The Relevance of the 2018 WHO Noise Guidelines to Australasian Road Traffic Noise Objectives

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ABSTRACT

Road traffic noise criteria are generally established by regulators with reference to exposure-response relationships. The release of the World Health Organisation (WHO) *Noise Guidelines for the European Region* in 2018 therefore had global relevance as it purported to present the most contemporary guidance on road traffic noise impacts. Consistent with European Union reporting requirements, the day-evening-night composite noise metric was referenced. In order to understand the implications of this WHO document on policies across Australasia it is necessary to undertake comparisons using a common noise descriptor. There are a range of noise metrics in use across the jurisdictions, however currently there is no robust process of converting the local noise metrics to the day-evening-night composite noise metric This paper uses a large data set of New South Wales (NSW) road traffic noise measurements collected from medium and highly trafficked routes as the basis for the development of such a process. This in turn allows comparison not only to the WHO studies, but also to ISO 1996-2:2017 and to the exposure-response studies that have underpinned the setting of noise objectives in NSW since 1999. In this respect, the conversion protocol has also provided for older studies to be reconstructed and compared to more contemporary studies.

1 INTRODUCTION

Following on from the seminal work of Schultz (1978), another pivotal piece of work by Miedema and Oudshoorn (2001) established an exposure-response relationship that has become the benchmark in research and by policy makers worldwide in setting road traffic noise assessment objectives. Regulators rely on scientific studies that provide insights into the effects of road traffic noise exposure on community response to inform decisions and develop strategies for protecting human health from exposure to excessive environmental noise. In late 2018, the World Health Organisation (WHO, 2018) released its *Environmental Noise Guidelines for the European Region*, which provided a range of health outcome measures that have global policy relevance. In particular, the newly established advisory target in terms of day-evening-night noise levels for minimising the effect of road traffic noise on acute annoyance was both contradictory to the work of Miedema and Oudshoorn (2001), and shown to be significantly more stringent than government objectives defined in national noise policies (Fenech and Rogers, 2019; Gjestland, 2019a). One major issue associated with WHO guidelines is that the strongly recommended target level has been derived by its guideline development group based on an exposure-response relationship rated as low quality in the systematic review undertaken by Guski et al. (2017). As such, the quality of evidence that underpinned the WHO recommendation has been subject to considerable discussion (Gjestland, 2019b).

Road traffic noise criteria for existing roads in New South Wales (NSW) have been established in EPA's *NSW Road Noise Policy* (2011), and its predecessor, the *Environmental Criteria for Road Traffic Noise* (1999), with reference to the synthesis of exposure-response relationships from Bradley and Jonah (1977), Brown (1978), Schultz (1978), Hall et al. (1981) and Nemecek et al. (1981). However, the supporting evidence was based upon data from over 30 years ago and it is unclear how it differs from contemporary standards (ISO 1996-2, 2017; Guski et al., 2017). The synthesised results in the *NSW Road Noise Policy* are presented in terms of the daytime equivalent continuous sound pressure level even though exposure-response relationships are most commonly established in terms of a day-evening-night (L_{den}) or day-night (L_{dn}) 24-hour composite noise indicator. Consequently, the research that supported the development of road traffic noise objectives in NSW is not directly comparable to findings reported by Miedema and Oudshoorn (2001) and the WHO systematic review (Guski et al., 2017).

Many health study outcomes and guidance documents including the Australian enHealth Report (2018) and various WHO guidelines report in L_{den} or L_{dn}. The interpretation of these documents to the Australian and New Zealand context requires conversion to the local noise metrics. Whilst various protocols have been proposed to allow a conversion between different noise indicators (Burgess, (1978); Parnell et al., 2010; Naish et al., 2011; Brink et al., 2018), these have not readily converted the local metrics to the European convention. Moreover, these protocols have generally been the result of averaging data from multiple roads without consideration of the traffic composition or volumes. In this present paper, a comparison between exposure-response relationships reported in the WHO systematic review, International Standards and those that supported the development of NSW road traffic noise objectives is presented. To facilitate the comparison of a variety of exposure-response relationships expressed using different noise indicators, conversion protocols are developed by taking into account the difference in daytime and night-time noise levels associated with different road classifications and traffic composition instead of simply averaging empirical data.

