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Determination And Application Of The Long Term Road Traffic Noise Attributes Of Road Pavement Surfaces In Queensland

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ABSTRACT

This paper presents an investigation into the road traffic noise attributes of five types of pavement surface currently in service in Queensland. The investigation, perhaps the most extensive of its kind ever undertaken in Australia, was configured to determine the acoustic performance of the set of pavement surfaces and how these performances varied over time. To do this, a considerable set of roadside noise data, measured according to the statistical passby technique, was collected at 29 sites in 2002, 2003, 2005, 2006 and 2007. These data were collected at 21 sites in South East Queensland and at 8 sites in North Queensland in the Townsville environs. Analyses of the data produced values of a parameter known as the Statistical Passby Index which are presented in the paper and which quantify the acoustic performance of the pavement surfaces. Moreover, some of the pavement surfaces exhibited very stable acoustical performance over the 2002 to 2007 period while the acoustical performance of others varied somewhat. From there the paper presents a new method developed by the authors for applying the outcomes of the investigation to the prediction of road traffic noise on the five types of pavement surface over a five year period, taking into account the age of each of the pavement surfaces involved.

INTRODUCTION

The present paper has ensued from a series of ongoing investigations of the acoustic attributes of road pavement surfaces in Queensland that have been conducted by the authors over the last few years (Samuels and Hall 2005 a, 2005 b, 2006 and 2008). Specific objectives of these investigations were to determine the noise attributes of the various pavement surfaces and to ascertain if and how the acoustic performance of these pavement surfaces varied over time. That is, these investigations were conducted by the authors for the Queensland Department of Main Roads (QDMR) in order to determine the long term noise attributes of pavement surfaces in Queensland. Outcomes of these investigations are summarised in the paper and a novel application of these outcomes is presented and discussed.

DATA COLLECTION AND ANALYSIS

Data collection

The investigations all shared a common experimental design which involved collecting samples of passby noise data from three vehicle types (cars, medium trucks and heavy trucks) on the pavement surfaces included in the investigations. These noise data were collected according to the statistical passby technique, which involved the simultaneous measurement of the noise and the speed of individual vehicles in the traffic stream as they passed by each measurement location (ISO 1997). Roadside measurement locations were set up for this purpose at each site included in the investigation. In each investigation there were 29 sites in all, of which 21 were situated in South East Queensland and 8 in North Queensland in the Townsville environs. The noise data were collected at all sites by the first author with a Bruel and Kjaer Type 2260 precision Sound Level Meter, the calibration of which was at specification throughout. Speed data were collected at all sites by an assistant utilising a radar speed meter situated adjacent to the noise measurement station. This speed meter was concealed as far as possible so as not to influence driver behaviour at or near to the measurement station. During all the measurements weather conditions were fine and mild throughout, with occasional very light breezes. At all 29 sites the passby noise levels (dB(A)) and speeds (km/h) were measured repeatedly for around 80 cars, 20 medium trucks and 20 heavy trucks.

The range of pavement surfaces included in the investigations is set out Table 1 below. There were no maintenance or other surface treatments applied to the pavement surfaces over the 2002 to 2007 period of the investigations. Note that the pavement surface types of Table 1 are as follows.

OGA: Open Graded Asphalt
SMA: Stone Mastic Asphalt
DGA: Dense Graded Asphalt
CS: Chip Seal (10mm)
PCC: Portland Cement Concrete

Table 1. Pavement surfaces included in the investigations

Pavement Surface Type	Number of sites included in the investigations	
	South East Queensland	Townsville
OGA	7	0
SMA	3	6
DGA	5	1
CS	3	1
PCC	3	0
Total	21	8

