Limit of predicted road noise emissions due to traffic constraints

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ABSTRACT

There is a limit to the number of vehicles that can travel on a road section per hour. As the traffic numbers increase, the traffic speeds decrease. In Queensland, road traffic noise emissions are based on the Calculation of Road Traffic Noise method (CoRTN). This method is dependent on both traffic volumes and speed, among other parameters. This paper presents a method for determining the upper limit of noise emissions from a road string, based on the CoRTN method. It is shown that there is point where due to the higher traffic volumes, there is a reduction of vehicle speed, causing the calculated noise emissions to decrease. These results have implications for the mitigation requirements for high traffic volume roads.

INTRODUCTION

The question was raised during a major road project by the project management team: “How much noise can come from a road.” The inference being that if the absolute maximum possible noise emissions were known, then the maximum noise mitigation requirements could be calculated, and the costs associated with such mitigation measures could be included in early design risk management strategies.

This question prompted a study aiming to determine the maximum amount of noise that a road can generate. The two defining factors being the number of vehicles on the road, and the speed at which the vehicles are travelling.

This paper considers how the speed of the traffic is limited by the number of vehicles on the road, and what affect this has on the noise emissions of that road.

Limits of the study

A few limits were placed on the study:

1. The calculation of the noise emissions would be based on the CoRTN method as published in *The prediction of noise levels L_{10} due to road traffic noise*, M.E. Delany et al, 1976.

2. The study would only consider noise from the normal use of the road. That is, it would not include engine braking noise, horns, excessive braking noise (skidding), loud car audio systems, etc.

3. The posted speed of the road segment under consideration would be 100km/h.

4. A single, free-flowing lane would be assessed

Current practice

It is standard practice in Queensland for the road noise emission calculations to be based on the posted speed of the road segment. This is based on the assumption of the normal use of the road, as the vehicles should not be travelling at higher speeds than those posted.

Assessment concept

The assessment method of this study is based on the number of cars passing a point during a period of time, in a single lane.

As an example, assume that all cars are 4.9m long (which is the length of a Holden Commodore). The maximum number of vehicles that can pass a point in one hour, on one lane, if they are bumper to bumper, and travelling at 100km/hr, is 20 571.

This is clearly a ludicrous situation (although it would be interesting to see a “Commodore Train” hurtling down the highway), however it does presents the absolute upper bound on the number of vehicles that can pass a point in one hour on a single lane. This figure cannot be exceeded.

Traffic volume verse speed

Discussions with road traffic modellers lead to the document entitled “Guide to Traffic Engineering Practice – Part 2: Road Capacity” (the Guide). This document, published by Austroads, is part of a series that form the basis of road traffic modelling in Australia.

The Guide proceeds to define the speeds at which vehicles will travel under certain traffic volume conditions. Table 5.1 from the Guide are reproduced below in Table 1. The design speed is required to be 10km/hr greater than the posted speed, so the relevant data from Table 1 is found in the column titled Design Speed 110km/hr.

Table 1: Reproduction of Table 5.1 from the Guide

Table 5.1 Level of Service Criteria for Basic Freeway Segments

Level of Service	Density	Design Speed 110 km/h			Design Speed 100 km/h			Design Speed 80 km/h		
	pc/km/lane	Speed[a] km/h	v/c[b]	MSF[c]	Speed km/h	v/c	MSF	Speed km/h	v/c	MSF
A	≤ 7.5	≥ 96	0.35	-	-	-	-	-	-	-
B	≤ 12.5	≥ 91	0.54	1,100	≥ 80	0.49	1,000	-	-	-
C	≤ 18.8	≥ 86	0.77	1,550	≥ 75	0.69	1,400	≥ 69	0.67	1,300
D	≤ 26.3	≥ 74	0.93	1,850	≥ 67	0.84	1,700	≤ 64	0.83	1,600
E	≤ 41.9	≥ 48	1.00	2,000	≥ 48	1.00	2,000	≥ 45	1.00	1,900
F	> 41.9	< 48	d	d	< 48	d	d	< 45	d	d

a. Average travel speed.
b. Volume/capacity ratio.
c. Maximum rate of service flow per lane under ideal conditions, rounded to the nearest 50pc/h/lane.
d. Highly variable.

