Acoustics 2019
Sound Decisions: Moving forward with Acoustics

Investigation of uniform and non-uniform traffic distribution on road traffic noise prediction for multi-lane roadways

Nic Hall (1), Jeffrey Peng (2), Jeffrey Parnell (3) and John Wassermann (1)

(1) Wilkinson Murray, Australia
(2) Transport for NSW, Australia
(3) Department of Planning, Industry and Environment, Australia

ABSTRACT

Road traffic noise prediction is routinely undertaken as part of environmental impact assessments to assist government planning authorities to understand the potential noise impact that could arise from proposed road infrastructure development projects. Typically, road traffic noise models developed in New South Wales detail all lanes of a roadway and assume uniform distribution of traffic volume and vehicle mix across the lanes of each carriageway. In this work, the effects of uniform and non-uniform traffic distribution on road traffic noise prediction for multi-lane roadways are investigated. Models with all lanes detailed are compared to simplified two-lane models for a range of receiver setback distances and shielding arrangements.

1 INTRODUCTION

Road traffic noise prediction is routinely undertaken as part of environmental impact assessments to assist government planning authorities in understanding the potential impacts that could arise from proposed infrastructure development projects (Steele, 2001; Peng et al., 2017). There are a number of traffic noise prediction models in current use, however the UK's Calculation of Road Traffic Noise (CoRTN) is the most widely used calculation procedure in Australia (Peng et al., 2019). According to the CoRTN manual (UK DoT, 1988), traffic noise emission levels from most urban roads can be computed by aggregating the traffic flow in both travel directions. However, in cases where the carriageways are separated by more than 5 metres, or where the heights of the outer edges of the two carriageways differ by more than 1 metre, traffic noise emission levels should be evaluated separately, allowing the ability to take into account the bi-directional traffic distribution.

The measured or predicted classified distribution of vehicles across multi-lane roadways is generally unavailable, particularly for a new or redeveloped roadway. Moreover, when it is available, it is found to vary widely across multiple-lane roads depending on traffic regulation, traffic composition, speed and hourly volume, the number of and location of access points, the origin-destination patterns of drivers, and local driver habits (TRB, 2000; Duret et al., 2012). Because of these aforementioned factors, there is no typical lane distribution. However, the common practice in New South Wales (NSW) is to model all lanes individually with either the detailed traffic information, or more commonly, by assuming uniform distribution of traffic volume and vehicle mix.

In providing guidance on the US Federal Highway Administration Traffic Noise Model (TNM), Bajdek et al. (2015) investigated best practices for dividing traffic volumes and vehicle mixes across roadways with multiple lanes for uniform and non-uniform lane distributions. In this US study, three cross-sectional geometries corresponding to at-grade, depressed and elevated roadways were evaluated. Differences between uniform and non-uniform lane distributions were found to be negligible at most distance setback from the roadway. The greatest discrepancy of up to 1.2 dB occurred at a distance of 50 feet (15.2 metres) from the nearest travel lane of an elevated roadway. The extent of discrepancy was found to increase relative to the increase in the percentage of heavy vehicles, which was assumed to be due to the contribution of truck exhaust noise emission. However, while the TNM model is known to over-represent the energy distribution at the elevated exhaust source height (Donovan and Janello, 2017) and its sound propagation model is fundamentally different to CoRTN (Steele, 2001), it was unknown if this assumption applied to CoRTN. For the Australian context, it is necessary to understand the prediction performance of CoRTN under uniform and non-uniform lane distributions to inform pragmatic and robust guidance. In this work, the effects of non-uniform and uniform traffic distributions on CoRTN road traffic noise prediction for 4-

lane and 6-lane dual carriageway roads are investigated under shielded and non-shield situations. Computed results for individual and aggregated lanes are compared.

2 ROAD AND TRAFFIC SCENARIOS EXAMINED

To examine the influence that traffic distribution has on noise predictions, a number of scenarios were selected from the broad range of distributions found on the NSW road network.

2.1 Road Scenarios

The road scenarios evaluated in this study represent road configurations commonly encountered, including:

Motorway	6 lanes - 3 lanes in each carriageway;
Motorway / Highway	4 lanes - 2 lanes in each carriageway;
Arterial Road	6 lanes - 3 lanes in each carriageway;
Arterial Road	4 lanes - 2 lanes in each carriageway;
Country Highway	4 lanes - 2 lanes in each carriageway; and
Country Highway	4 lanes - 2 lanes in each carriageway with high percentage of heavy vehicles.

