A re-examination of the relationship between the $L_{10(18hour)}$ noise level parameter and other road traffic noise level parameters

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ABSTRACT

Historically, the extent of intrusion of road traffic noise at residential locations has been quantified by the $L_{10(18hour)}$ noise level parameter. Well-researched prediction algorithms exist for this parameter. Various regulatory authorities set standards for acceptable levels of road traffic noise emission in terms of many other noise level parameters as well (eg. $L_{Aeq,1hr\ night}$). There are, however, few if any validated prediction algorithms for any of these other noise level variables. Rather, the most practical means of making accurate predictions has been to condense all of the alternative parameters to equivalent $L_{10(18hour)}$ values and use the lowest $L_{10(18hour)}$ value to set the acceptance standard. This paper extends work that was conducted in 2004 on this matter by one of the authors. It further refines the relationships between the alternative parameters and the $L_{10(18hour)}$ parameter. The practitioner, when confronted with the requirement to make predictions of the extent of road traffic noise intrusion in terms of parameters other than $L_{10(18hour)}$, may then make use of these updated results to establish a first order assessment of the likely equivalent predicable $L_{10(18hour)}$ value which may be used instead of the non-predictable alternative variables.

1. INTRODUCTION

In 2004, one the authors of the subject paper conducted an assessment of the relationship between the $L_{10(18hour)}$ noise level parameter and other commonly used road traffic noise level parameters. The assessment was based on data from the continuous noise level monitoring of road traffic noise levels at 35 sites in SE Queensland since September 2001.

The 2004 paper noted that the collection of noise level data at more sites in SE Queensland is an on-going matter. The earlier paper also stated that the results presented in the paper, while useful, had been based on only a fairly modest set of data. Improvement to the accuracy of the conclusions could be gained by the inclusion of the results of future logging exercises in a larger dataset.

Furthermore, the paper noted that future analyses may also include determination of the offset values for each of the $L_{10(12hour)}$, $L_{Aeq(15hr)}$ and $L_{Aeq(9hr)}$ noise level parameters.

The subject paper attempts to improve the accuracy of the conclusions presented in the earlier paper by expanding the dataset of monitored road traffic noise levels.

In addition, it uses the data gathered at the SE Queensland sites to determine the offset values for each of the $L_{10(12hour)}$, $L_{Aeq(15hr)}$ and $L_{Aeq(9hr)}$ noise level parameters. In doing so, it recognises that owing to matters relating to the commonly-encountered work hours of business and trades as well as the complications raised by the presence/absence of day light saving, these offset values derived solely from data gathered at sites in SE Queensland may not have universal applicability in other Australian States.

2. BACKGROUND

Various regulatory authorities in Australia have set criteria for acceptable levels of road traffic noise intrusion on residential developments in terms of a large number of noise level parameters. Commonly, compliance with these noise level limits is to be achieved under road traffic conditions that are expected to prevail at some future time, typically ten years hence.

The required assessment is usually undertaken using accepted prediction algorithms, with the application of algorithms conducted by proprietary software packages. Prediction algorithms for road traffic have been available for several decades. They have wide acceptance in Australia and elsewhere.

The most commonly used in Australia are the *Calculation of Road Traffic Noise* (CRTN '88) algorithms developed by UK DoE.

These algorithms can yield moderately accurate results for the $L_{10(18hour)}$ and $L_{A10,1hr}$ noise level parameters, but do not allow predictions of any other parameter to be made directly. $L_{10,1hr}$ is the noise level measured in dBA that is exceeded for 10% of the specific one hour period.

To overcome this shortcoming, it is now common practice to use the results of the site-specific noise logging to quantify the offset values of each of the relevant road traffic noise variables against the more commonly adopted $L_{10(18hour)}$ noise level parameter. The offset value is calculated as the difference between the parameter value and the $L_{10(18hour)}$ value, ie parameter value minus the $L_{10(18hour)}$ value.