Data analysis

All of the statistical passby data were collated and analysed in accord with the established, scientifically based procedures adopted in Samuels and Hall (2006). Parameters involved in the analysis included pavement surface type, vehicle type, vehicle speed and vehicle trajectory to microphone distance. From there, the measured noise levels were applied to calculating a set of Statistical Passby Indices, or SPBIs (ISO 1997). Originating from European work on the acoustic attributes of pavement surface types conducted during the 1990s, the Statistical Passby Index was developed as a parameter that could be used to quantify the overall effects of pavement surface type on road traffic noise (ISO 1997). The concept here was that the contributions of various vehicle types to the road traffic noise generated on a given pavement surface could be incorporated in a parameter which is a function of their noise emissions, their proportions in the total traffic volume and their speeds. It should be noted that the SPBI was not devised as a road traffic noise descriptor, such as the well known L_{eq}(24 hour) or the L_{10}(18 hour). Comparisons of the SPBIs associated with different pavement surfaces show the variations in road traffic noise levels that would occur on these pavement surfaces. The SPBI is defined below in Equation 1 (ISO 1997).

$$SPBI = 10\log\left(W_1 x10^{L1/10} + W_{2a}\,(V_1/V_{2a})x10^{L2a/10} + W_{2b}(V_1/V_{2b})x10^{L2b/10}\right) \quad (1)$$

Where

SPBI = Statistical Passby Index of a given pavement surface (dB(A))

L_x = Passby noise level of Vehicle Type X on the given pavement surface

at a reference speed of V_x and at a reference distance of 7.5m (dB(A))

W_x = Proportion of Vehicle Type X in the traffic (-)

V_x = Reference speed of Vehicle Type X (km/h)

There are three vehicle types involved and these, which are designated by the subscripts 1, 2a and 2b in Equation 1, are Cars (1), Medium Trucks (2a) and Heavy Trucks (2b). For the purposes of this paper the SPBIs were calculated for the speed condition known as "high", wherein cars and trucks were assigned the reference speeds of 110km/h and 85km/h respectively. The SPBI includes the influence of traffic composition through the parameters W_1, W_{2a} and W_{2b}. Specification of the values of these three parameters was made after consultation with relevant staff of QDMR and on the basis of the present authors' extensive experiences in the road industry. What ensued were four sets of traffic conditions that ranged from 50% cars, 10% medium trucks and 40% heavy trucks (designated 50-10-40) to 100% cars, 0% medium trucks and 0% heavy trucks (designated 100-0-0).

THE PAVEMENT SURFACE EFFECTS ON ROAD TRAFFIC NOISE OVER TIME

The Statistical Passby Indices

The SPBI data from the 2007 Investigation are presented in Table 2 for the four traffic compositions. Note that the standard deviations of the four sets of SPBI data are both small and very consistent with one another, thus reflecting the high quality of all the passby noise data collected. In Table 2 it is clear from the variations in the SPBIs with pavement surface type that the five Queensland pavement surface types have an effect on road traffic noise. The overall range of road traffic noise levels from the PCC to the DGA pavement surfaces in 2007 would have been 3.8 to 4.8 dB(A), depending on traffic composition.

Table 2. The 2007 Statistical Passby Indices over four traffic compositions at high speed

Pavement Surface Type	Average (and Standard Deviation) SPBI (dB(A))			
	Traffic: 50-10-40	Traffic: 70-10-20	Traffic: 90-5-5	Traffic 100-0-0
OGA	85.3 (1.8)	84.2 (1.8)	82.9 (1.9)	82.2 (2.0)
SMA	85.1(1.3)	83.7 (1.3)	81.9 (1.4)	80.8 (1.7)
DGA	84.8 (2.6)	83.3 (2.4)	81.4 (2.2)	80.2 (2.0)
CS	86.8 (1.5)	85.5 (1.4)	84.2 (1.4)	83.5 (1.5)
PCC	88.6 (2.2)	87.3 (2.1)	85.8 (2.0)	85.0 (2.0)
PCC – DGA	3.8	4.0	4.4	4.8

Indeed in Table 2 it is also apparent that the SPBIs increase with increasing heavy vehicle content in the traffic composition. This is an expected observation, for the following reason. If any given traffic volume remains constant and the proportion of heavy vehicles in that traffic increases, then a simple application of the British Calculation of Road Traffic Noise algorithms would demonstrate that the resulting level of road traffic noise will increase (UK DoT 1988). It is also apparent in Table 2 that the magnitudes of these SPBI increases with heavy vehicle content seem to differ with pavement surface type. This particular trend was simply quantified and is plotted in Figure 1 which shows the SPBI increases that occur as the proportion of heavy vehicles in the traffic increases on all five pavement surface types.