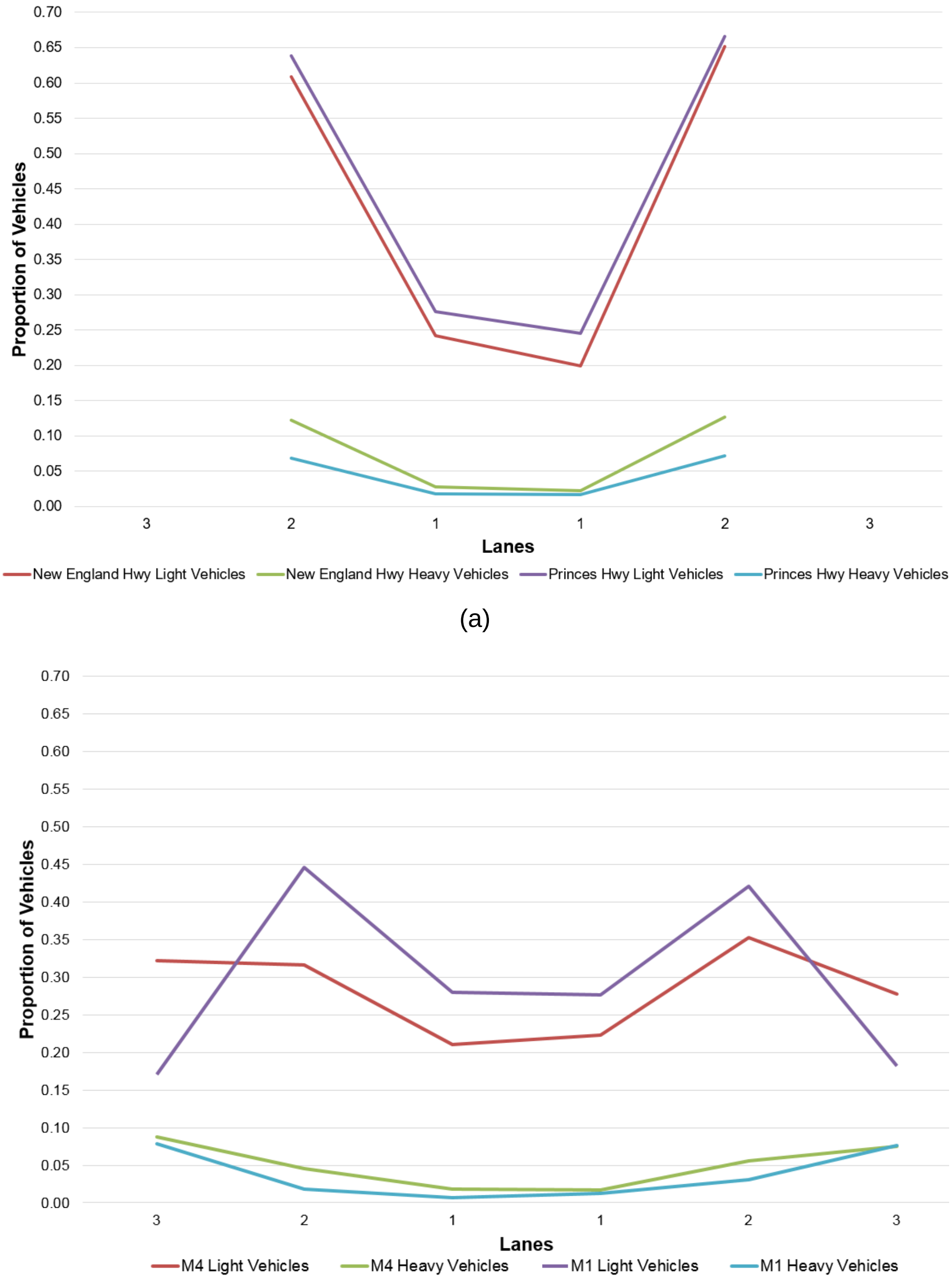
2.2 Traffic Scenarios

Table 1 presents a selection of traffic distributions, for light vehicles (LV) and heavy vehicles (HV), obtained from RMS's weigh-in-motion stations as a percentage of the average daily traffic (ADT) for the road configurations described in Section 2.1. The traffic distribution data for examples of 6-lane and 4-lane dual carriageway roads are also visually depicted in Figure 1.