In addition, in many situations, noise logging cannot be carried out successfully because site-specific matters make it infeasible, impractical or unsafe to do so. For example, noise logging would be infeasible, impractical or unsafe in situations where (i) the road has not yet been constructed, (ii) the road is currently undergoing roadworks, (iii) the noise level contributions from other sources of noise (eg rail noise, noise of nearby industry, noise of nearby earthmoving equipment, noise of insects in high summer) preclude accurate measurement of road traffic noise levels, (iv) there is no secure place to tether the noise logger or (v) damage to the noise logger may be occasioned by persons with malicious intent or by curious livestock.

In these circumstances, it is of significant benefit to be able to establish the offsets that may be reasonably expected to apply by reference to offset values determined at other sites under comparable conditions.

3. NOISE LEVEL PARAMETERS

A wide range of noise level parameters is currently in use in Australia to establish limits for acceptable levels of road traffic noise intrusion. These include, but are not limited to the following:-

- $L_{10(18hour)}$ is defined by UK DoE in CRTN ’88, as the arithmetic mean of each of the eighteen hourly $L_{10,1hr}$ levels between 6:00am and 12:00 midnight on an average weekday. While this terminology is not in strict accordance with the recommendations of Standards Australia because it does not identify the A-weighting requirement, it is adopted here to maintain consistency with CRTN ’88. For the purposes of this study, this definition has been extended to allow the $L_{10(18hour)}$ value to be calculated as the arithmetic mean of each of the seventy-two consecutive $L_{A10,15min}$ sound pressure levels measured between 6:00am and 12:00 midnight.

- $L_{Aeq,24hr}$ is the energy equivalent sound pressure level measured over a typical 24 hour period on an average week day.

- $L_{Aeq,1hr\ night}$ is the maximum rolling average $L_{Aeq,1hr}$ value from 10:00pm to 6:00am which, for the purposes of this paper, is determined as the logarithmic average of any four consecutive fifteen minute data samples (ie $L_{Aeq,15min}$) within the specified time period. In NSW, a slightly different nomenclature and definition has been adopted for this parameter for the night time period, $L_{eq,1hr}$: “the highest L_{eq} noise level for any hour during the period 10pm to 7am.”

- $L_{Aeq,1hr\ day}$ is the maximum rolling average $L_{Aeq,1hr}$ value from 6:00am to 10:00pm which, for the purposes of this paper, is determined as the logarithmic average of any four consecutive fifteen minute data samples (ie $L_{Aeq,15min}$) within the specified time period. Again in NSW, a slightly different nomenclature and definition has been adopted for this parameter for the day time period, $L_{eq,1hr}$: “the highest L_{eq} noise level for any hour during the period 7am to 10pm.”

- $L_{A90(18hour)}$ is the arithmetic mean of each of the eighteen hourly $L_{A90,1hr}$ sound pressure levels measured between 6:00am and 12:00 midnight on an average weekday where $L_{A90,1hr}$ is the sound pressure level measured in dBA that is exceeded for 10% of the specific one hour period, extended again to allow the $L_{A90(18hour)}$ value to be calculated as the arithmetic mean of each of the seventy-two consecutive $L_{A90,15min}$ sound pressure levels measured between 6:00am and 12:00 midnight.

- $L_{A90(8hour)}$ is defined as the arithmetic mean of each of the eight hourly $L_{A90,1hr}$ sound pressure level values measured between 10:00pm and 6:00am on an average weekday where $L_{A90,1hr}$ is the sound pressure level measured in dBA that is exceeded for 90% of the time over the specific one hour period, extended again to allow the $L_{A90(8hour)}$ value to be calculated as the arithmetic mean of each of the thirty-two consecutive $L_{A90,15min}$ sound pressure levels measured between 10:00pm and 6:00am.

