Noise monitoring program for assessing the impact of maximum traffic noise levels

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ABSTRACT

Maximum $L_{A,\ (Max)}$ Traffic Noise Events are reported in the literature as contributing to sleep disturbance in the community. The New South Wales Department of Environment and Conservation (DEC) has undertaken a noise monitoring program to measure maximum traffic noise levels at night using specialised "Mad Max" Noise Monitoring Equipment. The aim of the study is to better understand the characteristics of maximum noise events at night for selected roads and to investigate the behaviour of the Sleep Disturbance Index (SDI) as proposed by Bullen et al (1996) in these situations. The noise monitoring program involved selection of six noise monitoring sites, two sites each for low, medium and high anticipated maximum noise impacts. Maximum noise levels were measured in conjunction with concurrent traffic counts and classifications, using an Acoustics Research Laboratories EL215 data logger and Hewlett Packard Personal Data Assistant (PDA) configured with "Mad Max" software. The instrumentation and measurement methodology is explained to indicate how the SDI is evaluated using this system. SDI values calculated from the monitoring program are discussed with observations on what road traffic components appear to be significant in changing SDI values. Prediction approaches are discussed to indicate how SDI values may be evaluated as part of an impact assessment process.

INTRODUCTION

The New South Wales Department of Environment and Conservation (DEC) in reviewing the NSW Environmental Criteria for Road Traffic Noise (ECRTN) considered ways to improve guidance on sleep disturbance impacts caused by road traffic. An approach was sought that assessed the likely sleep disturbance impact in terms of the number and magnitude of maximum noise events, and the amount of emergence of these events above an ambient level.

One approach investigated was the application of the Sleep Disturbance Index (SDI) of Bullen et al (1996). The SDI is an index value derived from a formula that brings together night-time maximum noise values, emergence above an ambient level and number of maximum noise incidents using the formula SDI= N*W(Lmax)/100 where N=no. of events and W(L) is the weighting factor for a noise level of L. The weighting factor incorporates into the formula a best fit relationship between specific noise levels and probability of awakenings based on the results of 11 studies. It also takes into account emergence of maximum noise levels above an ambient level, (Bullen et al. 1996). The SDI values are considered by Bullen et al to correlate with some limitations with the extent of the sleep disturbance impact.

To consider any application of SDI in a policy framework it was important to better understand how the SDI formula worked under a range of actual traffic conditions in Sydney, and to gain an understanding of which particular traffic characteristics the SDI may be sensitive to.

METHODOLOGY

Site Characteristics

Six sites were selected to represent a range of traffic related maximum noise conditions affecting roadside residential receivers using both prior knowledge and observations of typical traffic patterns. The selected sites are described in Table 1. Night time traffic counts were established using standard rubber strip sensor equipment accepted by the NSW Roads and Traffic Authority (RTA). The traffic count sensors were located sufficiently distant from the noise monitoring equipment so as not to affect the noise measurements.

Table 1. Sydney Monitoring Locations and Times

Notional Maximum Noise Impact Expected and 85th percentile average .speed of vehicles counted

Low	Medium	High
(1)Barrenjoey Road, Avalon (65kph) 6-8/3/05; 10-13/3/05	(3)Pittwater Road, Mona Vale (69kph) 3-7/3/05	(5)Military Road, Cremorne (65kph) 5-8/3/05
(2)Galston Road, Hornsby Heights (67kph) 16-21/3/05	(4)Castle Hill Road, West Pennant Hills (69kph) 17-18/3/05 21-23/3/05	(6)Pennant Hills Road, Thornleigh (78kph) 15-20/3/05

The shortest distance between the curb on the subject road and the logger was measured as well as the distance from logger to the façade of the residence. All sites except for the Military Rd. site had noise loggers remote from the façade, and therefore had no façade correction applied to the results. For the Military Rd site, a façade correction of 2.5 dB(A) was applied to the noise data. Noise data was corrected to account for the distance from the logger to the façade. It should be noted that the SDI formula requires the use of internal noise levels. It was assumed that all façade windows were open, and therefore a difference of 10 dB(A) between the external and internal noise levels was assumed.

From an initial analysis of the traffic count data for the night-time period (10pm to 6am) Location 1 Barrenjoey Road appeared to have a low traffic volume and low number of heavy vehicles (HV) with Location 2 Galston Road appearing to have similar traffic characteristics (total traffic volume and numbers of heavy vehicles). Location 3 Pittwater Road and Location 4 Castle Hill Road both appeared to have moderate traffic volumes and higher numbers of heavy vehicles. However both Location 5, Military Road and Location 6, Pennant Hills Road appeared to have much higher traffic volumes, with Pennant Hills Road having high numbers of heavy vehicles. It was assumed initially that the percentage of heavy vehicles (HV) at night was a major indicator of whether a site had notionally low, medium or high maximum noise impacts.