Table 1: Measured vehicle distributions across lanes

Identifier	Broad vehicle type	Vehicle volume across each lane as a percentage of ADT					
		Direction (to)			Direction (from)		
		3	2	1	1	2	3
Warringah Road Arterial (Forestville)	LV	13.4%	18.3%	15.1%	12.9%	21.0%	14.0%
	HV	0.9%	1.1%	0.5%	0.9%	1.2%	0.5%
M4 Motorway (Eastern Creek)	LV	16.2%	16.0%	10.6%	11.0%	17.5%	13.8%
	HV	4.4%	2.3%	0.9%	0.9%	2.8%	3.7%
M1 Motorway (Cowan)	LV	8.5%	22.2%	14.0%	13.9%	21.1%	9.1%
	HV	3.9%	0.9%	0.3%	0.6%	1.6%	3.9%
M7 Motorway (Prestons)	LV	-	23.3%	16.2%	16.2%	24.0%	-
	HV	-	5.9%	3.9%	2.8%	7.7%	-
Hume Highway (Holbrook)	LV	-	30.9%	3.6%	4.6%	30.0%	-
	HV	-	13.7%	0.5%	0.7%	15.9%	-
Pennant Hills Road Arterial (Nth Parramatta)	LV	-	19.8%	27.0%	23.2%	22.6%	-
	HV	-	2.1%	1.6%	2.7%	0.9%	-

There are three interesting features that can be observed from the traffic distribution data presented in Table 1. Firstly, an even distribution of traffic across all lanes was not present on all roads examined. Secondly, on controlled access motorways and rural highways, the majority of vehicles travelled in the slow lanes, particularly heavy vehicles. Lastly, heavy vehicles tend to preference the middle lane (lane 2) on a 6-lane road (or median lane (lane 1) on a 4-lane road) when there are bus stops, side roads or direct driveway access from the kerbside lane. The graphical representations of two 6-lane, and two 4-lane roads in Figure 1 provide examples of the asymmetric distribution of heavy and light vehicles across lanes and carriageways of some NSW roads.



(a)

(b)

Figure 1: Proportion of light and heavy vehicles distributed across examples of 4-lane (a) and 6-lane (b) roads

3 NOISE MODELLING METHODOLOGY

To understand how CoRTN performs under the uniform and non-uniform distribution of light and heavy vehicles, a series of modelling exercises were undertaken to test the range of scenarios encountered on the NSW road network. The methodology used in this paper closely followed that adopted by Bajdek, et al. (2015), but modified for Australian inputs of road design and traffic mix. This common methodology allowed the comparison of roads of differing numbers of lanes and differing percentages of heavy vehicles by assessing predicted noise levels at a range of setback distances. To investigate the effect of shielding and breaking the line-of-sight, the height of the road relative to receivers was varied and included a depressed roadway, an elevated roadway and an at-grade roadway. The following describes the key variables that were examined.

3.1 Roads

Two functional road designs covering three examples were chosen to be examined:

- 4-lane dual carriageway
  - Eg. Metropolitan Highway similar to the M1 Waterfall to Wollongong Freeway with 15% Heavy vehicles;
- 4-lane dual carriageway
  - Eg. Country Highway where high percentage of trucks similar to the Hume Highway with 30% Heavy vehicles; and
- 6-lane dual carriageway
  - Eg. Metropolitan Motorway similar to the M2 Freeway with 12% Heavy vehicles.

3.2 Predictive Model

Noise levels from the proposed road designs were calculated using procedures based on the CoRTN (Calculation of Road Traffic Noise) (UK DoT, 1988) prediction algorithms. The standard prediction procedures were modified as follows:

- L_{eq} values were calculated from the L_{10} values predicted by the CoRTN algorithms using the well-validated approximation $L_{eq,1hour} = L_{10,1hour} - 3$ dB (NSW EPA, 2011). It is worth noting the predicted $L_{eq,1hour}$ is equivalent to the $L_{eq,period}$ as required by the noise criteria since the input is the “average” traffic flow per hour over the given daytime and night time periods.
- Noise source heights were set at 0.5 metres for cars, 1.5 metres for heavy vehicle engines and 3.6 metres for heavy vehicle exhausts, representative of typical values for Australian vehicles. Acoustic energy was assigned consistent with that recommended in Appendix B of the *Interim Road Noise Policy* (RTA, 1992).

3.3 Road Geometry

The road geometry was based on those presented in the *Recommended Best Practices for the Use of the FHWA Traffic Noise Model* (Bajdek et al., 2015), with some minor modifications to adopt SI units. Four cross-sectional geometries for each scenario were modelled, namely:

- roadway at-grade (Refer to Figure 2 for the 6-lane scenario);
- roadway at-grade with 4.0 metre barrier (Refer to Figure 2 for the 6-lane scenario);
- elevated roadway (6 metre above grade) (Refer to Figure 3 for the 6-lane scenario); and
- depressed roadway (6 metres below grade) (Refer to Figure 3 for the 6-lane scenario).