- $L_{Amax\ day}$ is defined in this paper as the arithmetic average of the maximum noise levels ($MaxL_{pA,15min}$) due to motor vehicle passbys measured over the period 6:00am to 10:00pm.
- $L_{Amax\ night}$ is defined in this paper as the arithmetic average of the maximum noise levels ($MaxL_{pA,15min}$) due to motor vehicle passbys measured over the period 10:00pm to 6:00am.
- $L_{10(12hour)}$ is the arithmetic mean of each of the twelve consecutive hourly $L_{A10,1hr}$ sound pressure levels measured between 6:00am and 6:00pm on an average weekday, extended again to allow the $L_{10(12hour)}$ value to be calculated as the arithmetic mean of each of the forty-eight consecutive $L_{A10,15min}$ sound pressure levels measured between 6:00am and 12:00 midnight.
- $L_{Aeq(15hr)}$ is the energy equivalent dBA sound pressure level measured over the period 7:00am to 10:00pm on an average week day. (NSW)
- $L_{Aeq(9hr)}$, also designated as $L_{Aeq(10pm\ to\ 7am)}$ is the energy equivalent dBA sound pressure level measured over the period 10:00pm to 7:00am on an average week day. (NSW)

4. RESULTANT OFFSET VALUES FROM NEW DATA

Over the period from 18 April 2008 to 4 April 2016, data logging of road traffic noise levels was conducted by the authors at a large number of sites in SE Queensland. The weekday data gathered at another 35 of these sites have been examined to quantify the offset values for each of the 10 noise level parameters defined above. In each case, the dominant noise source was road traffic on the nearby road.

Instrumentation consisted of the following:-

- Precision sound level meter: Norsonic type NOR131
- Precision sound level meter: Norsonic type NOR140
- Calibrator: ARL type ND9

The range of relevant site conditions is summarised below:-

- Data sample interval, T: 15 minutes at 33 sites, 10 minutes at 2 sites.
- Weather: Dry, calm to light wind conditions.
- Microphone height: 1.2-1.4m above ground level.
- Separation distance from road: Generally 10-45m from closest running lane, with the separation distance at only seven sites exceeding 40m. (Maximum separation: 300m adjacent to Pacific Motorway.)

Road types, surfaces and AADT traffic volumes varied significantly. Posted traffic speed limits varied from 60km/h to 110km/h. Details are presented in Table 1 below.

Table 1: Ranges of Relevant Road Parameters

Parameter	Sample Size	Min Value	Max Value
Traffic volume	35	2080	144500
Percentage Heavy Vehicles	35	2%	25%
Traffic Speed Limit (km/h)	35	60	110

The results of the measurements of each of the $L_{A10,T}$, $L_{Aeq,T}$ and $MaxL_{pA,T}$ parameters have been used to calculate the resultant $L_{10(18hour)}$, $L_{Aeq,24hr}$, $L_{Aeq,1hr\ night}$, $L_{Aeq,1hr\ day}$, $L_{A90(8hour)}$ and $L_{A90(18hour)}$, $L_{Amax\ day}$, $L_{Amax\ night}$, $L_{10(12hour)}$, $L_{Aeq(15hr)}$ and $L_{Aeq(9hr)}$ values.

For the two sites at which the data sample duration was 10 minutes, the calculation of the values for each of the 10 noise level parameters has taken account of the larger number of data records gathered over the averaging period applicable to each parameter.

The offset value for each parameter was calculated by simple subtraction of the value of the particular parameter from the $L_{10(18hour)}$ value. Thereafter, the offset value datasets were analysed to yield the maximum, minimum and arithmetic average values as well as the 90% and 95% confidence intervals.

The resultant offset values are presented in Table 2.

Table 2: Offset values (dBA) for each noise level parameter-v- $L_{10(18hour)}$ (current dataset 2008-2016)

Parameter	Min	Max	Ave.	Std Dev^n	Confidence Intervals			
					90%		95%	
$L_{Aeq,24hr}$	-4.2	-1.6	-3.0	0.8	-4.3	-1.7	-4.6	-1.5
$L_{Aeq,1hr\ night}$	-8.1	1.7	-3.2	2.4	-7.1	0.6	-7.9	1.4
$L_{Aeq,1hr\ day}$	-1.5	4.4	0.8	1.4	-1.4	3.1	-1.9	3.5
$L_{A90(18hour)}$	-34.0	-7.6	-21.2	6.5	-31.9	-10.5	-33.9	-8.5
$L_{A90(8hour)}$	-21.9	-4.3	-12.5	4.6	-20.0	-5.0	-21.4	-3.5
$L_{Amax\ day}$	4.0	14.7	9.9	2.3	6.0	13.7	5.3	14.5
$L_{Amax\ night}$	3.4	15.5	9.5	2.9	4.7	14.3	3.8	15.2
$L_{10(12hour)}$	-0.1	4.1	1.4	0.9	-0.1	2.8	-0.3	3.1
$L_{Aeq(15hr)}$	-6.3	-0.2	-2.7	1.1	-4.5	-0.9	-4.9	-0.6
$L_{Aeq(9hr)}$	-11.5	-3.9	-7.2	1.8	-10.1	-4.3	-10.6	-3.7

