Distribution of the noise level maxima from the pass-by of vehicles in urban road traffic streams

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Abstract

The paper reports the distributions of noise level maxima, $L_{A\text{Fmax}}$, generated during the pass-by of over 85,000 vehicles in service on urban arterials and motorways. These were measured under normal traffic and vehicle operating conditions on multilane roadways. They are indicative of the instantaneous maximum noise levels that would be experienced in the free field at the set-back distance of the facades of the first row of many dwellings fronting urban roadways in Australia, from vehicles travelling in the nearside lane. Noise levels are reported separately for four classes of vehicle and for roadways with five different posted speed limits. Results have been standardised as free-field levels 15 m from the centreline of vehicle travel. The data were collected in Brisbane but can be assumed to be representative of noise level maxima from vehicles operating throughout Australia. Maximum noise levels increase with vehicle class (from cars through to articulated trucks) and with roadway speed limits. The within-vehicle-class variance is large and the distributions of maxima from different vehicle classes overlap extensively. Sound Power Levels of the observed vehicles agree well with those from the European IMAGINE emission model. This investigation contributes essential information regarding the source and levels of noise events adjacent to urban road networks – the likely determinant of human sleep disturbance.

INTRODUCTION

Most measurements of road traffic noise – and criterion levels utilised for mitigation and planning purposes – use single-number metrics of the fluctuating signal of the road traffic noise stream. These include the tenth percentile exceedance level ($L_{10}$), the equivalent continuous sound level ($L_{eq}$), or derivatives of the latter over the whole day such as the day–evening–night level ($L_{den}$) or the night period ($L_{night}$). However, there is research evidence...
that the physiological effect of transport noise on human sleep may depend more on the level and number of noise events in traffic streams than on integrated energy measures such as $L_{eq}$ (Griefahn, Marks & Robens 2006; Pirrera, de Valck & Cluydts 2010).

Community reaction to sleep disturbance from night-time noise has been highlighted in a review of the increased operations of night-time freight traffic in Australia (Austroads 2007). That review recognised that community reaction to the noise made by heavy vehicles on urban roadways, particularly late at night when many trucks prefer to travel because of lower levels of congestion, will be a major constraint to the future movement of trucks in urban areas. It also noted that authorities have yet to develop criteria defining acceptable incidence (and magnitude) of traffic-related noise events, and that current noise measurement techniques do not readily accommodate the assessment of the discontinuous noise of large vehicles travelling at night.

All new road traffic vehicles are required to comply with regional and/or national regulations that include maximum noise levels they can generate during certain test procedures (Haider et al. 2007). Vehicle Standard (2005) specifies the test procedures and limits used in Australia – effectively a drive-by test under controlled acceleration/deceleration conditions. However, the relationship between noise levels generated by vehicles under this controlled test procedure and the levels they generate in practice on roadways under normal operating conditions is not clear. There are currently only a few published measurements of the maximum noise levels generated by in-service vehicles on Australian roadways (Campbell & Parnell 2004; Treagus & Beazley 2005; Naish 2010).

In this paper, we report the distribution of noise level maxima generated during the pass-by of a large number of vehicles, of different types, on urban roadways and motorways in Brisbane, Australia.

**THE FIELD STUDY**

**The study sites**

A study of a road corridor in Brisbane had been designed as a longitudinal assessment of the efficacy of a truck management scheme in reducing the impacts of urban truck flows on the adjacent residential community. Monitoring associated with the implementation of the scheme included, *inter alia*, the measurement of conventional metrics of noise at various points along the corridor (Brown et al. 2009) but also the measurement of the maximum levels of the noise events from individual vehicles passing in the traffic stream – the latter obtained by attended noise monitoring that included identification of the vehicle responsible for each noise event.

While designed to assess a traffic management scheme, not the source noise levels of vehicles (or Sound Power Levels), the data set provided an unprecedented opportunity to examine the noise level maxima generated by the pass-by of a very large number of vehicles under normal operating conditions (Figure 1) – though with some caveats, discussed in the next paragraph, with respect to the vehicle operation, measurement site and propagation conditions under which the data were collected.