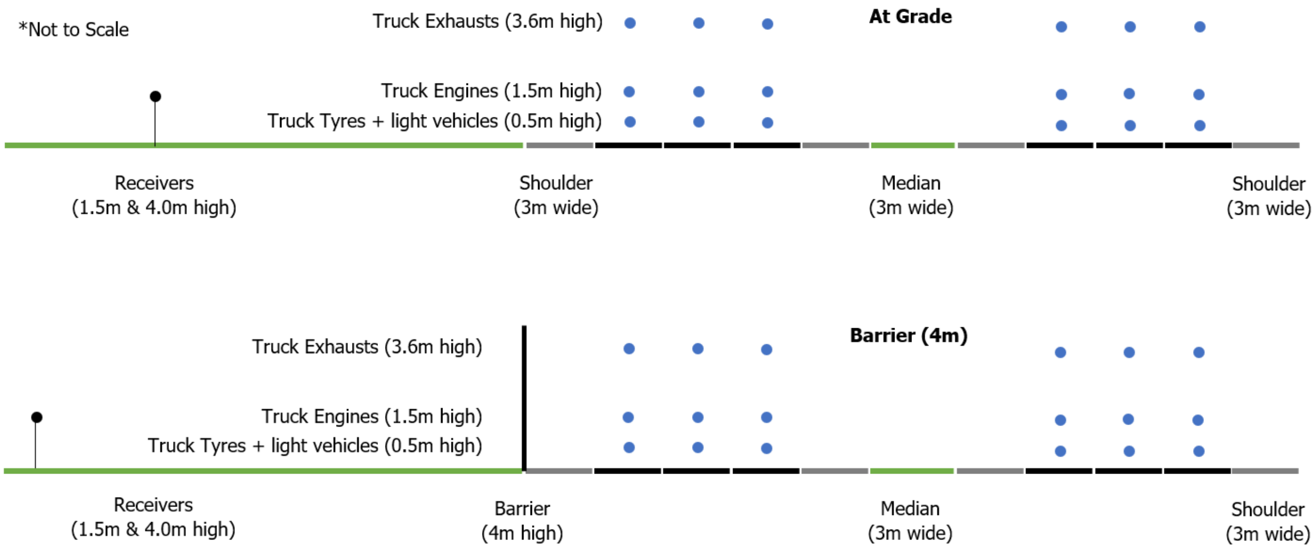


Figure 2: Cross Section of 3 lane at-grade and barrier noise model

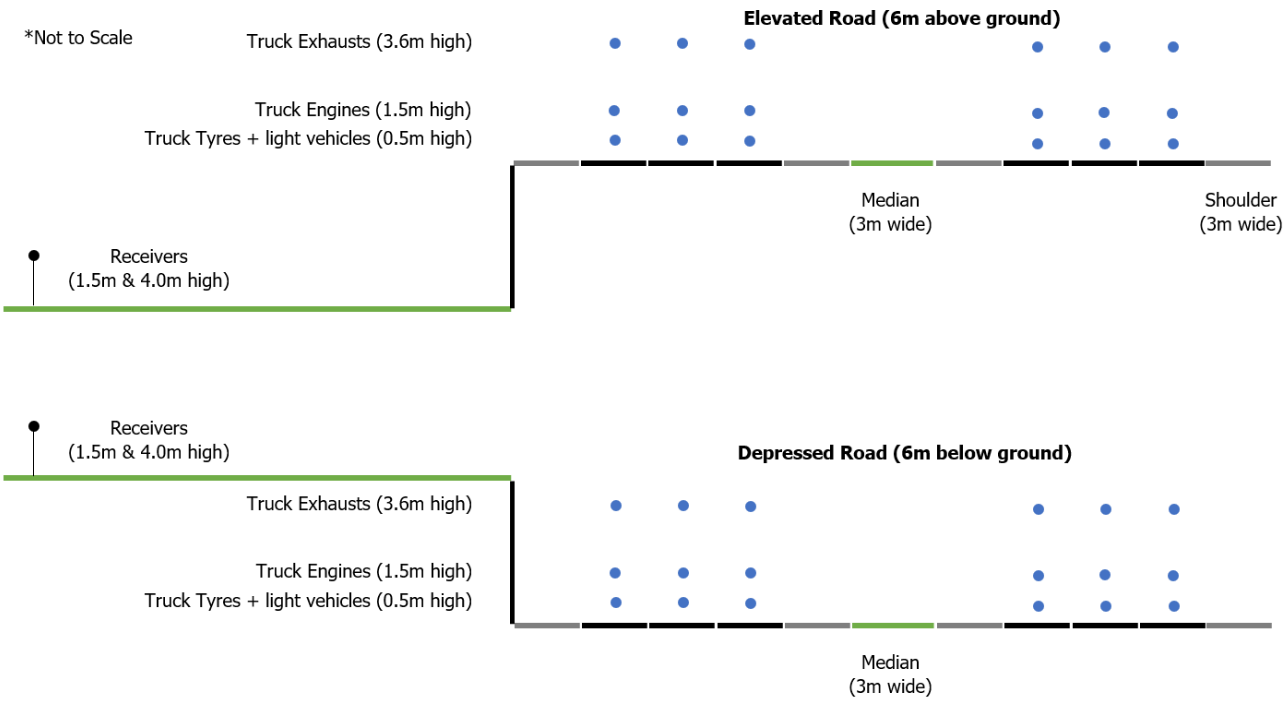
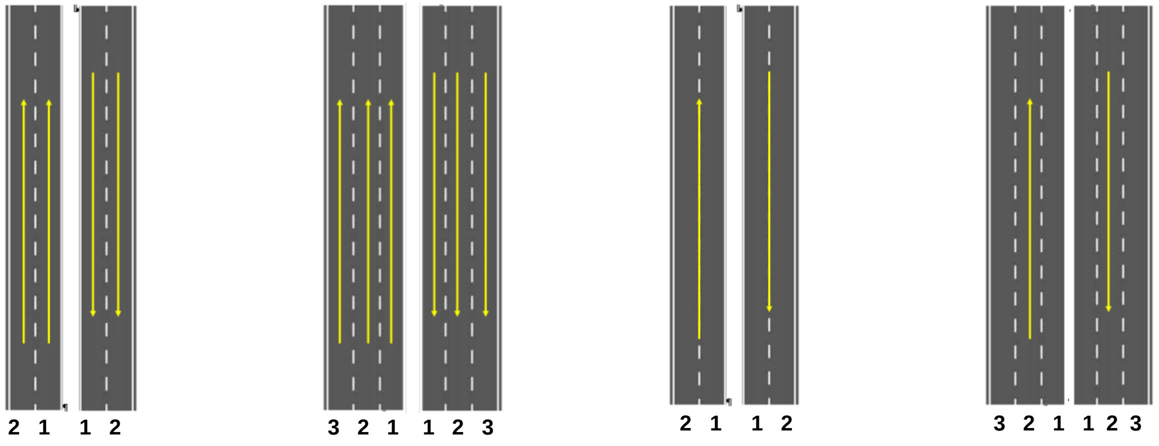