In addition, the increases in SPBI with traffic composition varied somewhat across the pavement surfaces. For the high speed traffic these increases ranged from 3.1 dB(A) on the OGAs to 4.6 dB(A) on the DGAs, as shown in Figure 1. However, these increases must be considered in relation to the mean (3.8) and the standard deviation (0.6) of the Figure 1 data. Here it is apparent that each of the five increases plotted in Figure 1 is within or about within one standard deviation of the mean. These observations would suggest that, despite the variabilities exhibited by these increases across the five pavement surface types, these increases are all representative of one overall trend.

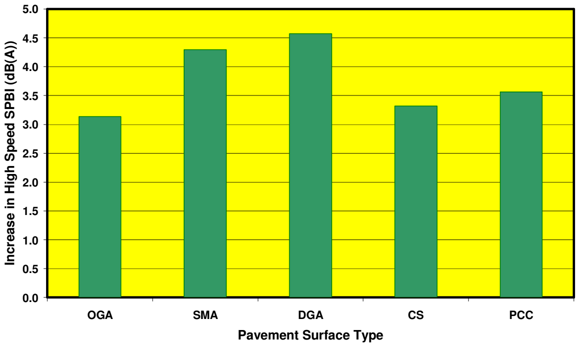

Figure 1. Variations in SPBI as traffic composition changes from 100-0-0 to 50-10-40 for high speed traffic conditions. (Data from Table 2.)

The nature of these data precluded any further statistical analyses. Consequently it was concluded from the trends observed in these 2007 data that the total range of the high speed traffic SPBIs on the five Queensland pavement surface types investigated would be on average 3.8 dB(A) when the traffic composition changes from 100-0-0 to 50-10-40. In other words, if the traffic composition changes from one extreme of 100-0-0 to the other of 50-10-40 under high speed traffic conditions, the total increase in traffic noise would be, on average, 3.8 dB(A) on any of the five pavement surface types.

Subsequently in Table 3 and Figure 2 the high speed SPBIs for just the 90-5-5 composition are shown over the 2002-2003-2005-2006-2007 periods. It is apparent that there have been only small variations in the SPBIs over the 2002-2003-2005-2006-2007 periods. While there have been some changes in the relativities over the five years, overall the trends in 2007 data are similar to those in 2006, 2005, 2003 and 2002 data. Overall, the PCCs tended to be the loudest pavement surfaces studied while the OGAs were consistently the quietest except in 2007 when the DGA's were the quietest. On average the total range from the PCCs to the OGAs was 2.9 dB(A) in 2007 (Table 3) and this range was less than in 2002, 2003, 2005 and 2006. The same trends were observed in the data of the other traffic compositions.

The relative and absolute acoustic performance of the pavement surfaces over time

The differences between the SPBIs over the five years were explored further in Table 4 where it is demonstrated that some small changes in road traffic noise levels would have occurred on the five pavement surfaces over the 2002-2003-2005-2006 periods. The trends apparent in Table 4 are summarised below the table and are based on the premise that the "high speed" 90-5-5 traffic conditions remained constant throughout the 2002-2003-2005-2006-2007 periods. Once more the same trends were observed in the data of the other traffic compositions.

- On the OGAs, road traffic noise levels would have remained essentially stable from 2002 to 2003, increased slightly from 2003 to 2005, increased slightly again from 2005 to 2006 and increased further from 2006 to 2007. On average, in 2007 the road traffic noise levels on the OGAs would have been 3.8 dB(A) higher than in 2002.
- On the SMAs, road traffic noise levels would have very slightly increased from 2002 to 2003, subsequently increased very slightly more from 2003 to 2005, increased slightly more from 2005 to 2006. On average, in 2007 the road traffic noise levels on the SMAs would have been 2.5 dB(A) higher than in 2002.