(Positive value = value of parameter is greater than $L_{10(18hour)}$ value)

5. RESULTANT OFFSET VALUES FROM EARLIER DATA

The resultant offset values presented in the 2004 paper are re-presented in Table 3 below. It is noted that during the preparation of the current paper, the data presented in the 2004 paper was re-examined to verify its accuracy. In doing so, a very minor discrepancy was uncovered with respect to the standard deviation calculated for the $L_{Amax\ night}$ parameter. In the 2004 paper this was reported as 3.9dBA. The correct value was 3.8dBA. This correction has been made to the data presented above in Table 3.

Table 3: Offset values (dBA) for each noise level parameter-v- $L_{10(18hour)}$ (2004 paper, 35 sites)

Parameter	Min	Max	Ave.	Std Dev^n	Confidence Intervals			
					90%		95%	
$L_{Aeq,24hr}$	-5.1	-1.6	-3.6	0.8	-5.0	-2.3	-5.2	-2.0
$L_{Aeq,1hr\ night}$	-7.5	0.7	-3.4	2.7	-7.8	1.1	-8.7	2.0
$L_{Aeq,1hr\ day}$	-1.7	2.9	0.4	1.2	-1.6	2.3	-1.9	2.7
$L_{A90(18hour)}$	-24.6	-5.3	-13.3	5.3	-22.1	-4.6	-23.7	-3.0
$L_{A90(8hour)}$	-36.6	-10.9	-22.8	6.3	-33.2	-12.5	-35.2	-10.5
$L_{Amax\ day}$	8.4	17.0	11.5	2.2	7.8	15.1	7.1	15.8
$L_{Amax\ night}$	2.9	22.4	8.1	3.8	1.7	14.4	0.5	15.6

(Positive value = value of parameter is greater than $L_{10(18hour)}$ value)

6. OFFSET VALUES DERIVED FROM BOTH DATASETS COMBINED

Combining both datasets, the offset values have been determined to be as shown in Table 4 below.

Table 4: Offset values (dBA) for each noise level parameter-v- $L_{10(18hour)}$ (all data, 70 sites)

Parameter	Min	Max	Ave.	Std Dev[n]	Confidence Intervals			
					90%		95%	
$L_{Aeq,24hr}$	-5.1	-1.6	-3.2	0.9	-4.7	-1.6	-5.0	-1.3
$L_{Aeq,1hr\ night}$	-8.1	1.7	-3.3	2.5	-7.4	0.9	-8.2	1.7
$L_{Aeq,1hr\ day}$	-1.7	4.4	0.6	1.3	-1.5	2.7	-1.9	3.1
$L_{A90(18hour)}$	-34.0	-5.3	-17.3	7.1	-29.0	-5.7	-31.2	-3.4
$L_{A90(8hour)}$	-36.6	-4.3	-17.6	7.5	-30.0	-5.2	-32.3	-2.8
$L_{Amax\ day}$	4.0	17.0	10.6	2.4	6.6	14.5	5.9	15.3
$L_{Amax\ night}$	2.9	22.4	8.9	3.4	3.3	14.5	2.2	15.5
$L_{10(12hour)}$	-0.1	4.1	1.4	0.9	-0.1	2.8	-0.3	3.1
$L_{Aeq(15hr)}$	-6.3	-0.2	-2.7	1.1	-4.5	-0.9	-4.9	-0.6
$L_{Aeq(9hr)}$	-11.5	-3.9	-7.2	1.8	-10.1	-4.3	-10.6	-3.7

(Positive value = value of parameter is greater than $L_{10(18hour)}$ value)

7. DISCUSSION

From the results presented in Tables 2 and 3, it can be seen that, for the important $L_{Aeq,T}$ noise level parameters, there has been only a very minor change in the offset values over the 14 year period between the collection of the two datasets.