Source : Adapted from TRB (1985) Table 3.1.

Source: (Austroads: 1999)
MSF = vehicles per hour past a point.

The first column of Table 1 uses a general descriptor "Level of service." For a detailed explaination refer to the Austroads document *Guide to Traffic Engineering Practice, Part 2.* A simple description of each level of service follows.

Level of service A is considered a free flowing road in which drivers are practically unaffected by other vehicles on the road.

Level of service B is considered a stable flowing road and drivers have considerable freedom within the traffic stream.

Level of service C is also a stable flow, however, speeds and manurverability are limited and the 'comfort and convenience' of the road decreases significantly.

Level of service D is close to the breakdown of stable flow. Speed and manuverability are serverly restricted.

Level of service E is unstable flow with no room to manuver and a high restriction on speed.

Level of service F is a breakdown of flow causing stop-start traffic, queuing and delays.

Using the values presented in Table 1 we can derive an equation to calculate the speed of the traffic for a particulare traffic volume. With a bit of exponential curve fitting we arrive at Equation 1:

$$v = a \times \exp(bx) + c \times \exp(dx) \tag{1}$$

Where:

v = traffic speed

x = traffic volume

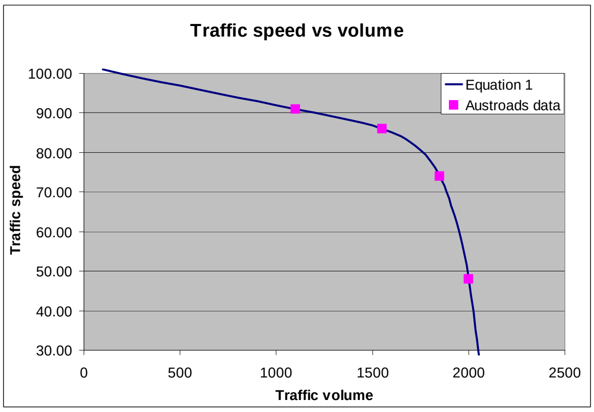
a = -2.665 E-06

b = 0.008194

c = 102

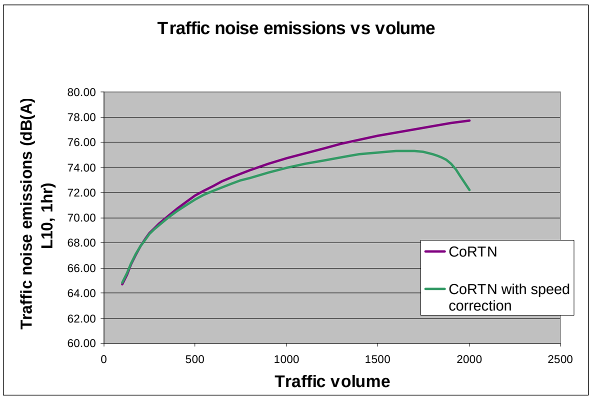
d = -0.0001036

Graph 1 below shows the accuracy of the equation



Graph 1: Comparison of Equation 1 and Austroads data

Using a reference distance of 10m, the 1 hour noise emissions based on the CoRTN method are shown in Graph 2 for the non-speed corrected, and speed corrected values for the range of traffic volumes.



Graph 2: Traffic noise emissions vs Traffic volume

From Graph 2, two observations can be made:

1. There is a greater difference between the speed corrected and the non-speed corrected noise emissions calculations at higher traffic volumes.