Table 3. Comparisons of the high speed SPBIs over the 2002-2003-2005-2006-2007 periods for 90-5-5 traffic composition

Pavement Surface Type	Average (and Standard Deviation) SPBI (dB(A))				
	2007 Data	2006 Data	2005 Data	2003 Data	2002 Data
OGA	82.9 (1.9)	81.4 (1.5)	80.4 (1.4)	78.9 (1.1)	79.1 (1.5)
SMA	81.9 (1.4)	81.2 (1.8)	80.6 (1.5)	80.1 (1.2)	79.4 (1.4)
DGA	81.4 (2.2)	81.4 (2.3)	80.9 (1.4)	81.1 (1.2)	80.8 (1.8)
CS	84.2 (1.4)	84.0 (1.2)	83.2 (1.3)	83.9 (0.8)	85.0 (0.8)
PCC	85.8 (2.0)	86.3 (1.9)	85.5 (1.9)	85.0 (1.3)	83.8 (0.6)
PCC – OGA	2.9	4.9	5.1	6.1	4.7

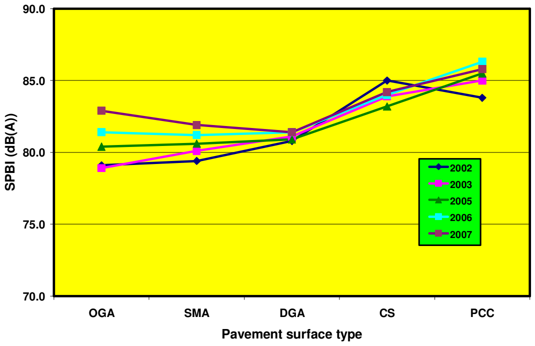

Figure 2 . Average SPBIs from the 2002, 2003, 2005, 2006 and 2007 data for 90-5-5 traffic composition and high speed traffic conditions.

Table 4. Changes in SPBIs over time for 90-5-5 traffic composition and high speed traffic conditions

Pavement Surface Type	Avge. SPBI (2003-2002 Data) (dB(A))	Avge .SPBI (2005-2003 Data) (dB(A))	Avge. SPBI (2006 - 2005 Data) (dB(A))	Avge. SPBI (2007-2006 Data) (dB(A))	Avge. SPBI (2007-2002 Data) (dB(A))
OGA	-0.2	1.5	1.0	1.5	3.8
SMA	0.7	0.5	0.6	0.7	2.5
DGA	0.3	-0.2	0.5	0.0	0.6
CS	-1.1	-0.7	0.8	0.2	-0.8
PCC	1.2	0.5	0.8	-0.5	2.0

- On the SMAs, road traffic noise levels would have very slightly increased from 2002 to 2003, subsequently increased very slightly more from 2003 to 2005, increased slightly more from 2005 to 2006. On average, in 2007 the road traffic noise levels on the SMAs would have been 2.5 dB(A) higher than in 2002.

- Road traffic noise levels on the DGAs would have remained essentially stable over the 2002-2003-2005-2006-2007 periods, being, on average, only 0.6 dB(A) higher in 2007 than in 2002.
- On the CSs, road traffic noise levels would have slightly decreased from 2002 to 2003, subsequently decreased very slightly more from 2003 to 2005, then increased slightly from 2005 to 2006 and subsequently remained essentially

stable from 2006-2007. On average, in 2007 the road traffic noise levels on the CSs would have been 0.8 dB(A) lower than in 2002.

- On the PCCs, road traffic noise levels would have slightly increased from 2002 to 2003, subsequently increased very slightly more from 2003 to 2005, increased slightly more again from 2005 to 2006 and reduced very slightly from 2006-2007. On average, in 2007 the road traffic noise levels on the PCCs would have been 2.0 dB(A) higher than in 2002.