The data set consisted of maximum noise levels from over 85 000 vehicles recorded at ten sites beside urban motorways and urban arterial roadways. Posted speed limits on these roadways ranged from 60 to 100 km/h and eight of the ten sites carried freely flowing traffic. Site conditions and vehicle-operation conditions were often divergent from those that would have been chosen had the study been one of controlled measurements of vehicle pass-by noise levels. For example, all roadways had two carriageways and each carriageway had two or three lanes. Roadway widths and median strip widths varied across the study sites, as did the setbacks of the measurement sites from the roadways. Measurements were conducted on one side of the roadway, with maxima detected from vehicles passing by on both the near and far carriageways. Actual vehicle speeds were not able to be measured and would have varied around the posted speed limit. At some sites, the acoustic field was influenced by buildings fronting the roadway and measurements at these were located at a standard 1 m from the building facade. All road surfaces were DGAC (dense graded asphaltic concrete). The section of roadway at each of the measurement sites was of zero gradient, but several had adjacent sections of roadway with non-zero gradients that could have resulted in residual effects on driver behaviour or vehicle operation as vehicles passed the measurement site.

Vehicle pass-by noise levels would normally be obtained using measured or controlled vehicle speeds, vehicle-to-receptor distances and vehicle accelerations. Divergences from controlled site and vehicle operational conditions in this study will have resulted in increased dispersion in the measured maximum noise levels. However, the advantage is that the current data set robustly represents the maximum vehicle noise levels that
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are experienced, in practice, adjacent to many urban roadways carrying freely flowing traffic. They are indicative of the instantaneous maximum noise levels, from vehicles travelling in the nearside lane, experienced in the free field at distances that approximate the set-back of facades of the first row of many dwellings fronting roadways in urban Australia.

The manner in which the pass-by noise levels were collected, manipulated and filtered is described below.

**Measurement of maximum vehicle pass-by noise level, \( L_{AF_{\text{max}}} \)**

All measurements were conducted in the Brisbane metropolitan area. Four sites were adjacent to two-way urban arterial roadways (four to six lanes with posted speeds of 60 or 70 km/h) and six were beside dual carriageway urban motorways (two-lane carriageways with posted speeds of 80, 90 or 100 km/h). Measurements were made of vehicles travelling on both near and far carriageways. Distance from the microphone to the centreline of the respective carriageway carrying freely flowing vehicles ranged from 13 to 38 m, with the median distance being 16 m for vehicles on the near carriageway and 27 m for vehicles on the far carriageway.

Noise measurements used Acoustic Research Laboratories Environmental Noise Loggers in conjunction with SPLendid loggers. The latter were set to record the \( L_{AF_{\text{max}}} \) during noise events according to the following operational characteristics:

- sampling period 200 ms
- minimum value of recorded maxima 60 dB(A)
- required drop in noise level before next maximum 5 dB(A)
- maximum wait time for above drop in noise level 25 s
- minimum period before next maximum 3 s.

These event-detection characteristics were the same as utilised by Campbell and Parnell (2004). Calibration of the equipment was checked at the beginning and end of each site measurement using a Brüel & Kjær 4231 calibrator.

When the equipment detected a noise event under this protocol, operators identified the vehicle type responsible for the event (a judgement as to which passing vehicle was acoustically dominant) and the direction in which the vehicle was travelling. The demands of visually identifying the vehicle responsible for each noise event resulted in some events being unassigned, and these have been excluded from further analysis. Exclusions can be considered random in terms of vehicle type.

Measurements were conducted between the times 2200 and 0500. These night-time hours were dictated by the original purposes of the truck management study, but they had advantages for vehicle pass-by measurement in that movement on the roadways was not constrained by congested flow conditions. The larger vehicle headways at these hours increased the likelihood that maximum pass-by noise levels of individual vehicles would be detected, and the particular vehicle source would be visually identified. Measured vehicle pass-by noise levels will have included some unquantified contribution from other vehicles (and other non-traffic related sounds) in the vicinity of the vehicle.
that triggered the noise event. Given the relatively lower flow rates on the roadways during the nighttime periods, the error in vehicle maximum noise level introduced in this way is likely to have been small for the majority of event maxima.

Equipment-based noise event measurement can result in non-detection of the pass-by of quieter vehicles when noise levels fail to reach the trigger level set for event detection – 60 dB(A) in this instance. Such non-detection occurred systematically in this study for quieter cars passing in the far carriageway at several measurement sites distant from the far carriageway. All cars detected on these carriageways were excluded from the data set to avoid introducing systematic bias in reporting the distribution of their pass-by maxima.