Figure 3: Cross Section of 3 lane elevated road and depressed road noise model

3.4 Noise Source Location and Distribution

Three methods for the allocations of sound power sources to a roadway were modelled in this study. One method involved modelling an individual line source in the middle of each lane (see Figure 4(a)) and with uniform distribution of sound power per lane ie. 50% each of 2 lanes or 33% each of 3 lanes in each carriagway. Another method involved modelling a single line source in the middle of the carriageway and represent the aggregated sound power of all lanes in that carriageway (see Figure 4(b)). The final method involved modelling an individual line source in the middle of each lane (see Figure 4(a)) and with non-uniform distribution of sound power per lane consistent with the traffic distributions described in Section 3.5.



(a)

(b)

Figure 4: All lanes assigned a line source (a) and each carriageway assigned a line source (b)

3.5 Non-Uniform Distribution

The modelling of non-uniform traffic distributions was based on measured traffic distributions from a range of road categories representative of the NSW road network. Whilst the actual traffic distributions were measured, to eliminate the asymmetric nature of traffic in each carriageway, the characteristics of the North Bound Carriagway were duplicated to the South Bound Carriageway in each instance. The distribution of traffic to each modelled roadway is given in Table 2 to Table 4.).

Table 2: Scenario 1, Metropolitan Highway, Modelled traffic distribution,

4-lane highway with 15% heavy vehicles

	Vehicle volume across each lane as a percentage of ADT			
Lane	2	1	1	2
% Cars	24	18.5	18.5	24
% Trucks	5	2,5	2.55	5
% Total Traffic	29	21	21	29

Table 3: Scenario 2, Country Highway, Modelled traffic distribution,

4-lane highway with high % heavy vehicles of 30%

	Vehicle volume across each lane as a percentage of ADT			
Lane	2	1	1	2
% Cars	31.5	3.5	3.5	31.5
% Trucks	14	1	1	14
% Total Traffic	45.5	4.5	4.5	45.5

Table 4: Scenario 3, Metropolitan Motorway, Modelled traffic distribution,

6-lane motorway with 12% heavy vehicles

	Vehicle volume across each lane as a percentage of ADT					
Lane	3	2	1	1	2	3
% Cars	12.5	19	12.5	12.5	19	12.5
% Trucks	4	1.5	0.5	0.5	1.5	4
% Total Traffic	16.5	20.5	13	13	20.5	16.5

3.6 Additional Modelling Inputs

- 1,000 metre long roadway segment with zero-percent grade;
- 3.5 metres lanes, 3 metre shoulders, and a 3 metre median;
- Uniform speeds across all travel lanes;
- Equal traffic volume, vehicle mix and lane distribution for each direction;
- Receivers for each cross-section geometry at 7.5, 10, 15, 30, 60, 90 and 120 metres from centerline of near lane of travel;
- Two different receiver heights: 1.5 and 4.0 metres above ground level, corresponding to the minimum and equivalent heights adopted in the *Environmental Noise Directive 2002/49/EC (EC, 2002);*
- Ground type ground factor of 50% over residential areas;
- Uniform speeds across all travel lanes (100km/h);
- Road surfaces - +0 dB Asphalt;
- No façade correction; and
- The model was implemented using CADNA 2019 using CoRTN Australia (NSW).