Instrumentation

Wilkinson Murray Pty. Ltd. developed software and hardware to identify and record individual maximum noise level events, called “Mad-Max”. The “Mad-Max” instrumentation comprised a Hewlett Packard Personal Data Assistant (PDA) which, when connected to an Acoustic Research Laboratories (ARL) EL-215 noise data logger, was configured to identify and record individual maximum noise level events. In this study the Mad-Max loggers were configured as follows; (1) a minimum drop between maximum noise events of five decibels, (2) a minimum time between maximum noise events of three seconds, (3) a maximum wait time of twenty five seconds and (4) a minimum recorded maxima of 65 dB(A).

It should be noted that at some locations, higher minimum recorded maxima were configured on the loggers with the result of recording a significantly different amount of maximum noise level events. Care should be taken when setting the Mad-Max instrumentation, as these settings can alter number of maximum noise level events recorded and hence the SDI. The Mad-Max system allows absolute $L_{A, (Max)}$ values and their frequency of occurrence to be measured. The SDI formula also requires the “emergence” to be measured, the emergence being defined as the difference between $L_{A, (Max)}$ values and the ambient traffic noise. The ambient traffic noise is the logarithmic average of the $L_{Aeq, (15\ minute)}$ data over an 8-hour night-time period (10pm to 6am) measured by the EL-215 noise data logger.

The PDA stored the maximum noise level data, which was downloaded to a Personal Computer after the monitoring was completed.

To remove noise level data affected by adverse meteorological conditions such as rain and winds greater than 5 m/s, meteorological data was obtained from the Macquarie University weather station. It was noted that the University weather station is considered to be generally representative of the meteorological conditions experienced at all the logger locations.

Traffic count data were collected concurrently with noise readings and included total counts and counts for each of the AUSTROADS vehicle classifications. The split up into vehicle types provided an additional analysis of the contribution each of these vehicle types made to the distribution of maximum noise events such as the contribution made by heavy vehicles. The count data was obtained from CFE Information Technologies, a contractor of the RTA in this field.

Analysis of the Mad-Max data and calculation of SDI values for each of the six sites was conducted by Acoustics Dynamics Pty Ltd. Individual nightly SDIs were arithmetically averaged to determine a single SDI for each site . The results of the analysis are summarised in Table 2.

RESULTS

The Barrenjoey Road location with a low traffic volume and with few recorded maximum noise events produced an expected low SDI reading. The Galston Road location by contrast produced an unexpectedly high SDI value although the traffic volume and numbers of heavy vehicles were similar to Barrenjoey Road. The analysis of this result is discussed later.

The Pittwater Road location, with greater traffic volume than Barrenjoey Road, still resulted in a low SDI as the magnitude of night time recorded maximum noise levels was low. The other notionally medium maximum noise impact site, Castle Hill Road, also had a low SDI although having greater traffic volumes like Pittwater Road it lacked large numbers of noisy traffic passbys (Note: “passbys” means the movement of an individual vehicle past a residential receiver).

The two notionally high maximum noise disturbance impact sites, Military Road and Pennant Hills Road, both showed high night time traffic volumes. However most of Pennant Hills Road’s noisy maximum noise level events appeared to be from heavy vehicles whereas the maximum noise level events at Military Road appeared to be from less noisy cars. As expected, the SDI values were high for both sites.

Table 2. SDI, Traffic Data and Noise level Analysis.

Location	Total average traffic volume per night	Average no. of maximum noise events recorded	Distance from road to façade (m)	Cars (% of Total)	Heavy Vehicles (% and number per night)	Average internal $L_{Aeq,8\ hr}$ (dB(A))	Largest proportion of internal maximum noise levels (dB(A))	Average SDI (Range of data set)
(1)Barrenjoey Road, Avalon	750	96	16.0	92.9%	6.0% / 45	40 dB(A)	49-54dB(A)	1.1 (0.9-1.3)
(2)Galston Road, Hornsby Heights	905	654	12.0	96.8%	2.7% / 25	48 dB(A)	54-59dB(A)	7.7 (7.3 – 8.2)
(3)Pittwater Road, Mona Vale	2648	437	18.0	94.8%	4.9% / 130	44 dB(A)	49-54dB(A)	1.2 (0.7-1.6)
(4)Castle Hill Road, West Pennant Hills	2240	260	20.0	92.4%	7.2% / 161	48 dB(A)	49-54dB(A)	0.9 (0.2 – 1.4)
(5)Military Road, Cremorne	6194	1301	11.3	95.6%	4.0% / 246	53 dB(A)	54-59dB(A)	6.5 (4.7 – 7.8
(6)Pennant Hills Road, Thornleigh	4949	1538	11.0	77.0%	22.4% / 1108	60 dB(A)	64-69dB(A)	10.5 (6.6-13.3)

There were daily variations of SDI values at each site (see column 9 of Table 2). Apparent causes for these variations were not confined to any one factor although the main influences appeared to be variations in either the number of maximum noise events of over 5dB above the L_{Aeq} or the value of the L_{Aeq} itself.