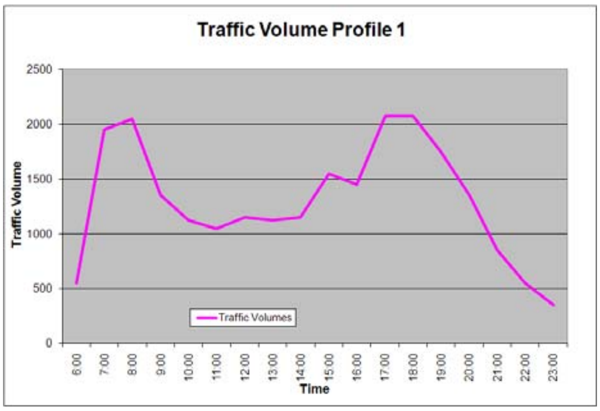
2. According to the speed corrected noise emissions calculation, there is a point at which increasing traffic volumes decreases the noise emissions.

Simply speaking, when taking into account the effect of traffic volumes on traffic speed, there is a fixed upper limit of the noise emissions from traffic on one lane. This upper limit is 75.3dB(A) $L_{10,\ 1hr}$, and corresponds to a traffic volume of between 1600 and 1700 vehicles per hour.

This is a simple but useful observation as it states that a single lane has a maximum amount of noise that it is able to emit. The immediate repercussion is that this maximum level could be used as initial assessment to determine the maximum mitigation that a road project may require.

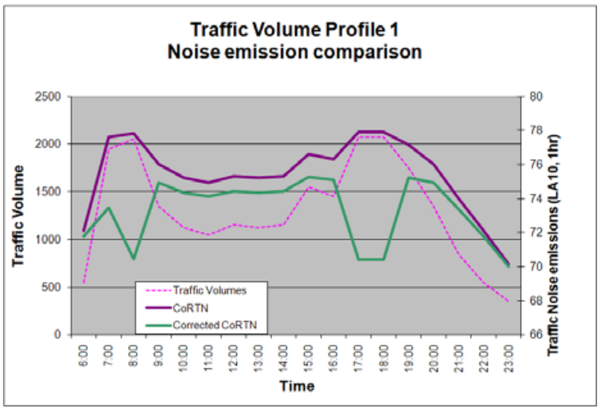
COMPARISON USING TRAFFIC VOLUME PROFILES

Traffic volume profiles are an hourly count of the traffic on a road segment for a day. Graph 3 shows a typical traffic volume profile for a week day on a road segment.



Graph 3: Typical traffic volume profile for a weekday

Applying the assessment to the typical traffic volume profile shown in Graph 3 produces some interesting comparisons. Graph 4 shows the calculated results of the road noise emissions for both the speed corrected, and non-speed corrected 1 hour CoRTN calculations.



Graph 4: Traffic profile with noise emission predictions

Graph 4 shows a large difference in peak hour noise emissions between the speed corrected and non-speed corrected CoRTN calculations. In the case of the speed corrected calculation, the highest noise level is no longer during the peak traffic volume hour. Rather, it occurs during the 3pm hour.

The highest 1 hour noise level for the non-speed corrected calculation is 77.9 dB(A), whereas the highest speed corrected calculation is 75.3. This is a difference in the highest peak hour of 2.6dB(A).

18 hour assessment

The CoRTN method also produces an 18 hour noise emission level. A comparison using the example traffic volume profile is shown below.

Deleny et al, state in their Prediction of Noise Levels Due to Road Traffic (CoRTN):

> By definition L_{10} (18-hr) is the arithmetic mean of the 18 one-hourly readings of L_{10} over the period 0600-2400 hrs

For this assessment, L_{10} (18-hr) values have been produced for each case by arithmetically averaging the L_{10} one-hourly values, and are shown in Table 2.

Table 2: Calculated L_{10} 18 hour values

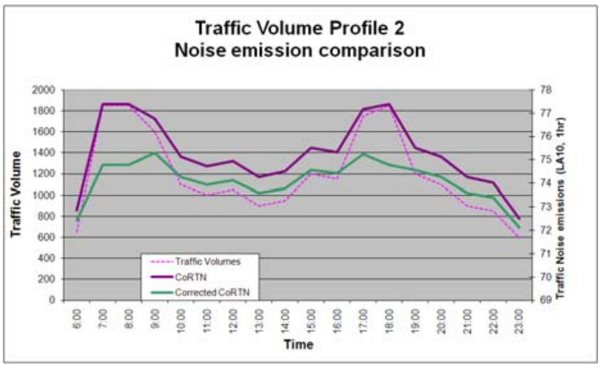
	L_{10} (18-hr)
Non-speed corrected	75.4 dB(A)
Speed corrected	73.2 dB(A)

The difference of 2.2 dB(A) is significant especially for road projects which are located close to sensitive receivers.