4 DIFFERENCE IN CALCULATED NOISE LEVELS BETWEEN NON-UNIFORM AND UNIFORM LANE DISTRIBUTIONS

Tables 5 to 10 summarise the difference in CoRTN calculated sound levels between non-uniform traffic distribution and uniform traffic distribution for multi-source and single-source approaches. In what follows, Section 4.1 first describes the results for a 4-lane motorway with 15% heavy vehicles across the range of the cross-sectional geometries, source modelling approaches as well as at different receiver heights. Subsequently, Section 4.2 reports on the results for a 4-lane highway with the percentage of heavy vehicles increased to 30% and lane distribution modified. In Section 4.3, the results corresponding to a 6-lane motorway with 12% heavy vehicles are then evaluated.

4.1 4-Lane Metropolitan Highway (15% Heavy Vehicles)

Tables 5 and 6 respectiviely present the results for a 4-lane Metropolitan Highway with 15% heavy vehicles at receiver heights of 1.5 metres and 4 metres above ground. From Table 5, it can be seen that the difference in calculated noise levels between non-unform and uniform traffic distributions is generally zero across all cross-sectional geometries considered when the receiver height is set at 1.5 metres and distance setback from the road is greater than 15 metres from the centreline of the near lane of travel. When the setback distance is more than 15 metres, the difference in calculated noise levels between non-uniform and uniform traffic distributions is negligible with the exception of the elevated road configuration, in which noise levels calculated based on a non-uniform distribution of traffic across each lane are found to be higher than those of uniform distribution by up to 0.3 dB. Compared to the multi-lane approach with uniform traffic distribution, the difference in noise levels for the single-source approach (in each direction of travel) is found only up to 0.2 dB higher for the elevated road configuration (on fill) and up to 0.5 dB lower for the depressed road configuration (in cut). When the receiver height is increased from 1.5 metres to 4.0 metres (see Table 6), the extent of under- and over-prediction relative to the multi-lane approach with non-uniform traffic distribution is shown to reduce marginally by up to 0.4 dB.

Table 5: Difference in dB noise levels at 1.5 m receiver height between non-uniform and uniform traffic distributions for a 4-Lane Metropolitan Highway carrying 15% heavy vehicles

Receiver Distance (m)	At-grade		Barrier (4m)		Elevated Road (6m)		Depressed Road (6m)	
	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single
7.5	0.1	0.3	0.1	0.1	0.2	0.4	0.0	-0.5
10	0.1	0.2	0.1	0.1	0.2	0.3	-0.1	-0.4
15	0.1	0.1	0.0	0.0	0.3	0.5	0.0	0.0
30	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0
60	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 6: Difference in dB noise levels at 4.0 m receiver height between non-uniform and uniform traffic distributions for a 4-Lane Metropolitan Highway carrying 15% heavy vehicles

Receiver Distance (m)	At-grade		Barrier (4m)		Elevated Road (6m)		Depressed Road (6m)	
	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single
7.5	0.1	0.2	0.0	0.0	0.2	0.3	0.1	0.1
10	0.0	0.1	0.0	0.0	0.2	0.4	0.0	0.1
15	0.1	0.1	-0.1	0.0	0.2	0.4	-0.1	-0.2
30	0.1	0.1	-0.1	0.0	0.1	0.1	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.2 4-Lane Country Highway (30% Heavy Vehicles)

In contrast to the results reported in Tables 5 and 6 for the 4-lane motorway with 15% heavy vehicles, Tables 7 and 8 respectively present the results for a 4-lane highway with 30% heavy vehicles at receiver heights of 1.5 metres and 4 metres above ground to draw special attention to the influence of heavy vehicle percentage. When the percentage of heavy vehicles is increased to 30% and when more heavy vehicles are allocated to the kerbside lanes, the difference in noise levels between non-uniform and uniform traffic distributions increases marginally for cross-sectional geometries corresponding to at-grade, barrier and elevated road. Additionally, the extent of over-prediction in the case of the depressed road configuration is higher compared to the results reported in Tables 5 and 6 for the 4-lane motorway with 15% heavy vehicles.