DISCUSSION

Understanding what are the dominant contributors to determining an SDI value was a focus in the analysis of results. The analysis by Acoustic Dynamics of all the data collected indicated three main influences to the resulting SDI:

(1) frequency and magnitude of noisy events
(2) average indoor $L_{Aeq,\ (8\ hour)}$ from traffic
(3) largest proportion of maximum noise levels.

It follows that distance from source to receiver is important as the maximum noise level is a function of it

Distance from source to receiver.

It is obvious that when a receiver is closer to the road a greater number of noisy passbys will be recorded. This was evident from the results where the sites could be grouped in terms of distance with sites 2,5 and 6 (Galston Road, Military Road and Pennant Hills Road) being somewhat closer to the curbside than the other sites. These sites also had the highest SDI values.

During the analysis, the effect of a change in distance on the SDI value was investigated, using the Pennant Hills Road location as the example. The calculated SDI at this site on 15 March 2005 was 11.3 for a curb-to-façade distance of 11.0 metres. The distances were then varied. With a doubling of the distance to 22.0 metres the SDI was re-calculated as 3.0. When the distance was halved to 5.5m the SDI was recalculated as 28.3. The change of SDI resulting from reducing the distance compared with the change in SDI from increasing the distance suggests that SDI is sensitive to distance from source to receiver, especially where this distance is low.

Frequency and magnitude of noisy events

All of the “Mad Max” individual $L_{A,\ (Max)}$ levels were grouped in 5 dB(A) categories, i.e., number of $L_{A,\ (Max)}$ incidents of values 54-59dB(A); number of $L_{A,\ (Max)}$ incidents of values 59-64dB(A); and so on. In this way a picture of the distribution of noisy events could be mapped for each site and those categories influencing the SDI value the most could be identified.

Heavy Vehicles

Initially it was considered that heavy vehicles would be the greatest influence on the recorded maximum noise events. This held true for Pennant Hills Road with an average of 1108 heavy vehicles per night, and about 1100 maximum noise level events above 64dB(A), suggesting that most if not all of these events were from heavy vehicles. Note that the average $L_{Aeq,\ (8\ hour)}$ was 60.4dB(A) at this location.

The number of night-time heavy vehicles on Pennant Hills Road was 4-5 times higher than at the next highest site, Military Road with a nightly average of 246 heavy vehicles. The SDI value was 10.5 at Pennant Hills Road compared with 6.5 at Military Road.

From this it could be concluded that the number of heavy vehicles a night (not their percentage of total traffic) may influence the value of the SDI because of their inherently high $L_{A,(Max)}$ levels. However for receivers closer to the road and where traffic profiles are more uniform i.e., have a more even spread across all vehicle classifications, cars may also be a significant contributor to the SDI. This study has not correlated the recorded maximum noise level events with specific traffic types. As discussed later, more investigations are needed in this area to fully understand the relationship of different vehicle types to SDI.

Average indoor $L_{Aeq,(8\ hour)}$ of traffic

This value represents the point of emergence of individual events. The higher the L_{Aeq} the higher still individual events have to be in terms of dB(A) to be above the L_{Aeq} level to contribute to the SDI. Both low and high ambient levels (ie from low and high traffic volumes respectively) can lead to high SDI values provided that there is a sufficient number of noisy recorded passbys greater than 5 dB above the ambient. The Galston Road location provides an example of this for low traffic volumes (SDI of 7.7, $L_{Aeq,(8\ hour)}$ of 48dB(A) and the Pennant Hills Road location for high traffic volumes (SDI 10.5, $L_{Aeq,(8\ hour)}$ of 60dB(A)).

The calculated internal $L_{Aeq,(8\ hour)}$ noise level at the locations that were representative of low and medium traffic volumes were significantly lower than the $L_{Aeq,(8\ hour)}$ levels determined for the two notionally high maximum noise impact sites.