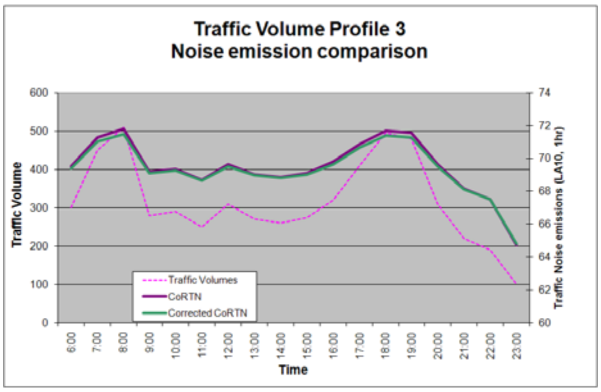
For reference, the total number of vehicles in the example traffic profile is 23 500.

ADDITIONAL TRAFFIC PROFILE ASSESSMENTS AT 100KM/H DESIGN SPEED

Included for further study are another two traffic profiles, their speed corrected and non-speed corrected noise emission calculations, and a summary table.



Graph 5: Traffic profile with noise emission predictions (21 550 vehicles total)



Graph 6: Traffic profile with noise emission predictions (5720 vehicles total)

Table 3: Summary of noise emission calculations

	Profile 1 L_{10} (18-hr)	Profile 2 L_{10} (18-hr)	Profile 3 L_{10} (18-hr)
Non-speed corrected	75.4 dB(A)	75.3 dB(A)	69.5 dB(A)
Speed corrected	73.2 dB(A)	74.1 dB(A)	69.3 dB(A)
Difference	2.2	1.2	0.2

OUTCOMES

Upper limit

Using a speed corrected CoRTN method, it was observed that the noise emission from a road segment has a maximum upper limit which is not exceeded. This is due to the large reduction in vehicle speed at high traffic volumes.

This upper limit could be used to determine the maximum noise mitigation requirements of a road.

1 hour assessment

The speed corrected one hour noise emission calculations show a significant difference in level, particularly during peak hour flow conditions. A difference of up to 2.6dB(A) was observed using a typical traffic volume profile for a road segment at a posted speed of 100km/h.

As the criteria in Queensland for educational facilities, community buildings, and health care facilities, are based on a one hour assessment, this difference presents a very large potential reduction in mitigation requirements, when compared to the mitigation requirements needed to achieve the same criteria when the non-speed corrected noise level calculations are used.

18 hour assessment

A difference of up to 2.2dB(A) was observed from the speed corrected and non-speed corrected assessments of the 18 hour traffic volumes.

In the major road project that first raised the leading question, this difference equates to 12 less houses requiring air-conditioning and a reduction of over 8000 square metres of noise barriers. This is would be a cost saving of over 2 million dollars.

Other observations

Where the traffic flows are predicted to be free flowing, the difference between the speed corrected and non-speed corrected noise calculations will be small. Therefore the difference between the calculated noise levels of the speed corrected and non-speed corrected methods will be minimal for roads which are designed to have traffic volumes of less than 1100 vehicles per hour, per lane.

ADDITIONAL WORK

This assessment does not include the impact of heavy vehicles on the speed of the traffic, or the traffic noise emissions. Future study should address this and combine it with the method presented in this paper.

Additionally, the sensitivities for different posted speeds such as 80km/h should be investigated.

REFERENCES

Saunders, R., Samuels, S., Leach, R., and Hall, A. 1983, *An Evaluation of the U.K. DoE Traffic Noise Prediction Method,* Australian Road Research Board, Australia.

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Delany, M., Harland, D., Hood, R., and Scholes, W. 1976, *The prediction of road noise L_{10} due to road traffic,* Journal of Sound and Vibration, Wales.