It is also of importance to note the relevance here of what is known as "within type" variability in pavement surface noise data. This particular type of variability occurs for any type of pavement surface for which data are collected at several sites (Samuels and Dash 1996). Put simply, this means that the noise produced by a given pavement surface type at one site will not always be exactly the same as that measured on the same pavement surface type at another site. In pursuing this issue a little further, the within pavement surface type variabilities in the 2007, 2006, 2005, 2003 and 2002 data were determined and appear in Table 5. These variabilities are, in fact, the standard deviations associated with the average SPBIs in Table 2. It is quite apparent that the within type variabilities of Table 5 were all very small over the five pavement surface types of the 2007, 2006, 2005, 2003 and 2002 data and this observation is in accord with expectation (Samuels and Dash 1996). Overall, the average within type variabilities of 1.8, 1.7, 1.5, 1.1 and 1.2 dB(A) for the five data sets shown in Table 5 are very consistent with one another. What has now become apparent is that the magnitudes of these within pavement surface type variabilities are comparable to the magnitudes of the SPBI differences over time in Table 4. This is a rather important observation which assists in explaining the fluctuations evident in the data of Figure 2 and of Tables 3 and 4 as already discussed.

Table 5. Within pavement surface type variabilities in the high speed SPBIs for 90-5-5 traffic composition

Pavement Surface Type	Magnitude of SPBI Variability (dB(A))				
	2007 Data	2006 Data	2005 Data	2003 Data	2002 Data
OGA	1.9	1.5	1.4	1.1	1.5
SMA	1.4	1.8	1.5	1.2	1.4
DGA	2.2	2.3	1.4	1.2	1.8
CS	1.4	1.2	1.3	0.8	0.8
PCC	2.0	1.9	1.8	1.3	0.6
Mean	1.8	1.7	1.5	1.1	1.2
Standard Deviation	0.4	0.4	0.2	0.2	0.5

APPLICATIONS TO ROAD TRAFFIC NOISE PREDICTION

Allowing for the effects of pavement surface type in the prediction of road traffic noise

Of particular importance now are two key outcomes of the investigations discussed above and which are summarised as follows.

- Pavement surface type has an effect on the generation of road traffic noise. In 2007 the overall magnitude of this effect was such that the road traffic noise levels on the loudest pavement surfaces, the PCCs, would, on average, exceed those on the quietest pavement surfaces, the DGAs, by 4.4 dB(A). (Refer to Table 3.)
- The effect of pavement surface type on road traffic noise varied over the 2002-2003-2005-2006-2007 periods and the magnitudes of these variations differed amongst the five pavement surface types. From 2002 to 2007 these variations were greatest for the OGA pavement surfaces where the 2007 road traffic noise levels on these pavement surfaces would have exceeded their 2002 counterparts, on average, by 3.8 dB(A). They were least for the DGA pavement surfaces where the 2007 road traffic noise levels would have been, on average, a negligible 0.6 dB(A) greater than the 2002 values. (Refer to Table 4.)

As a consequence of the above outcomes, there are two processes that may be adopted in allowing for the effects of pavement surface type in the prediction of road traffic noise. The first involves the prediction of road traffic noise levels on pavement surfaces whose ages match those included in the 2007 Investigation. The second process is concerned with predicting road traffic noise levels on pavement surfaces whose ages match those included in the 2002, 2003, 2005, 2006 and 2007 investigations. Both processes involve the application of pavement surface correction factors to be applied in road traffic noise predictions in Queensland. These factors, which are based on the 2002, 2003, 2005, 2006 and 2007 Investigation outcomes, may be applied to prediction models such as the British Calculation of Road Traffic Noise (UK DoT 1988) (CoRTN) and the American Traffic Noise Model (Menge, Rossano, Anderson and Bajdek 1998).