During the analysis, the effect on the SDI value of varying the internal $L_{Aeq,(8\ hour)}$ noise level was investigated, using the Pennant Hills Road location as the example. The calculated SDI on 15 March 2005 was 11.3. The calculated indoor $L_{Aeq,(8\ hour)}$ on the same night was 60.5dB(A). When the internal $L_{Aeq,(8\ hour)}$ level was lowered by 1dB to 59.5dB(A) the SDI was re-calculated at 14.1. When the internal $L_{Aeq,(8\ hour)}$ level was increased by 1dB to 61.5dB(A) the SDI was re-calculated at 6.7. This inverse relationship is expected because a lower ambient level means greater emergence of maximum noise events and vice versa.

This observation points to the need to have accurate internal $L_{Aeq,(8\ hour)}$ levels, which is difficult if only external data is available.

Table 3. Number of maximum noise events by noise level ranges and associated partial SDI contribution.

MaxNoise level (dB(A)\ --------------------- (av.indoor Leq)	Location	44-49	49 - 54	54-59	59-64	64- 69	69-74	74- 79	79- 84	85-89
(1)Barrenjoey Road, $L_{Aeq,8hr}$ 40.2 dB(A)	No. events		91	24	5	-	-	-	-	
	Partial SDI		0.4	0.5	0.2					
(2)Galston Road,	No. events	-	71	412	140	29	3	-	-	
$L_{Aeq,8hr}$ 47.8 dB(A)	Partial SDI		0.1	3.1	2.9	1.2	0.2			
(3)Pittwater Road, $L_{Aeq,8hr}$ 44.4 dB(A)	No. events	312	185	34	15	2	-	-	-	
	Partial SDI	0.0	0.3	0.4	0.4	0.1				
(4)Castle Hill Road, $L_{Aeq,8hr}$ 47.9 dB(A)	No. events	384	439	97	16	1	-	-	-	
	Partial SDI	0.0	0.1	0.5	0.3	0				
(5)Military Road, Cremorne $L_{Aeq,8hr}$ 52.6 dB(A)	No events	-	214	810	507	33	2	-	-	
	Partial SDI		0.0	0.9	4.3	1.0	0.1			
(6)Pennant Hills Road, $L_{Aeq,8hr}$ 60.4 dB(A)	No events	-	22	146	711	717	186	11	2	1
	Partial SDI		0.0	0.0	0.1	2.1	7.1	0.7	0.1	0.0

Largest proportion of maximum noise levels

Barrenjoey Road, Pittwater Road and Castle Hill Road all had low traffic activity with few maximum noise level events with Barrenjoey Rd and Pittwater Road having less than 100 incidents above 54dB(A) (internal). These sites has low SDI values. However for the Military Road location there were about 1300 maximum noise level events recorded per night above 54dB(A) (internal).

As the data analysis for this study grouped individual $L_{A,(Max)}$ data into 5dB ranges, the importance of each range regarding its contribution to SDI was examined. This is set out in Table 3 which gives an insight to how the SDI formula works. Firstly the number of events contributed to the SDI value only when the maximum noise values were high enough above the ambient, approximately more than 8dB above the ambient. Site 6 illustrates this where 717 maximum noise events only contributed a partial SDI of 2.1 whereas the maximum noise events for the next highest decibel range contributed a partial SDI of 7.1 for only 186 events. Many events emerging only 5 to 10dB above the ambient did not make a significant contribution to SDI compared with the contribution of fewer but noisier events.

It follows that the effect on the SDI value of maximum noise level events grouped in categories; e.g.,59,5 – 64.5dB(A); 64.5 – 69.5dB(A); and so on showed that the group that contributed most to the SDI value was not the group with the most events but the group that emerged the most above the ambient while still having a significant number of events compared with higher noise level categories. Galston Road results were an exception to this pattern as the maximum noise category with the greatest contribution to the SDI value was in fact the group with the most events. The significance of this is explained below

The result at the Galston Road location

The Galston Road location shares with the Barrenjoey Road location some features such as similar traffic volumes (Barrenjoey Road=750; Galston Road=905) with only a few heavy vehicles (Barrenjoey Road=45; Galston Road=25). However the internal $L_{Aeq, (8 hour)}$ for the Galston Road location was much higher (Barrenjoey Road=40dB(A); Galston Road=48dB(A) and the resulting SDI of 7.7 for Galston Rd. was certainly not comparable to the Barrenjoey Rd. SDI value of 1.1. It was more comparable to the notionally high maximum noise impact sites of Military Road and Pennant Hills Road, sites with approximately 5 times more traffic. Two factors may be relevant at the Galston Road location, firstly the short distance of 12 metres between the façade and curb. This proximity to the road may then result in a high proportion of passbys being recorded as maximum noise level events. Secondly, despite the lack of heavy vehicles, the nature of the traffic along Galston Road may have contributed if there was a high proportion of noisier "light" vehicles such as 4WD, modified vehicles and motorcycles.