2 CONVERSION BETWEEN NOISE INDICATORS

The L_{den} incorporates varying penalties for the more sensitive periods of evening and night, before averaging into a single composite number. Whilst similar to the L_{dn} descriptor used in the US, neither of these metrics are used in Australia or New Zealand. The European Commission *Position Paper on EU noise indicators* (2000) defines the default times and penalties for the tri-chotomised day-evening-night descriptor as shown in Table 1.

Table 1. Definition of assessment time periods (Peng et al. 2019b)

Jurisdiction	Assessment time period		
	Day	Evening	Night
	Time specific indicators		
Northern Territory, Queensland, Victoria	0600-2400 (18h)	Combined with day	Not specified
Tasmania	0600-2400 (18h)	Combined with day	2300-0700 (8h)
Australian Capital Territory, New South Wales, South Australia	0700-2200 (15h)	Combined with day	2200-0700 (9h)
Western Australia	0600-2200 (16h)	Combined with day	2200-0600 (8h)
New Zealand	0000-2400 (24h)	Combined with day	Combined with day
	24-hour composite indicators		
US Federal Transit Authority	0700-2200 (15h)	Combined with day	2200-0700** (9h)
World Health Organisation	0700-1900 (12h)	1900-2300* (4h)	2300-0700** (8h)

* This period attracts a 5 dB penalty.
** This period attracts a 10 dB penalty.

Australian and New Zealand road noise policies do not separately identify an evening time-period, therefore it is not possible to extract the evening time period from processed results. Additionally, as the L_{den} is reported as an incident (free field) result the European Commission position paper (2000) recommends subtracting 3 dB from any reflected measurement at 1.2 m and 1 m from a façade, which is effectively the measurement location for Australian and New Zealand surveys.

2.1 The NSW Data Set

174 data sets were examined as part of this present paper, all of which were collected by the authors in accordance with ISO 1996-1 (2016) and in response to complaints of excessive noise. Consequently, the vast majority of the data falls within a narrow band between L_{den} 62 – 70 dB(A), in a spread of data points between 55 and 77 dB(A). The data sets were examined in detail for extraneous noise, and such events excluded or the data sets

omitted. Following the screening process, 7-day data sets from 121 locations in NSW were analysed. The data was all inclusive of façade reflections, generally representative of free-flowing conditions, and was not focused around intersections or other traffic devices that may increase or cause non-typical road noise. The majority of roads were in suburban or rural locations where traffic noise was dominant.

Whilst the range of data in this study does not cover a large scale of noise levels, it is representative of the bracket in which road authorities need to manage their activities most carefully. The authors are aware that many studies use third party data and have little intimate knowledge of where, how, or of the original purpose of the data collection exercise. Such studies will also often aggregate their data and produce averages from sets of data covering very different roads, with very different traffic mixes. The use of the L_{den} is particularly prone to this variability because of the way it heavily penalises the night-time noise level, particularly in instances where the 6 – 7am timeslot may see a significant increase in morning peak traffic volumes. For this reason, the authors caution against carte blanche averaging. Rather, in this present study the authors have sought to develop a method which provides for a differentiation of roads that carry consistent traffic throughout the night (primarily interstate key freight routes) and those which tend to exhibit commuter traffic patterns (primarily suburban and urban routes with low percentages of heavy vehicles).

2.2 Monitoring Locations and Noise Metrics

The data from 121 sites that were deemed to be satisfactorily free of extraneous noise and influences were processed into a full range of noise metrics. A selection of these metrics were then further analysed for the purpose of this paper as nominated in Table 1, and the locations plotted in Figure 1.