Three corrections have been made to the measured maximum noise levels to normalise the results reported below. First, a –3 dB facade correction was applied to those measurements made within 1 m of building structures to remove the effect of facade reflections, in accordance with Nordtest (2002). Second, as variation in the terrain between vehicle source and microphone at the different sites will have influenced the measured noise levels (depending on terrain and the flow resistivity of the ground surface between source and microphone), these have been corrected to free-field conditions. This correction was made, independently for each carriageway at each site, using the propagation effect-of-terrain component of the Nord2000 model. The model identifies a Fresnel zone of reflection on the intervening ground surface (Plovsing & Kragh 2006) and estimates the terrain effect based on one-third octave bands. This correction resulted in an estimate of the noise level at the measurement location that would have resulted from spherical propagation alone from the vehicle source (no effects from ground, or facade, reflection or from shielding). Third, all noise levels have been normalised to a distance of 15 m from the carriageway. This choice of 15 m approximates the median propagation distance in Australian cities between dwelling facades and the nearest roadway lane: Brown and Lam (1994) reported the median distance from facades to roadway kerbs as 13 m.

It had not been feasible to record the lane of the carriageway in which the pass-by vehicle travelled, and the normalisation of the maximum noise levels to a distance of 15 m were based on the assumption that vehicles travelled on the centreline of the carriageway. This introduced an error, the magnitude of which depended on the actual lane of travel (error increased with the number of lanes in the carriageway) and the setback of the measurement equipment from the carriageway (error decreased with increasing setback). To ensure that this error did not exceed 2 dB(A) for any measurement, carriageways were excluded from the analysis where measurement sites were less than 5 m from a carriageway of two lanes and 12 m from a carriageway of three lanes. In fact, most such errors would have been considerably less than 2 dB(A) as the median carriageway to measurement setback at the sites at which data were collected for this study was 24 m.

**Vehicle classification**

The vehicle judged by operators as responsible for each noise maximum was classified as car, articulated truck, non-articulated truck, bus or motorcycles. In the reporting below, buses have been incorporated into the non-articulated trucks category. The relationship of this four-type vehicle classification with Austroads and other (noise-related) classification schemes is shown in Table 1.

**RESULTS**

**Free-flow roadways**

The distributions of the free-field maximum noise levels, $L_{A_{fmax}}$, for each vehicle type are shown in the histograms of Figures 2 to 5. Noise levels for the eight free-flowing sites, and from both near and far carriageways, are aggregated in these results, comprising 71 035 of the available 85 562 vehicle noise level maximum measurements. The balance of measurements is of vehicles at sites where traffic behaviour was influenced by traffic control devices, and these are reported separately below.

For the free-flow sites, separate distributions of vehicle noise level maxima are reported within each figure for each posted speed limit. As there was a large difference in the numbers of available measurements at different posted speed limits, Figures 2 to 5 report frequency counts, rather than relative frequencies, to clearly convey the different sample sizes of vehicle types and speeds within the data set. For ease of comparison, the mean and median vehicle pass-by noise levels of each of the distributions shown in Figures 2 to 5 are tabulated in Table 2.

As expected, the maximum noise levels from each class of vehicle increase with posted speed limit as both vehicle propulsion noise and noise from tyre–pavement interaction increase with vehicle speed (Haider et al. 2007; Jonasson 2007). Also as expected, articulated trucks tend to generate higher maximum noise levels than do non-articulated trucks, which in turn generate higher noise levels.
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than cars. Motorcycle maxima are similar to those of non-articulated trucks.

The variance of the noise levels within all vehicle classes is high, with the $L_{AF\text{max}}$ of some 90% of the vehicles of each type extending over a range of 12–20 dB on roadways with posted speeds of less than 100 km/h, and up to 30 dB where the posted speed limit was 100 km/h. The large variance in the noise levels from each class of vehicle results in the distributions of their maxima overlapping extensively. This means, for example, that the noisiest of events at any location is likely to be from the passing of an articulated truck, some cars and non-articulated trucks will have $L_{AF\text{max}}$ higher than those of articulated trucks. Figure 6 shows which types of vehicles produced maxima at two posted speed limits: 60 and 100 km/h. For 60 km/h roadways, $L_{AF\text{max}}$ of up to 72 dB were generated predominantly by cars, but maxima above this were generated predominantly by articulated trucks. For 100 km/h roadways, this transition occurred above 78 dB.