There was a greater proportion of total traffic contributing to the SDI than at other sites. There were about 350 maximum noise level events recorded above 58dB(A) (internal), which is 10dB or more above the average $L_{Aeq, (8 hour)}$ of 48 dB(A). This represents about 40% of the traffic volume. As well all recorded maximum noise events comprised over two thirds of total traffic numbers. These noisy passbys affected the $L_{Aeq, (8 hour)}$ by increasing it to 48dB(A) which is the same ambient for the Castle Hill Road location - a site with over twice the traffic volume. The energy to lift the L_{aeq} level came from many individual maximum noise events rather than a general hum of traffic as with Castle Hill Road and other busier sites. So with Galston the largest grouping of events all occurred approximately in excess of 8dB above ambient which meant that all of these contributed to the SDI value. In contrast Pittwater Road with 3 times the traffic only had a SDI of 1.2 because most traffic had maximum noise levels too close to the ambient level to contribute to the SDI. In other words the site had few individually noisy vehicles.

This level of $L_{A, (Max)}$ incidents at Galston (at comparable magnitudes above the ambient) was at least 3.5 times the levels reported for the notionally low to medium maximum noise impact sites 1, 3 and 4. However the fact that for a relatively low use road the SDI result exceeded that of Military Road with total traffic 6 times that of Galston Road, suggests a need for further investigation of the site and traffic characteristics to better understand why the SDI formula is suggesting sleep disturbance impact may be similar for both.

Prediction

Prediction of SDI values requires prediction of (1) maximum internal noise levels; (2) predicted number of maximum noise events: and (3) predicted internal $L_{Aeq, (8 hour)}$. As the SDI is sensitive to distance from source to receiver, it is important to be as accurate as possible in predicting the internal levels of $L_{Aeq, (8 hour)}$ and $L_{A, (Max)}$. Ideally measurement of noise data that may be used in predictions should be made internally to avoid assumptions about facade attenuation.

Although quantifying a predicted SDI requires considerable knowledge, this study has shown that there are general night time indicators that can flag the potential for high SDI values and can therefore act as a screening test for potentially high SDI sites. These are:

(1) high traffic volumes with high percentage heavy vehicles during the night-time. These sites are typically characterised by high $L_{Aeq, (8 hour)}$ and high $L_{A, (Max)}$ levels from road traffic, as represented in this study by the Pennant Hills Road location. Any road with high traffic volumes and high numbers of heavy vehicles during the night-time is likely to belong to this category.

(2) proximity of façade to curbside. As shown in this study, the SDI is very sensitive to the source-to-receiver distance. Sites where the residential façade alignments are close to the curbside (typically 12 m or less) may experience greater $L_{A, (Max)}$ contributions in terms of both magnitude and number of events than sites further away. These sites are represented in this study by Galston Road, Military Road and Pennant Hills Road. Sites that are close to a road may have potential for high SDI regardless of the traffic flows.

(3) low night-time traffic volumes but with a significant proportion of passbys recording maximum noise events.

These sites are characterised by low traffic volume (with relatively low ambient levels) but with a significant proportion of passbys that would be recorded as noisy events (ie those with relatively high $L_{A, (Max)}$ levels). This type of site does not appear prima facie as a potentially high SDI site, however if a high proportion of traffic contributes to noisy events recorded then SDI values can be high. This is illustrated in this study with the Galston Road location.

SUMMARY AND CONCLUSION

The study aimed to investigate the behavior of the SDI index with a view to using SDI as a guide to assessing the impact of maximum noise levels from road traffic at night. In this study the SDI values generally behaved as anticipated; a low SDI for sites with low traffic volume and low number of maximum noise events, a medium SDI for sites with medium traffic volume and more maximum noise events and a high SDI for sites with high traffic volume and large numbers of maximum noise events.

The SDI did not behave as expected for the Galston Road location, as the low traffic volume were expected to result in a low SDI. Any advances in guidance on maximum noise impacts may derive from the traffic and site characteristics that affects the SDI value rather than the SDI itself. These are listed above as (1) high traffic volumes with a high number of heavy vehicles, (2) closeness of receiver to the roadway , and (3) low traffic volumes but with a high proportion of passbys recorded as significant maximum noise events.

Any rigorous relationship between SDI values to specific sleep disturbance descriptors requires research beyond the scope of this study. This further research may also include an investigation of the time of night that particular maximum noise events occur, a possible additional factor in sleep disturbance assessment that is not taken into account in the SDI formula.

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