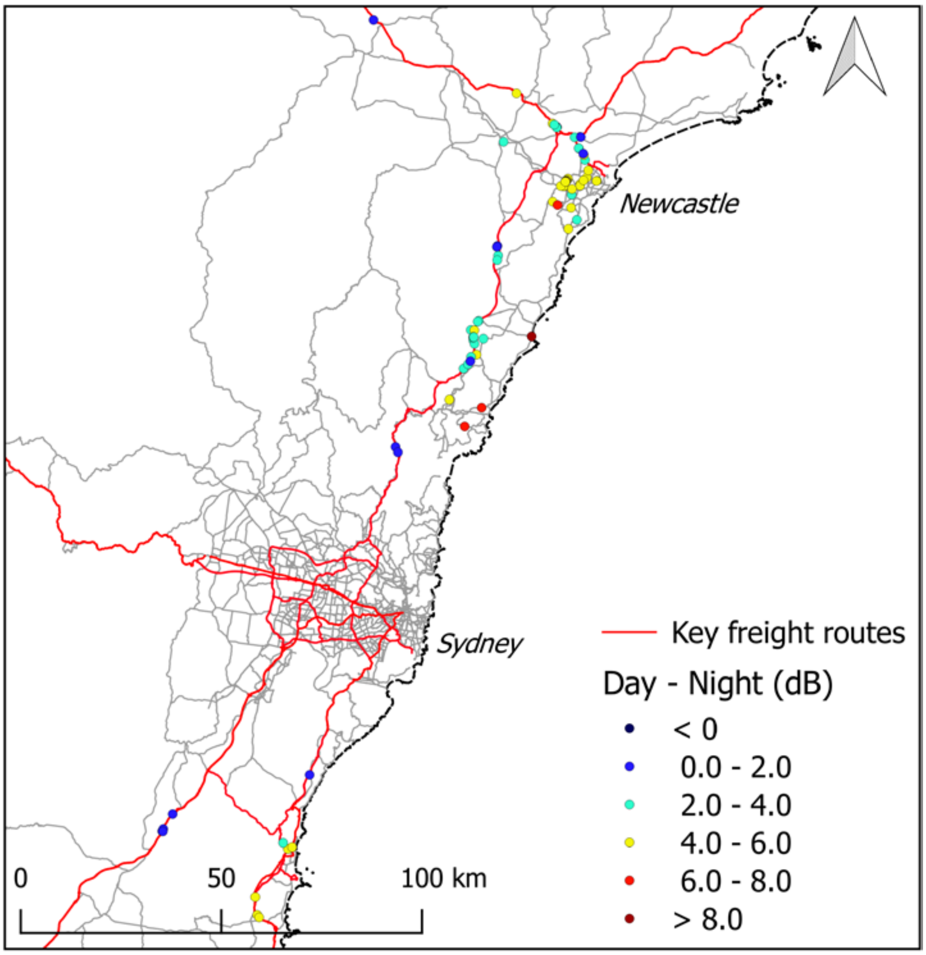


Figure 1. Difference between daytime and night-time equivalent sound pressure levels along key freight routes and classified roads

As road traffic noise is largely a function of volume, particularly that of heavy vehicles, the dichotomisation of the data into day and night-time periods is effectively a surrogate for traffic flow. With this in mind, the various noise metrics were plotted against the difference between the relevant L_{eq} daytime levels and the L_{eq} night-time levels as shown in Figures 2 to 5.

2.3 Data Screening and Categorisation

In the initial screening process, it was observed that daytime road traffic noise data was less susceptible to contamination than night-time data. Whilst this is primarily because of an improved signal-to-noise ratio, it is also because extraneous events such as lawn mowing were more obvious. The relationship between L_{10} and L_{eq} is very strong where road traffic noise is constant and it can be used as a good screening tool for identification of extraneous noise. However, the L_{10}-L_{eq} relationship falls away when traffic flow becomes more intermittent such as often occurs during the night. When combined with a lower signal-to-noise ratio, the ability to confidently and consistently identify contaminated night-time data points is diminished. Unsurprisingly, it was also observed that the difference between day and night-time noise levels had a very strong correlation to the functional road category, confirming the relationship of traffic flow to noise level. Given these reasons, it was deemed a more accurate result could be achieved by developing a L_{den} conversion protocol which was related to the daytime noise measurements rather than the night-time data.