**Interrupted flow roadways**

Vehicle noise level measurements from the two sites where traffic was not freely flowing permit some useful, though limited, observations on the noise level maxima under interrupted flow conditions. Interrupted flow is associated with traffic congestion, signalised and non-signalised intersections, stop lines, roundabouts and toll booths. Road traffic noise generated at intersections and traffic control devices has been subjected to considerable investigation and modelling (Quartieri et al. 2010; Chevallier et al. 2009; de Coensel & Botteldooren 2007) with a focus on how the kinematics of vehicles in these conditions influences overall noise levels, $L_{A\text{eqr}}$ compared to noise levels under free-flow conditions.

Table 1

Comparison of vehicle type classification used in this study with the classifications of Austroads, IMAGINE, Australian Vehicle Standards and TNM

<table>
<thead>
<tr>
<th>Vehicle type classification</th>
<th>This study</th>
<th>Cars</th>
<th>Non-articulated trucks (and buses)</th>
<th>Articulated trucks</th>
<th>Motorcycles</th>
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</thead>
<tbody>
<tr>
<td>Austroads&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Cat. 1 &amp; 2</td>
<td>Cat. 3 two axles</td>
<td>Cats 4–12 three or more axles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMAGINE&lt;sup&gt;2&lt;/sup&gt;</td>
<td>[1] light motor vehicles</td>
<td>Passenger cars, delivery vans &lt;3.5 t SUVs, MPVs</td>
<td>[2] medium heavy vehicles</td>
<td>Heavy duty vehicles, touring cars, buses, with three or more axles</td>
<td></td>
</tr>
<tr>
<td>EU/ECE type approval&lt;sup&gt;3&lt;/sup&gt; and referred to in Australian Vehicle Standard (&lt;sup&gt;2005&lt;/sup&gt;)</td>
<td>M1 and N1</td>
<td>M2, M3 and N2, N3</td>
<td>M2 and N2 with trailer, M3 and N3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Two axles and four tyres, &lt;10 pass, or cargo (vans light trucks) GVW &lt; 4.5 t</td>
<td>Buses [4]</td>
<td>Three or more axles GVW &gt; 12 t</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Passenger cars, delivery vans &lt;3.5 t</td>
<td>Medium heavy vehicles, delivery vans &gt;3.5 t buses, with two axles and twin tyre on rear axle</td>
<td>Heavy duty vehicles, touring cars, buses, with three or more axles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Austroads (undated)
2 Peeters & van Blokland (2007)
3 European Commission (2010)
4 Traffic Noise Model (FHWA 2008).
Distributions of the noise level maxima, $L_{A\text{Fmax}}$ of cars ($n = 37,686$) standardised as free-field levels at 15 m from the centreline of vehicle travel. Separate distributions are shown for vehicles travelling on carriageways with different posted speed limits. These results aggregate measurements from all free-flowing sites, and from both near and far carriageways. The distributions include only those passing vehicles that generated at least 60 dB(A) at the measurement point (before standardisation); hence vehicles generating less than this are not included in the population of cars studied.

Distributions of the noise level maxima, $L_{A\text{Fmax}}$ of non-articulated trucks ($n = 6832$) standardised as free-field levels at 15 m from the centreline of vehicle travel. Separate distributions are shown for vehicles travelling on carriageways with different posted speed limits.
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Figure 4
Distributions of the noise level maxima, $L_{\text{AFmax}}$, of articulated trucks ($n = 25,527$) standardised as free-field levels at 15 m from the centreline of vehicle travel.

Separate distributions are shown for vehicles travelling on carriageways with different posted speed limits.

Figure 5
Distributions of the noise level maxima, $L_{\text{AFmax}}$, of motorcycles ($n = 990$) standardised as free-field levels at 15 m from the centreline of vehicle travel.

Separate distributions are shown for vehicles travelling on carriageways with different posted speed limits.
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conditions. There has been less attention to how they influence the maximum vehicle pass-by noise levels.