Table 7: Difference in dB noise levels at 1.5 metres receiver height between non-uniform and uniform traffic distributions for a 4-Lane Country Highway carrying 30% heavy vehicles

Receiver Distance (m)	At-grade		Barrier (4m)		Elevated Road (6m)		Depressed Road (6m)	
	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single
7.5	0.5	0.6	0.3	0.3	0.6	0.8	-0.2	-0.6
10	0.4	0.5	0.1	0.1	0.6	0.8	-0.2	-0.5
15	0.2	0.3	0.1	0.1	0.8	1.0	-0.2	-0.1
30	0.1	0.2	0.0	0.0	0.5	0.4	-0.1	0.0
60	0.1	0.1	0.0	0.0	0.3	0.3	0.0	0.0
90	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

Table 8: Difference in dB noise levels at 4.0 metres receiver height between non-uniform and uniform traffic distributions for a 4-Lane Country Highway carrying 30% heavy vehicles

Receiver Distance (m)	At-grade		Barrier (4m)		Elevated Road (6m)		Depressed Road (6m)	
	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single
7.5	0.3	0.4	0.1	0.1	0.6	0.8	0.2	0.2
10	0.3	0.4	0.0	0.0	0.6	0.8	0.0	0.0
15	0.3	0.3	0.0	0.0	0.7	0.8	-0.5	-0.5
30	0.1	0.1	0.0	0.0	0.4	0.4	-0.1	-0.1
60	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0
90	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.3 6-Lane Metropolitan Motorway (12% Heavy Vehicles)

Tables 9 and 10 respectively present the results for a 6-lane motorway with 12% heavy vehicles at receiver heights of 1.5 metres and 4 metres above ground. For this scenario, the majority of the heavy vehicles are located in the kerbside lanes whereas light vehicles are normally distributed around the middle lane as seen in Table 4. Similar to the previous sections, it can be seen in Tables 9 and 10 that the difference in calculated noise levels between non-unform and uniform traffic distributions is generally zero across all cross-sectional geometries considered when the distance from the centreline of the near lane of travel to the receiver is greater than 15 metres. Similarly, the greatest discrepancy also occurred for the elevated road configuration at distances less than 30 metres from the centreline of the near lane of travel.

Table 9: Difference in dB noise levels at 1.5 metres receiver height between non-uniform and uniform traffic distributions for a 6-Lane Metropolitan Motorway carrying 12% heavy vehicles

Receiver Distance (m)	At-grade		Barrier (4m)		Elevated Road (6m)		Depressed Road (6m)	
	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single
7.5	0.3	0.6	0.1	0.2	0.3	0.6	0	-0.4
10	0.2	0.4	0.1	0.2	0.4	0.7	-0.2	-0.3
15	0.2	0.3	0.0	0.0	0.5	0.9	-0.2	-0.2
30	0.0	0.1	0.0	0.0	0.4	0.6	0.0	-0.1
60	0.0	0.1	0.0	0.0	0.2	0.3	0.0	0.0
90	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 10: Difference in dB noise levels at 4.0 metres receiver height between non-uniform and uniform traffic distributions for a 6-Lane Metropolitan Motorway carrying 12% heavy vehicles

Receiver Distance (m)	At-grade		Barrier (4m)		Elevated Road (6m)		Depressed Road (6m)	
	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single	Multi-lane	Single
7.5	0.2	0.4	0.1	0.1	0.4	0.7	0.1	0.2
10	0.2	0.3	0.0	0.0	0.5	0.8	0.0	0.0
15	0.2	0.2	0.0	0.0	0.5	0.8	-0.3	-0.3
30	0.1	0.1	0.0	0.0	0.2	0.4	-0.1	-0.2
60	0.0	0.0	0.0	0.0	0.1	0.2	-0.1	-0.1
90	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

5 DISCUSSION

In comparison to the non-uniform scenarios, the uniform assignment of traffic distribution across all lanes results in no difference, or under-prediction of road traffic noise levels at all receivers except those adjoining a depressed roadway. For depressed roadways, the discrepancy in predicted noise levels between non-uniform and uniform traffic distribution can be attributed to lane preference of traffic, particularly heavy vehicles, to travel in the slower lanes. Slower lanes are the most shielded when a roadway is depressed. Thus, applying a uniform distribution of traffic across all lanes will assign more vehicles, particularly heavy vehicles, to the more exposed faster lanes, which in turn, will result in higher noise levels being predicted than will actually occur. For elevated road configurations, the uniform assignment of traffic across lanes has the effect of moving traffic away from the kerbside land and receiver than would occur on a normally functioning road, which in turn increases the effect of shielding on road traffic noise. Further, heavy vehicles are much noisier than passenger vehicles and they tend to travel predominantly in the slower lanes closer to the kerb. Therefore, any actions which reassign them to other lanes will have a greater impact than moving lighter vehicles. The magnitude of these departures from the measured non-uniform scenarios becomes negligible beyond 30 metres with differences being 0.2 dB or less.