Because the authors had access to both the raw noise data files and traffic information it was possible to categorise the monitoring sites based on their exposure to various traffic patterns. Whilst the quality of traffic data would have supported greater categorisation, for the purposes of this paper, only two broad functional road categories were derived from traffic data in Peng et al (2019a), being *Metropolitan Roads* and *Key Freight Routes*. A proposed definition is given in Table 3.

The authors reasoned that where a road can be confidently nominated into either of these two categories, then a more representative conversion coefficient can be assigned. This can be done with only minimal knowledge of traffic patterns and without specific knowledge of the road traffic noise levels. Where, more information is known about the Day-Night dichotomisation of either the traffic flows or the road traffic noise levels, then the coefficients can be further refined as discussed in Section 2.5.

2.4 Data Observations

Figure 1 plots the scale of Day-Night difference on a NSW road network map, which also indicates the primary key freight routes. As can be seen, the differences are lowest on these designated key freight routes, particularly when the location was remote from lager population centres and the influence of daytime commuter traffic. Conversely, the higher differences can be seen to be associated with roads that would be expected to exhibit typical commuter flow patterns. These findings were consistent with the initial Metropolitan Road and Freight Route classification based on traffic data and proposed in Table 3.

2.5 Calculations of L_{den} and L_{dn}

To avoid the issue associated with a single conversion coefficient being unrepresentative of the larger range of data points, a conversion equation was calculated as shown in Figures 2 to 5 and presented in Table 2. The graphs have been colour coded on the basis of a 4 dB difference between daytime and night-time noise levels which also tends to delineate between roads performing as either a Freight Route or a Metropolitan Road. This method may be used to convert dichotomised noise metrics or where this dichotomisation is not available, a Day-Night differences may be assumed, based on some knowledge of traffic patterns and guidance from Table 3. For the set of data analysed in this paper it was found on average that the L_{dn} was 0.1 dB lower than the standard L_{den} regardless of the functional category of the road. Consequently, it is considered that L_{den} and L_{dn} can be used interchangeably without significant error in most cases. As such, detailed results for L_{dn} are not reported in this paper.