Of the two interrupted flow sites in this study, one was located on a 60 km/h urban arterial roadway between two sets of traffic signals (40 and 70 m distant) that controlled intersections with minor roadways. The operation of individual vehicles on the arterial was influenced by both the upstream and downstream traffic signals during particular signal phases, though vehicles flowed freely during the extended green phase for traffic on the major roadway. The other site was located 160 m from a toll booth on a 100 km/h freeway, with vehicles on the nearside carriageway accelerating to full speed after stopping to pay the toll, and vehicles on the farside carriageway decelerating towards the toll booth.

Figure 7 compares the distribution of $L_{AFmax}$ at the site affected by traffic signals with the distribution under free-flow conditions on a roadway with the same posted speed limit (60 km/h). Results are shown only for articulated trucks, though the findings are similar for cars and non-articulated trucks. At this between traffic lights site, the noise level maxima of articulated trucks covers the same range as those of the free-flow sites, but with a large reduction in the proportion of trucks producing noise levels near the modal value of 76 dB. This, together with a flattening of the distribution, indicates that articulated trucks tend to produce lower maximum noise levels under this type of interrupted flow conditions. More investigation of the effects of traffic signals on vehicle maxima is warranted given that the spatial variation in the effects of traffic signals on vehicle emissions is complex (de Coensel & Botteldooren 2007). The interrupted flow distribution of maxima in Figure 7 is likely a combination of two or more underlying distributions: one of the maxima of vehicles passing during much of the green phase on the arterial roadway, the other(s) of the maxima of vehicles travelling at lower speeds, decelerating or accelerating as the traffic signals changed.

Figure 8 shows the distribution of $L_{AFmax}$ at the site affected by the toll booth, again for articulated trucks. At this site, some 160 m from the booth, trucks departing the toll booth (the accelerating carriageway) and approaching the toll booth (the decelerating carriageway) generated maximum pass-by noise levels much lower than those measured under free-flow conditions – particularly so for the latter. This presumably resulted from lower vehicle speeds at the measurement site than in free-flow conditions, and the reduction in propulsion noise from those vehicles coasting on their approach to the booth.

**COMPARISON OF SOUND POWER LEVELS OF VEHICLE TYPES**

Using the median values from the distributions (Figures 2 to 4) of the noise level maxima of each vehicle type (motorcycles have not been included because of their relatively low sample size in the current study), the Sound Power Level of the

### Table 2
Mean, median and standard deviations of the distributions of noise level maxima (dB re 20 μPa) in Figures 2–5

<table>
<thead>
<tr>
<th>Posted speed limit km/h</th>
<th>Cars</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>67</td>
<td>69</td>
<td>69</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>67</td>
<td>70</td>
<td>69</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>4.6</td>
<td>5.1</td>
<td>3.5</td>
<td>4.4</td>
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<tr>
<td>Non-articulated trucks</td>
<td>mean</td>
<td>71</td>
<td>73</td>
<td>75</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>72</td>
<td>73</td>
<td>74</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>5.1</td>
<td>5.5</td>
<td>4.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Articulated trucks</td>
<td>mean</td>
<td>73</td>
<td>76</td>
<td>77</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>75</td>
<td>77</td>
<td>77</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>6.0</td>
<td>5.7</td>
<td>4.1</td>
<td>6.0</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>mean</td>
<td>69</td>
<td>72</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>69</td>
<td>72</td>
<td>75</td>
<td>75</td>
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<tr>
<td></td>
<td>sd</td>
<td>5.5</td>
<td>5.3</td>
<td>5.8</td>
<td>5.1</td>
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</table>
vehicles can be estimated. As the measured $L_{A\text{max}}$ values have been corrected to free-field noise levels at 15 m from the centreline of vehicle travel, Sound Power Levels, $L_W$, of the vehicle sources can be calculated by allowing for the effects of spherical divergence of the sound energy from source to receiver (after Beranek 1971):

$$L_W = L_{A\text{max}} + 20 \log(r) + 10 \log(4\pi)$$  \hspace{1cm} (1)

This denotes the propagation effect of divergence over a sphere with a surface area of $4\pi r^2$. With $r = 15$ m, Equation 1 can be rewritten as:

$$L_W = L_{A\text{max},15\text{m}} + 34.5$$  \hspace{1cm} (2)

Sound Power Levels estimated from the current measurements at each posted speed limit are shown in Table 3. This approximation ignores any specific source directivity of vehicles. No directivity for

For roadways with posted speed limits of 60 km/h (upper) and 100 km/h (lower), the figures show the proportion of the noise events of any level of $L_{A\text{max}}$ that have been generated by each of the four vehicle types.