The current study has investigated the effects of using uniform and non-uniform traffic distribution on road traffic noise prediction by using CoRTN (NSW) instead of FHWA-TNM in a prior investigation by Bajdek et al. (2015). The current study also utilised different traffic inputs, and whilst the Australian and American studies cannot be compared numerically, the methodologies and conclusions are qualitatively similar. Additionally, whilst both studies predicted noise levels close to the roadway (7.5 metres in this study and 25 feet in the Bajdek study), Bajdek et al. (2015) did not report these results, justifying the decision by stating a receiver setback distance of 7.5 metres is very difficult to find in real-world scenario. This comment is also applicable to the present study, and caution should be exercised with the interpretation of any near field predictions.

With respect to the common practice in NSW where light vehicles and heavy vehicles are distributed uniformly across each lane of a multi-lane roadway, the current investigation has identified situations where the model can be regressed to the original guidance given in the CoRTN manual, in which only a single source line is used to represent each carriageway. The findings indicate that, when only uniform traffic distribution is available, single lane and multi-lane approaches resulted in virtually identical predicted noise levels across all receiver distances and roadside configurations considered. However, modelling each individual lane assuming uniform traffic distribution can still be useful in providing incremental improvements to the model's prediction performance, particularly when receivers are located in close proximity to the road, or where the roadway is elevated or depressed.

6 CONCLUSIONS

The CoRTN model was utilised as the basis of investigation to study the effects of lane distribution on predicted noise levels. The difference in noise levels between uniform and non-uniform traffic distribution were reported for various road configurations corresponding to at-grade road with and without barrier, as well as elevated and depressed roads. Models that utilised non-uniform distribution of traffic generally resulted in marginally higher predicted noise levels than models that used uniform distribution with the exception of depressed roadways. The study also found that noise levels predicted from the approach that assigns uniform distribution of light and heavy vehicles across multiple lanes resulted in reasonably similar levels compared to only modelling a single source line for each carriageway. This work highlights, when traffic distribution is unavailable, there is no discernible benefit from undertaking detailed lane-by-lane road traffic noise modelling, particularly when receiver locations are situated more than 30 metres from the nearside carriageway. These findings are consistent with that reported by Bajdek et al. (2015) in the best practice guideline for FHWA TNM.

ACKNOWLEDGEMENTS

Any opinions expressed are those of the authors, and do not necessarily reflect those of the New South Wales State Government.

REFERENCES

Bajdek C., Menge C., Mazur R. A., Pate A., Schroeder J., 2015. *Recommended Best Practices for the Use of the FHWA Traffic Noise Model (TNM, TNM Object Input, Noise Barrier Optimization, and Quality Assurance Final Report — December 8, 2015*. Federal Highway Administration Office of Planning, Environment, & Realty.

European Commission, 2002. European Noise Directive 2002/49/EC of the European Parliament and of the Council, of 25 June 2002, relating to the assessment and management of environmental noise.

Donovan P., Janello C., 2017. '*Mapping heavy vehicle noise source heights for highway noise analysis'*. Transport Research Board, National Academy of Sciences, NCHRP 842, Washington, DC.

Duret A., Ahn S., Buisson C., 2012. 'Lane flow distribution on a three-lane freeway: General features and the effects of traffic controls'. *Transportation Research* Part C 24: 157-167. https://doi.org/10.1016/j.trc.2012.02.009.

Environment Protection Authority, 2011. *Road Noise Policy*. The Government of New South Wales, Sydney, Australia.

Roads and Traffic Authority, 1992. '*Environmental Manual:Interim Traffic Noise Policy*'. The Government of New South Wales, Sydney, Australia.

Peng J., Kessissoglou N., Parnell J., 2017. '*Evaluation of Calculation of Road Traffic Noise in Australia*'. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings* (Vol. 255, No. 1, pp. 6025-6036). Institute of Noise Control Engineering.

Peng J., Parnell J., Kessissoglou N., 2019. 'A six-category heavy vehicle noise emission model in free-flowing condition'. *Applied. Acoustics* 143: 211–221. https://doi.org/10.1016/j.apacoust.2018.08.030.

Steele C., 2001. 'A critical review of some traffic noise prediction models'. *Applied Acoustics* 62 (3): 271-287. https://doi.org/10.1016/S0003-682X(00)00030-X.

Transportation Research Board, 2000. '*Highway Capacity Manual*'. The National Academy of Sciences, ISBN 0-309-06681-6.

UK Department of Transport. 1988. *Calculation of Road Traffic Noise*. UK DoT Welsh Office, UK.