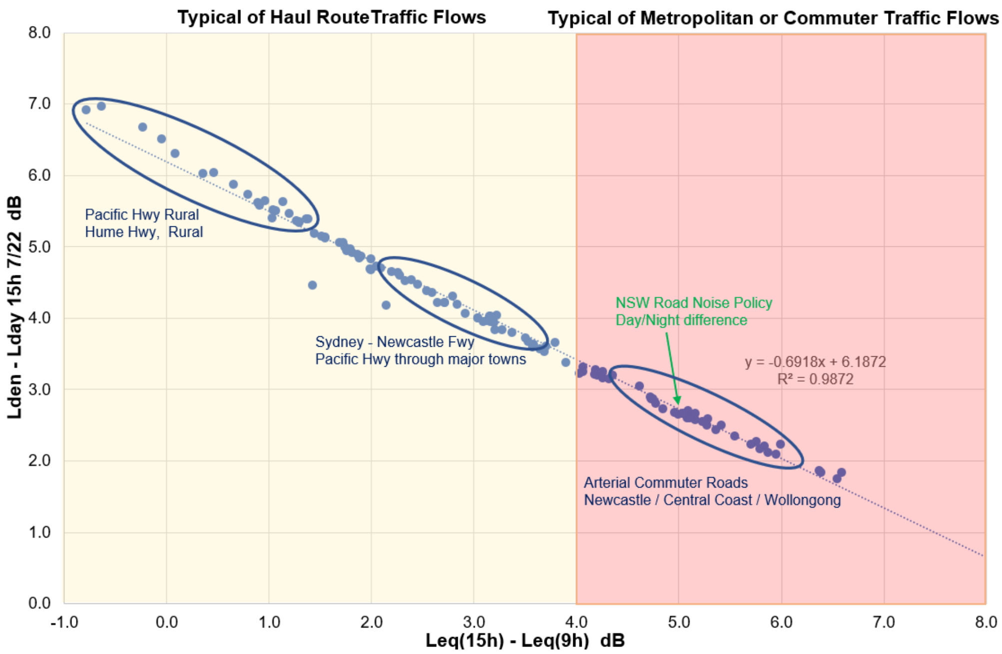


Figure 2. NSW example of $L_{eq(15h)}$ to L_{den} conversion showing typical road categories