Figure 6
Distribution of noise events for different vehicle types.

Figure 7
Relative frequencies of the noise level maxima, $L_{A\text{max},1305}$ of articulated trucks on roadways with posted speed limit of 60 km/h.

The figure compares the maxima ($n = 1305$) recorded under interrupted flow conditions between two sets of traffic lights, 40 m and 70 m distant from the measurement site, to maxima measured under free-flow traffic conditions.
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hemispherical propagation needs to be included in these equations as the adjustment utilized for effect-of-terrain from the Nord2000 model corrected the measured levels to free-field levels.

The Harmonoise/IMAGINE model has been developed in the EU over the last 10 years in order to create a single harmonised method for noise mapping in all of the EU member states. Source modelling in both IMAGINE (Peeters & van Blokland 2007) and Harmonoise (Nota, Barelds & van Maercke 2005) is divided in two parts: rolling (tyre–pavement) noise \( (L_{WR}) \) and propulsion noise \( (L_{WP}) \). The Sound Power Level of the vehicle sources in these models, \( L_W \), comprises two terms:

\[
L_W = 10 \log(10^{L_{WR}10} + 10^{L_{WP}10})
\]

The propulsion and rolling noise terms respectively are dependent on the vehicle speed \( s \) and coefficients \( -A \) and \( B \):

\[
L_{WR} = A_R + B_R \log \left( \frac{s}{s_{ref}} \right)
\]

\[
L_{WP} = A_P + B_P \frac{s - s_{ref}}{s_{ref}}
\]

Using coefficients \( A_R, B_R, A_P \) and \( B_P \) from the IMAGINE model and the Harmonoise model (Nota, Barelds & van Maercke 2005) and the \( s_{ref} \) being 70 km/h, \( L_W \) can be calculated using Equations 3 to 5.

The estimated Sound Power Levels of vehicle sources in IMAGINE are also shown in Table 3. The median Sound Power Levels from the present study are very close to those of IMAGINE (a mean difference of +0.3 dB across all speeds and vehicle types, with a maximum difference of –3 dB), but somewhat lower than those of the older vehicle source strengths from the Harmonoise model (a mean difference of –1.6 dB across all speeds and vehicle types, with a maximum difference of –5 dB).

Naish (2010) performed a measurement study in Queensland with 2241 vehicles on several different pavement surface types. Sound Power Levels for the different vehicle types and surface types were calculated from measured noise level (shown for the DGAC road surface in Table 3) and compared them with those in the prediction models Harmonoise (Nota, Barelds & van Maercke...
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2005) and DK 2000 (Jonasson 2006). His measured results are 2–6 dB higher than the median values measured in this study, with the largest difference being for articulated trucks. There is no immediate explanation for this difference. Both studies were in-situ measurements of pass-by vehicles, though the locational and traffic contexts of the measurements, and measurement procedures, were very different in the two studies.

CONCLUSIONS

Pirrera, de Valck & Cluydts (2010) conclude in their review of the consequences of nocturnal road traffic noise and sleep:

When performing research in the field of noise and sleep, it is important to clarify the different features of traffic noise and to apply a reliable noise–dose descriptor, which not only includes mean $L_{Aeq(t)}$, but also the number and maximum level of noise events.

There is a dearth of information available on the number and maximum level of noise events generated from the traffic streams operating on roadways in urban areas in Australia. Future management of sleep disturbance from road traffic noise, and of night-time operations of freight traffic and other vehicle sources that generate noise events, will depend on the availability of better information on the sources, characteristics, measurement and extent of such noise events in nocturnal road traffic streams. The data presented in this paper is a contribution to increased understanding of the sources, relative numbers and levels, of noise event maxima from traffic streams adjacent to urban arterial roadways and motorways in Australia. The focus is on the noise immission levels of these events at distances from roadways where people may live, rather than on the noise emission levels from the vehicle sources – though estimates of source levels have been provided for comparison purposes.