Prediction of road traffic noise levels on pavement surfaces whose ages match those included in the 2007 Investigation

The 2007 SPBI data presented above may now be applied to allow for the effects of Queensland pavement surface type in the prediction of road traffic noise levels on pavement surfaces whose ages match those included in the 2007 Investigation. Specifically, from the complete set of data in Table 2 the average differences between the SPBI of the DGA and those of each of the other four pavement surface types were calculated for all four traffic compositions. These differences, which were very consistent for each pavement surface across the traffic compositions, were then averaged. They appear in Table 6 which sets out the Queensland pavement surface correction factors to be applied in predicting road traffic noise levels on the five pavement surface types whose ages match those of the pavement surfaces of the 2007 Investigation.

Table 6. Queensland pavement surface correction factors for application in predicting road traffic noise levels on Queensland pavement surfaces whose ages match those of the pavement surfaces included in the 2007 Investigation.

Pavement surface type (and average age (years))	Pavement surface correction factor (dB(A))	68% confidence limits around Correction Factor (dB(A))	95% confidence limits around Correction Factor (dB(A))
OGA (8)	+ 1.2	+0.5 to +1.9	- 0.3 to + 2.6
SMA (6)	+ 0.4	+0.3 to+ 0.5	+ 0.2 to + 0.6
DGA (6)	0.0	0.0	0.0
CS (8)	+ 2.6	+ 2.0 to + 3.2	+ 1.4 to + 3.8
PCC (7)	+ 4.3	+ 3.9 to + 4.7	+ 3.5 to + 5.1

Notes to Table 6.

- The data are based on the 2007 Investigation outcomes.

- The data are valid for "high", "medium" and "low" speed conditions.
- The data are valid for traffic compositions that range from 50% cars, 10% medium trucks and 40% heavy trucks to 100% cars and no trucks.
- All the data in Table 6 have been rounded to the nearest decimal place.

The application of the Correction Factors in Table 6 may be understood by way of a simple situation of using the CoRTN method to predict the road traffic noise level adjacent to a two lane, two way road with, say, a 8 year old CS pavement surface. As documented in UK DoT (1988), there is a sequence of steps to be undertaken when using CoRTN and these take into account the effects of many variables such as traffic flow, traffic composition, traffic speed and topographical conditions on the predicted noise level generated by the traffic on the road in question. The outcome of each of these steps is a number which must be added to those arising from all the other steps to produce the final predicted noise level. It is of some importance to note here that the prediction process is based on the assumption that the pavement surface of the road is a DGA. Therefore, the step concerned with the effect of pavement surface type involves assigning the relevant Correction Factor from Table 6 as an adjustment relative to DGA. In the present simple example where an 8 year old CS pavement surface is involved, the Correction Factor is + 2.6 dB(A).

The 68% and 95% confidence limits in Table 6 are not directly applied to the prediction process. Rather these are figures which quantify the within-type variability in pavement surface acoustic attributes as discussed previously. Consequently the 68% and 95% confidence limits should be borne in mind when the predicted noise level is being applied in, for example, assessing the likely road traffic noise impacts associated with the predicted noise level. Note that the accuracy of this predicted noise level has been determined from independent studies such as that discussed in Samuels, Peters and Hall (2004). Consequently the Table 6 confidence limits may be regarded as factors which can contribute to the accuracy associated with the predicted level.

Prediction of road traffic noise levels over time

The average age of the pavement surfaces of the 2007 Investigation are listed in the first column of Table 6. By way of further explanation, the average age of the pavement surfaces in 2002, 2003, 2005, 2006 and 2007 are presented below in Table 7. It is apparent that the average ages of all five groups of pavement surfaces are within two years of one another.