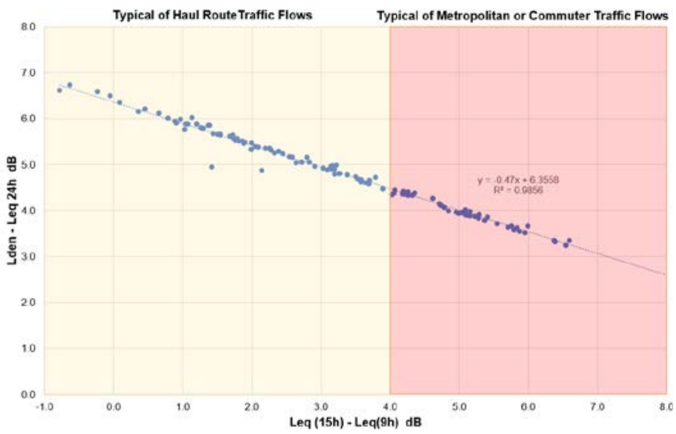


Figure 3. $L_{eq(24h)}$ to L_{den} Conversion

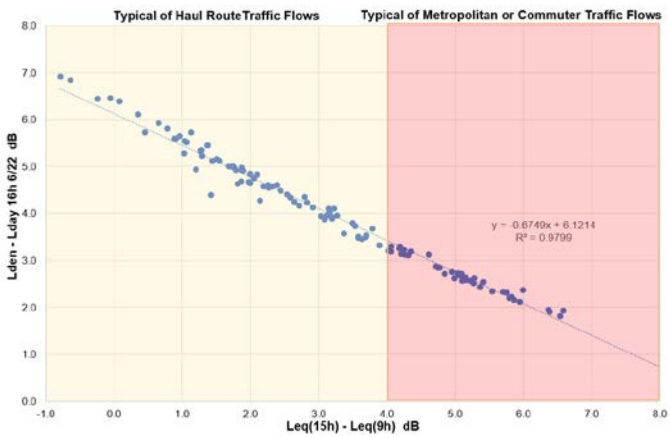


Figure 4. $L_{eq(16h)}$ to L_{den} Conversion

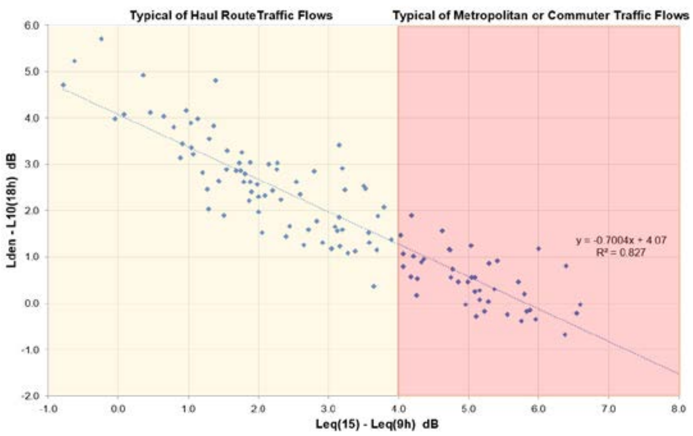


Figure 5. $L_{10(18h)}$ to L_{den} Conversion

Table 2. Conversion Equations

Noise Metric	Conversion Equation	R^2
$L_{eq(15h)}$	$L_{den} = L_{eq(15h)} - 0.69\delta + 6.19$	0.99
$L_{eq(16h)}$	$L_{den} = L_{eq(16h)} - 0.67\delta + 6.12$	0.98
$L_{eq(24h)}$	$L_{den} = L_{eq(24h)} - 0.47\delta + 6.36$	0.99
$L_{10(18h)}$	$L_{den} = L_{10(18h)} - 0.70\delta + 4.07$	0.83

Where $\delta = L_{eq(15h)} - L_{eq(9h)}$

Table 3. Categorisation of Day-Night Noise Difference and Typical Examples

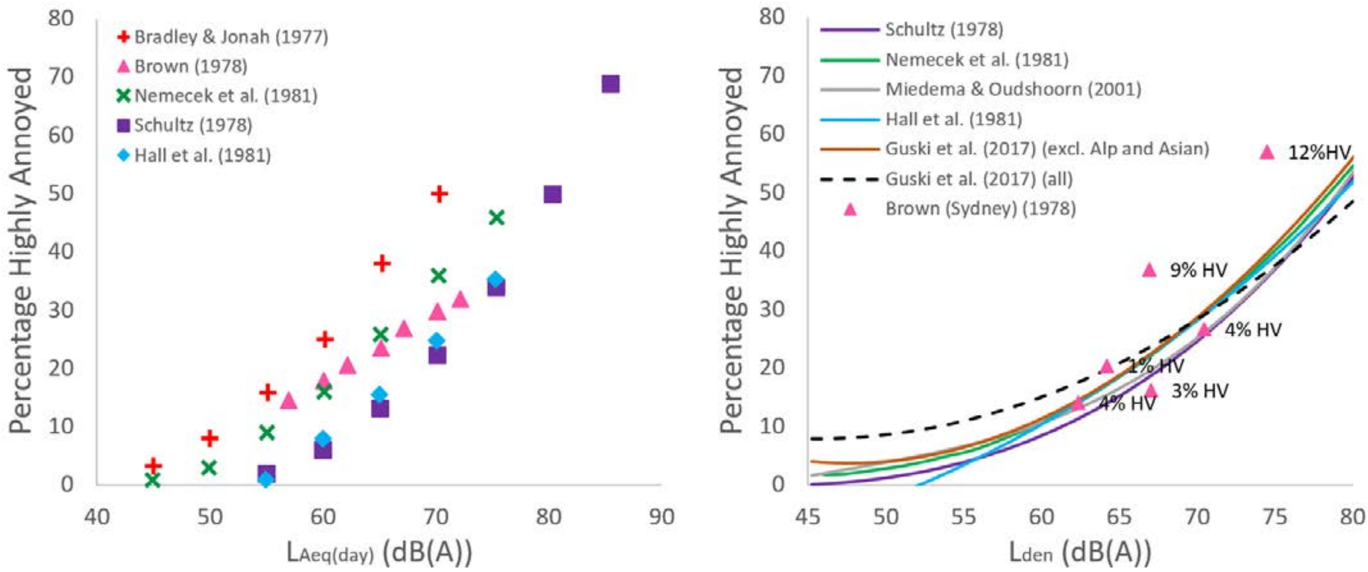
Lday – Lnight Difference	Description of Typical Roadway
Key Freight Routes	$L_{eq(15h)}$ minus $L_{eq(9h)}$ from around -1 to 4 dB. Recommended default of 2 dB.
	Primary and secondary freight routes, other roads generating consistent high levels of road noise particularly during the night-time period.
-1 to 2 dB	*Freight routes, often interstate. Generally sections of highways that are remote from population centres or are town bypasses. High % of heavy vehicles in the traffic mix often > 10% during the day and > 40% at night.*
2 to 4 dB	*Typically roads that have a consistent flow of heavy vehicles in addition to significant volumes of passenger vehicles during daytime hours. Whilst truck volumes may be relatively consistent over a 24-hour period, the % of total traffic composition may fluctuate from as low as 10% during the day, to > 15% at night.*
Metropolitan Roads	$L_{eq(15h)}$ minus $L_{eq(9h)}$ from around 4 to 8 dB. Recommended default of 6 dB.
	Roads that carry a high proportion of commuter traffic and localised commercial traffic during the day. These roads typically display morning and afternoon peaks and have substantially lower traffic volumes at night.
4 to 6 dB	*Generally represented by metropolitan roads which carry a range of local trucks, commercials and passenger vehicles during the day, with lower volumes of all types of vehicles during the night. Often these are commuter roads that exhibit distinct peak traffic periods. Heavy vehicles generally make up less than 10% of any period particularly the daytime*
> 6 dB	*Roads with such large differences between day and night traffic noise levels are usually commuter roads that do not connect between major centres. Often these can be roads connecting the Pacific Highway to coastal towns or can be the Princes Highway on the far South Coast, both of which are dominated by passenger vehicles and do not carry any substantial quantities of commercial traffic at night.*