Noise level maxima, $L_{A\text{fmax}}$, generated by the pass-by of a large number of vehicles, standardised as free-field noise levels at 15 m from the centreline of vehicle travel, on DGAC road surfaces, have been reported above. Separate distributions of maxima have been reported for vehicles travelling on carriageways with posted speed limits from 60 to 100 km/h. The maximum noise levels within each class of vehicle increase with posted speed limit.

Articulated trucks tend to generate higher maximum noise levels than do non-articulated trucks, and they in turn generate higher noise levels than cars. Motorcycle maxima are similar to those of non-articulated trucks. For 60 km/h roadways, the majority of $L_{A\text{fmax}}$ of up to 72 dB(A) were generated by cars, but maxima above this were generated by articulated trucks. For 100 km/h

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Comparison of the estimated Sound Power Levels (dB re 20 µPa) of cars, non-articulated trucks and articulated trucks in the present study with those predicted by the Harmonoise and IMAGINE models, and those measured by Naish (2010) on DGAC road surfaces</th>
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<tr>
<td></td>
<td>Posted speed limit km/h</td>
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<td><strong>Cars</strong></td>
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<td><strong>Non-articulated trucks</strong></td>
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<td><strong>Articulated trucks</strong></td>
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</table>
roadways, this transition occurred above 78 dB(A). However, the distributions of noise level maxima from different vehicle types overlap extensively. While the very noisiest of events at any location is likely to be from the passing of an articulated truck, some cars and non-articulated trucks will generate $L_{A_{\text{max}}}$ higher than do some articulated trucks.

The variance of the maxima within all vehicle classes is high, with the $L_{A_{\text{max}}}$ of some 90% of the vehicles of each type extending over a range of between 12 and 20 dB(A) on roadways with posted speeds of less than 100 km/h, and up to 30 dB(A) where the posted speed limit was 100 km/h. The large variance in vehicle maxima reflects not just differences in vehicle source strengths, but their measurement under real-world operating conditions on urban arterial roadways and motorways. These real-world conditions, as compared to controlled conditions generally used in measurement of pass-by noise levels of vehicles, include vehicles travelling on either of the near or far carriageways, and on any lane of either carriageway. Real-world conditions also include variability in driver operating behaviour, with speed and acceleration determined primarily by the posted speed limit of the roadway and interaction with other vehicles. The distributions of vehicle noise level maxima reported here thus robustly represent the distributions of maxima that will be experienced near roadways. They are indicative of the free-field maximum noise levels, from individual vehicles travelling in the nearside lane, at the setback distances of the façades of many dwellings in Australia that front urban arterial roadways.

The Sound Power Levels of cars, non-articulated trucks and articulated trucks have been estimated on the basis of the median of the distributions of noise level maxima measured in this study. These estimates are generally consistent with those predicted by the European Harmonoise/IMAGINE traffic noise models for vehicles on DGAC roadway surfaces. Differences averaged 0.3 dB across all speeds and vehicle types, with a maximum difference of −3 dB for the IMAGINE predictions. The noise levels are 2 to 6 dB lower than those measured by Naish (2010) for the same vehicle types, DGAC road surface and individually measured vehicle speeds of 80 to 100 km/h.

The work is a contribution to further understanding of the nature of noise events in streams of road traffic, and to future strategies for their measurement and management. Knowledge of the maximum noise levels generated by different vehicle categories under operating conditions is also important for any program of noise management using noise camera installations to identify individual noisy vehicles (Klos 2006).

REFERENCES


Distribution of the noise level maxima from the pass-by of vehicles in urban road traffic streams


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Lex Brown is Professor of Environmental Planning in the Urban Research Program, Griffith School of Environment in Brisbane, Australia. His major research interests lie in tools that interface between the environmental scientist and the planning and engineering professions. He works extensively in environmental assessment of all aspects of development, at project and strategic levels, and in both developed and developing countries. He began his research career as a transport engineer working on ARRB supported projects in the 1970s, examining human response to road traffic noise. He continues this acoustic work across diverse areas of human perception of noise, effects on human health, prediction and modelling of transport noise, effects on wildlife and, more recently in soundscapes—in which the acoustic environment is conceived as a resource. He is a Board member of the International Commission on the Biological Effects of Noise, and member of an ISO Working Group in Acoustics.

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