Table 7. Average ages of the pavement surfaces included in the pavement surface noise investigations

Pavement surface type	Average age of each group of pavement surfaces (Year)				
	2002 Investigation	2003 Investigation	2005 Investigation	2006 Investigation	2007 Investigation
OGA	3	4	6	7	8
SMA	1	2	4	5	6
DGA	1	2	4	5	6
CS	3	4	6	7	8
PCC	2	3	5	6	7

In order to predict road traffic noise levels over time a process is involved which commences with the prediction of road traffic noise levels in what might be described as a base study year on pavement surfaces whose ages correspond to those of the pavement surfaces included in the 2002 Investigation. Subsequently the road traffic noise levels are predicted on these pavement surfaces as they age over the next five years, based on the outcomes of the 2003, 2005, 2006 and 2007 Investigations. Just as explained immediately above, this process requires the application of road surface correction factors. The correction factors required here have been derived from the data of Tables 3 and 4 which present the SPBIs determined for 2002, 2003, 2005, 2006 and 2007. Consequently it is only possible herein to provide pavement surface correction factors for scenarios up to five years out from the base study year. If more data become available from any ongoing investigations of 2008 and beyond, scenarios of six and more years out will become possible. However, there will be a limit to this process for some pavement surfaces as they are subjected to periodical maintenance procedures. Initially just consider the 2002 and 2007 years and OGA pavement surfaces. Then, Equations 2 and 3 describe the process of determining the OGA pavement surface correction factors for 2002 and 2007 from the SPBIs of Table 3.

$$\mathrm{OGACF}_{2002} = \mathrm{SPBI}_{\mathrm{OGA2002}} - \mathrm{SPBI}_{\mathrm{DGA2002}} \qquad (2)$$

$$\mathrm{OGACF}_{2007} = \mathrm{SPBI}_{\mathrm{OGA2007}} - \mathrm{SPBI}_{\mathrm{DGA2007}} \qquad (3)$$

Where OGACF_{2002} = OGA pavement surface correction factor in 2002 (dB(A))

OGACF_{2007} = OGA pavement surface correction factor in 2007 (dB(A))

$\mathrm{SPBI}_{\mathrm{OGA2002}}$ = OGA SPBI determined in 2002 (dB(A))

$\mathrm{SPBI}_{\mathrm{DGA2002}}$ = DGA SPBI determined in 2002 (dB(A))

$\mathrm{SPBI}_{\mathrm{OGA2007}}$ = OGA SPBI determined in 2007 (dB(A))

$\mathrm{SPBI}_{\mathrm{DGA2007}}$ = DGA SPBI determined in 2007 (dB(A))

In relation to data in the OGA and DGA rows in Table 3, Equations 4 and 5 quantify the differences between the OGA SPBIs in 2002 and 2007 (Equation 4) and between the DGA SPBIs in 2002 and 2007 (Equation 5).

$$\mathrm{SPBI}_{\mathrm{OGA2007}} - \mathrm{SPBI}_{\mathrm{OGA2002}} = 3.8 \qquad (4)$$

$$\mathrm{SPBI}_{\mathrm{DGA2007}} - \mathrm{SPBI}_{\mathrm{DGA2002}} = 0.6 \qquad (5)$$

Now Equations 4 and 5 may be rearranged as follows in Equations 6 and 7.

$$\mathrm{SPBI}_{\mathrm{OGA2007}} = \mathrm{SPBI}_{\mathrm{OGA2002}} + 3.8 \qquad (6)$$

$$\mathrm{SPBI}_{\mathrm{DGA2007}} = \mathrm{SPBI}_{\mathrm{DGA2002}} + 0.6 \qquad (7)$$

Equations 6 and 7 may now be substituted into Equation 3 and subsequently manipulated as follows:

$$\begin{aligned}\mathrm{OGACF}_{2007} &= \mathrm{SPBI}_{\mathrm{OGA2007}} - \mathrm{SPBI}_{\mathrm{DGA2007}} \qquad (3)\\ &= (\mathrm{SPBI}_{\mathrm{OGA2002}} + 3.8) - (\mathrm{SPBI}_{\mathrm{DGA2002}} + 0.6)\\ &= \mathrm{SPBI}_{\mathrm{OGA2002}} - \mathrm{SPBI}_{\mathrm{DGA2002}} + 3.8 - 0.6\\ \mathrm{OGACF}_{2007} &= \mathrm{SPBI}_{\mathrm{OGA2002}} - \mathrm{SPBI}_{\mathrm{DGA2002}} + 3.2\end{aligned}$$