Note. The above description of traffic carrying composition is for guidance only. There are many factors which influence the difference between the noise generated on roads and should be considered on a site-by-site basis.

Where a road can only be confidently designated into either a Freight Route or Metropolitan Road, then the default for that classification can be adopted. Where there is no confidence in assigning a category, then it is recommended to default to either the relevant jurisdiction noise objectives or a Day-Night difference of 4 dB.

3 BASIS OF THE NSW AND WHO OBJECTIVES

The current NSW road traffic objective for existing roads (60 dB(A) day / 55 dB(A) night) approximates a L_{den} of 63 dB(A). Comparison to the WHO L_{den} objective of 56 dB(A) (53 + 3 façade correction) indicates that this NSW road traffic noise objective at 1 metre from the façade would exceed the WHO recommendation by around 7 dB. Moreover, working backwards would suggest that to meet the WHO recommended levels in NSW would require no greater than $L_{eq(day)}$ 53 dB(A) and $L_{eq(night)}$ 49 dB(A) (using the empirically derived 4 dB difference midpoint for NSW data). The synthesised exposure-response relationships displayed in EPA's *NSW Road Noise Policy* is reproduced in this paper in Figure 6(a). It should be noted that although majority of the aforementioned studies evaluated noise exposure in terms of the L_{den} noise indicator, the response depicted by the percentage of people highly annoyed has been plotted against the daytime L_{eq} noise levels (including façade correction) in the *NSW Road Noise Policy*. To facilitate a comparison with exposure-response relationships by Miedema and Oudshoorn (2001) and WHO systematic review (Guski et al., 2017), the authors have reconstructed the synthesis plot in Figure 6(a) in terms of L_{den} since it is not possible to accurately transform 24-hour composite noise indicator (e.g. L_{den}, L_{dn}) to $L_{eq(day)}$ without having access to individual exposure-response data points and the underlying traffic data. Further, the generic exposure-response relationship representing Brisbane, Sydney and Melbourne by Brown (1978) has been de-constructed, whereby the results from six individual sites in NSW (transformed from $L_{10(18h)}$ to L_{den}) are shown together with the percentage of heavy vehicles (HV). The updated synthesis of exposure-response relationships is presented in Figure 6(b) without façade correction.



