power vs angle for 300 m sideline distance

The results for the 6 metre and 50 metre sideline distances are similar to the initial testing results; however the following anomalies are noted:

- For the 6 metre sideline distance there is a significant difference in sound power level near 0° for the north and south directions, however this is not observed at 180°.
- For the 50 metre sideline distance there is a distinct rise in sound power level between 75° and 105°.

At this stage, the reason for the anomaly at the 6 metre side-line distance is unknown to the author; however this result does not adversely impact on the purpose of this study.

The anomality at the 50 metre sideline distance is thought to be due to shielding provided by the roadside embankment between 30°–75° and 105°–150°; hence there is not a rise in sound power level at 90°, rather a perceived reduction either side of it.

The results at the 300 metre sideline distance do not exhibit any significant beaming characteristics. The slight rise at 45° is most likely due to the meteorological conditions.

Figure 13 presents the data used in Figure 10 as a polar plot to assist with providing a visual comparison of the sound power level vs angle to the CoRTN and FHWA models as shown in Figures 1 and 3. This clearly demonstrates the "beaming" directivity of the vehicle noise emissions.

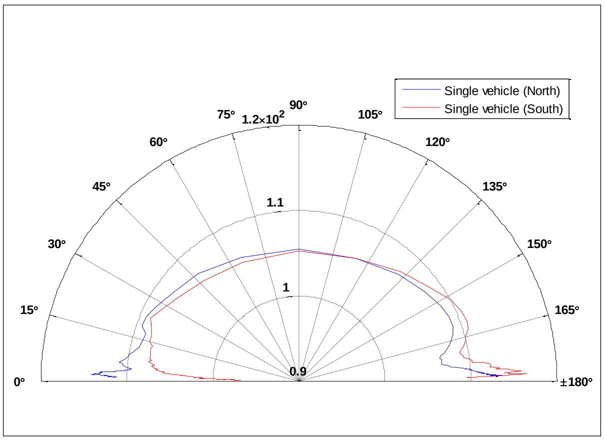

Figure 13. Sound power vs angle for 6 m sideline distance

Figure 14 presents the results of the sound energy against radial distance for each of the sideline measurements.

Results from the additional testing are similar to the initial testing. Based on Figure 14, an appropriate search radius to use when modelling road traffic noise would be approximately 300 metres for receivers within 50 metres of the road corridor, and 500 metres for receivers located within 300 metres of the road corridor. Once again, beyond this distance the additional energy added is less than 0.2 dB(A). These results suggest a significantly lower search radius than the default value of 5 000 metres provided in SoundPlan software.

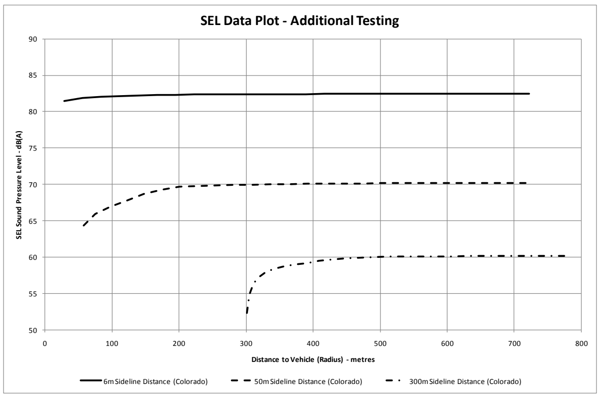

Figure 14. Sound energy vs distance

CONCLUSION

The purpose of this study was to determine whether the increase in noise emission levels directly in front of the road line segment (beaming) was observed, which it appears to be, and if so determine what may be an appropriate search radius to use when modelling a road. The directivity and sound energy results have been compared to the graphical CoRTN and FHWA outputs from SoundPlan.

Whilst a logical result appears to have been obtained for an appropriate search radius, future work is required to compare the measured results on a curved section of road against a calibrated noise model.

REFERENCES

Braunstein + Berndt GmbH / SoundPLAN LLC *SoundPLAN User's Manual* (2007)

United Kingdom, Department of Transport (UKDOE), Welsh Office HMSO, *Calculation of Road Traffic Noise* (1988)

APPENDIX

Figure 15. 2001 Toyota Landcruiser Utility

Figure 16. 2001 Toyota Landcruiser Utility Tyre

Figure 17. 1997 Mitsubishi Lancer

Figure 18. 1997 Mitsubishi Lancer Tyre

Figure 19. 2009 Holden Colorado

Figure 20. 2009 Holden Colorado Tyre