That is, $\mathrm{OGACF}_{2007} = \mathrm{OGACF}_{2002} + 3.2 \qquad (8)$

Equation 8 quantifies the relationship between the 2002 and 2007 OGA pavement surface correction factors and, importantly, allows for the differences in the OGA SPBIs between

2002 and 2007 along with the small differences in the DGA SPBIs between 2002 and 2007. In other words, by allowing for the differences in the 2002 and 2007 SPBIs, the 2007 pavement surface correction factors can be calculated from the 2002 values. There are, of course other ways of deriving Equation 8. These include manipulating the data in Tables 3 and 4. However, the process set out above is the most fundamental of all these and assists in understanding both the detailed nature and origin of each pavement surface correction factor and how the 2007 factors were determined from the 2002 values.

The process set out above was applied to all pavement surface types to produce the pavement surface correction factors of Table 8. These factors are presented for a base study year (based on the 2002 data) and subsequently for one, three, four and five years beyond the base study year (based on the 2003, 2005, 2006 and 2007 data respectively). Note the close agreement between the pavement surface correction factors in the sixth column of Table 8 for five years out from the base study year with the corresponding factors for each pavement surface type determined in 2007 as listed in the second column of Table 6. This close agreement confirms the integrity of the process documented immediately above. Note also that for each pavement surface type the factors of Table 8 are only applicable to pavement surfaces whose ages correspond to those set out in Tables 7 and 8.

Table 8. Queensland pavement surface correction factors for application in predicting the levels of road traffic noise in Queensland in a base study year and up to five years beyond.

Pavement Surface Type	Pavement Surface Correction Factor (dB(A)) Pavement Surface Age (Years))				
	Base Study Year	One year out from base study	Three years out from base study year	Four years out from base study year	Five years out from base study year
OGA	-1.7(3)	-2.2(4)	-0.5(6)	0.0(7)	1.5(8)
SMA	-1.4(1)	-1.0(2)	-0.3(4)	-0.2(5)	0.5(6)
DGA	0.0(1)	0.0(2)	0.0(4)	0.0(5)	0.0(6)
CS	4.2(3)	2.8(4)	2.3(6)	2.6(7)	2.8(8)
PCC	3.0(2)	3.9(3)	4.6(5)	4.9(6)	4.4(7)

CONCLUSIONS

On the basis of what appears in the present paper the following conclusions have been drawn.

- Pavement surface type has an effect on the generation of road traffic noise. In Queensland during 2007 the overall magnitude of this effect was such that the road traffic noise levels on the loudest pavement surfaces, the PCCs, would, on average, exceed those on the quietest pavement surfaces, the DGAs, by 4.4 dB(A). (Refer to Table 3.)
- The effect of pavement surface type on road traffic noise in Queensland varied over the 2002-2003-2005-2006-2007 periods and the magnitudes of these variations differed amongst the five pavement surface types. From 2002 to 2007 these variations were greatest for the OGA pavement surfaces and were least for the DGA pavement surfaces. In 2007 road traffic noise levels on the OGA pavement surfaces would have exceeded their 2002 counterparts, on average, by 3.8 dB(A). Also in 2007, the road traffic noise levels on the DGA pavement surfaces would have been, on average, a negligible 0.6 dB(A) greater than the 2002 values. (Refer to Table 4.)
- Pavement surface correction factors for each of the five pavement surface types included in the 2007 Investigation were determined. These factors, which are applied in the process of the prediction of road traffic noise levels, varied from +0.4 dB(A) and +1.2 dB(A) for the SMAs and OGAs respectively to +2.6dB(A) and + 4.3 dB(A) for the CSs and PCCs respectively.
- By allowing for the age of the pavement surfaces included in the 2002, 2003, 2005, 2006 and 2007 Investigations, pavement surface correction factors were determined to facilitate road traffic noise predictions to be conducted over a five year time frame.
- The complete outcomes of the 2007 Investigation are documented in Samuels (2008).

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