(a) Original (b) Updated

Figure 6. Synthesis of exposure-response relationships

Figure 6 shows the existing and updated synthesis of exposure-response relationships differ significantly. At a given noise exposure level, for example $L_{eq(day)}$ of 65 dB(A) (with façade correction) and L_{den} of 65 dB(A) (free field), the difference in %HA between studies by Nemecek et al. and Schultz are 13% (26% - 13%) and 4% (19% - 15%) respectively in the original and updated synthesis plots. The same comparison was made by Nemecek et al. (1981) in which a difference of 4% was nominated. The discrepancy observed in the original EPA synthesis plot in Figure 6(a) is likely to be attributed to the conversion error from L_{dn} to $L_{eq(day)}$. Such conversion error can be problematic during the development of evidence-based policy. For example, environmental noise objectives for transportation-related noise sources are typically established with the aim of having only 10 in 100 people with highly annoyed response at a given noise exposure level (EPA, 2011; WHO, 2019), corresponding to L_{den} of 60 dB(A) in Figure 6(b) or $L_{eq(day)}$ of 60 dB(A) including façade correction. However, potential errors introduced in the original synthesis plot can lead policy makers to believe otherwise, where 18 in 100 people are said to be highly annoyed in the *NSW Road Noise Policy* compared to 10 in 100 people according to international consensus.

The updated synthesis plot presented in Figure 6(b) shows three interesting features. Firstly, the regression curves proposed by Guski et al. (2017) changed considerably from free field L_{den} of approximately 53 dB(A) (WHO recommendation) to 60 dB(A) at 10% highly annoyed simply when the Alpine and Asian studies were excluded on the basis that they are not comparable to other studies undertaken in European cities in terms of study design and environmental context. Secondly, the proposition that there is little evidence to suggest that the body of knowledge associated with road traffic noise has changed much since the annoyance value at L_{den} of 60 dB(A) suggested by Miedema and Oudshoorn in 2001 is closely supported by Guski et al. (excluding Alpine and Asian studies) in 2017. Similar observations were also made by Gjestland (2019b), whereby the average community tolerance to road traffic noise found in exposure-response studies over the past 45 years has remained largely unchanged. Lastly, when the Australian data is reported as individual data instead of a generic regression best fit line, community responses associated with metropolitan commuter roads with less than 4% heavy vehicles are shown to be comparable to well-established exposure-response relationships of European cities. A striking feature of Figure 6(b) is the marked parallelism in exposure-response between sites with over 9% and less than 4% heavy vehicles. It is important to note that the percentage of heavy vehicles has been identified as a co-determinant of annoyance response along with noise levels as far back as 1970s by Langdon (1976) and in the early 1990s by Miedema (1993).

4 SUMMARY

The synthesis of exposure-response relationships that underpinned the road traffic noise criteria in NSW in terms of daytime equivalent sound levels has been updated to reflect 24-hour composite noise indicators, thereby facilitating a common basis of comparison with contemporary standards. Conversion protocols from common noise metrics used across Australasia to 24-hour composite noise metrics have been derived from 121 sites adjacent to medium to highly trafficked roads in NSW. Rather than providing a single conversion factor for each pair of noise indicators, it was found that more accurate conversions could be achieved when consideration was given to the traffic flow and composition associated with road classifications corresponding to freight routes and metropolitan commuter roads. The updated synthesis of exposure-response relationships exhibited a similar and distinctive attribute to the conversion protocols such that the exposure-response estimates are notably lower in communities adjacent to commuter roads with a low percentage of heavy vehicles. The use of traffic mix as a confounding factor is likely to have important impact on the certainty of the exposure-response estimate and better describe the exposure-response estimate across communities impacted by different traffic flows.

Regulators rely on reliable scientific guidance to inform decisions and develop strategies to minimise environmental impact across affected communities. Whilst it is important not to underestimate the impacts of road traffic noise, overestimation can lead to significant problems itself, including the management of unreasonable expectations and anxiety. This in turn diverts resources from addressing real, rather than perceived health impacts. Issues regarding the limitations of the quality of the WHO data set that were identified in the WHO systematic review by Guski et al. (2017) and concurred with by the present authors, would need to be addressed, and recommendations revised before any actions could be contemplated. Further, any such actions should only be considered for recommendations made for roads and situations relevant to the Australasian road network.

ACKNOWLEDGEMENTS

Any opinions expressed are those of the authors and do not necessarily reflect those of the New South Wales State Government.

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