If the results of the combined dataset are examined, it can be seen that the value of the $L_{Aeq,1hr\ day}$ parameter lies very close to $L_{10(18hour)}$ value, ie the average difference is only 0.6dBA. The standard deviation is relatively small as well with 90% of the values of the offsets between these two parameters lying within the range –1.5dBA to 2.7dBA.

Similarly, it can be seen that the $L_{Aeq,24hr}$ and $L_{10(18hour)}$ values are also fairly closely related: the average offset was –3.2dBA with a 90% confidence interval –4.7dBA to –1.6dBA.

Analysis of the offsets of the $L_{Aeq,1hr\ night}$ parameter yielded a larger standard deviation value than was the case for either $L_{Aeq,1hr\ day}$ or $L_{Aeq,24hr}$. Almost universally, the maximum $L_{Aeq,1hr}$ value at night occurred during the hour from 5:00am to 6:00am. Small and even positive offset values were encountered at sites where the daily traffic flow was well established by 5:30am, notably Bruce Highway.

As might be expected and as demonstrated by the larger standard deviation values, the $L_{A90(18hour)}$ and $L_{A90(8hour)}$ parameter values (s = 7.1dBA and 7.5dBA, respectively) are less strongly linked to the $L_{10(18hour)}$ values. While the average values may be useful in providing an estimate of the differences between the values of each of the parameters and $L_{10(18hour)}$ value, the confidence intervals are sufficiently wide that the only reliable way of determining the actual $L_{A90(18hour)}$ and $L_{A90(8hour)}$ values in any particular situation would be by direct measurement.

Of course, any application of these offset values to predict the future values of the non-predictable noise level parameters over the 10 year planning horizon imposed by the regulatory authorities assumes that the offset values remain constant over the ten years. While this assumption may have some validity for $L_{Aeq,24hr}$, $L_{Aeq,1hr\ night}$ and $L_{Aeq,1hr\ day}$, it is unlikely to be appropriate for $L_{Amax\ night}$. The value of $L_{Amax\ night}$ is sensitive to both the night traffic volume and the measurement sampling period. If the offset between $L_{Amax\ night}$ and $L_{10(18hour)}$ is to be constant over a number of years, the distribution of traffic volumes during the full 24 hour period would need to remain constant as well. For roads which are lightly trafficked at present, this is unlikely to be the case. In view of this, and given the wide confidence intervals, prediction of future $L_{Amax\ night}$ values may very likely produce inaccurate results.

8. DIFFERENCE VALUES FOR MEASURED AND PREDICTED $L_{10(18hour)}$ LEVELS

The data that was logged at each of the 70 sites of this study each formed part of a large study of the impact of road traffic noise intrusion onto each particular site.

As part of the analysis conducted at each site, a SoundPLAN noise model was prepared so that the extent of road traffic noise intrusion onto the site could be assessed. In each case, the noise levels at the logger location were predicted using the (CRTN '88) algorithms applied by SoundPLAN and by adopting the particular road traffic and site-specific parameters current at that site at the time of the data logging.

Almost invariably, it was found that SoundPLAN over-predicted the $L_{A10(18hour)}$ value at the logger location. Based on the results of the analysis of the data collected at the 70 sites, the average over-prediction was 0.9dBA.

9. CONCLUSIONS

From the results presented in Tables 2-4, it can be concluded that, for the important $L_{Aeq,T}$ noise level parameters, there has been only a very minor change in the offset values over the 14 year period between the collection of the two datasets.

It is considered that the practitioner will find the results presented in Table 4 to be of assistance in making informed decisions about the offset values that may be applied in situations where noise logging cannot be carried out successfully because site-specific matters make it infeasible, impractical or unsafe to do so.

REFERENCES

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