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Comparison of equivalent continuous noise levels and day-evening-night composite noise indicators for assessment of road traffic noise

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ABSTRACT

Environmental road traffic noise exposure indicators adopted by Australasian road authorities, corresponding to equivalent continuous sound levels specified over different assessment time periods within a 24-hour period, are compared with 24-hour composite indicators comprising day-evening-night and day-night assessment periods that place higher importance on night-time noise impact. The aforementioned equivalent continuous sound levels specified over different assessment time periods and composite noise indicators are calculated using measured hourly road traffic noise levels at representative locations in urban and rural areas in New South Wales. Further, the corresponding road traffic data (full classification vehicle counts and vehicle speeds) are used as inputs to the well-established CNOSSOS-EU, CoRTN and FHWA-TNM road traffic noise prediction models, from which the equivalent continuous sound levels and composite noise indicators are then predicted. Using the noise indicators, measured noise levels and predicted noise levels from the three road traffic models at roadside locations along an urban arterial road and an interstate freight route are compared.

1 INTRODUCTION

Outdoor noise exposure is customarily used in road traffic noise impact assessments for characterising the prevalence of potential noise disturbance in affected communities (EC, 2000; FTA, 2018; EPA, 2011; WHO, 2018). In Australasia, the most common noise indicator used by regulatory authorities to assess road traffic noise impact is the A-weighted equivalent continuous sound pressure level, $L_{\mathrm{Aeq,period}}$. The $L_{\mathrm{Aeq,period}}$ integrates the time-varying noise level over a specified period of the day, for example, over an entire 24-hour period, or across a daytime period (between 0600h and 2200h or between 0700h and 2200h) and a night-time period (between 2200h and 0600h or between 2200h and 0700h). In an attempt to facilitate comparison of noise exposure with health outcome measures established by the World Health Organization (WHO, 2011), composite indicators that place higher weighting on equivalent continuous sound levels at night-time are also gaining increasingly widespread consideration by regulatory authorities (enHealth, 2018). In this work, time-specific equivalent continuous sound levels, $L_{\mathrm{Aeq,period}}$, and 24-hour composite noise indicators, L_{dn} and L_{den}, predicted using well established road traffic noise models corresponding to CoRTN, FHWA-TNM and CNOSSOS-EU are compared with measured roadside noise data from an urban arterial road and an interstate freight route in New South Wales.

2 METHODOLOGY

The peformances of CoRTN, FHWA-TNM and CNOSSOS-EU are examined by comparing the computed and measured noise levels at two representative locations in New South Wales, corresponding to an urban arterial road in Western Sydney and an interstate freight route through the Mid North Coast of New South Wales. The approach adopted by Brink et al. (2018) is utilised in this study to evaluate the hourly variation in road traffic noise emission, in which the hourly noise level as a fraction of a 24-hour day is calculated from measured traffic volume and vehicle classification data. The computed hourly noise level is then compared with roadside noise monitoring data obtained simultaneously with traffic data. Subsequently, hourly noise level is converted to time-period specific and 24-hour composite noise indicators. These time-period specific and composite noise levels adopted by American, Australasian and European jurisdictions are described in what follows.

2.1 Assessment time period

The specific start time and finish time adopted for road traffic noise assessment using the time-specific equivalent continuous sound pressure level by various regulatory authorities in Australia, New Zealand and the United States (US) as well as the World Health Organization (WHO) are summarised in Table 1 (EPA, 2011; NZTA, 2016; FTA, 2018; WHO, 2018). The US and Australian authorities share a similar underlying construct in defining assessment time periods in which day and evening time periods are aggregated together. In contrast, the WHO defines an evening time period when residents are more likely to be at home. In the Northern Territory, Queensland and Victoria, road traffic noise occurring in the night-time period between 0000h and 0600h is not considered. In New Zealand, the time-varying road traffic noise is integrated across the entire 24-hour period without distinction between day, evening and night.

Table 1: Definition of assessment time periods

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 Organization	0700-1900 (12h)	1900-2300 (4h)	2300-0700 (8h)

2.2 Time-period specific equivalent continuous sound level

The A-weighted equivalent continuous sound pressure level that integrates the time-varying road traffic noise over a time period with specific start and finish time in hours, h, can be expressed as a function of noise emission from each vehicle category:

$$L_{\text{Aeq,period}} = 10\log_{10}\left(\frac{1}{|\text{start}-\text{finish}|}\sum_{h=\text{start}}^{\text{finish}-1}\left(r_{\text{LV},h}10^{L_{\text{Aeq},h,\text{LV}}/10} + \sum_{i=1}^{j} r_{\text{HV}i,h}10^{L_{\text{Aeq},h,\text{HV}i}/10}\right)\right) \tag{1}$$

where $\mathrm{r}_{\text{LV},h}$ is the proportion of light vehicles in the hourly traffic flow, $\mathrm{L}_{\text{Aeq},h,\text{LV}}$ is the hourly equivalent continuous sound pressure level of light vehicles, $\mathrm{r}_{\text{HV}i,h}$ is the proportion of each group of heavy vehicles in the hourly traffic flow and $\mathrm{L}_{\text{Aeq},h,\text{HV}i}$ is the hourly equivalent continuous sound pressure level for each group of heavy vehicles.

In Eq. (1), the diversity of heavy vehicles on the road network in Australia can be described by six distinct groups corresponding to 2 axle rigid trucks (HV1), 3-4 axle rigid trucks (HV2), 3-5 axle articulated trucks (HV3), 6 axle articulated trucks (HV4), 9 axle double-trailer trucks (HV5) and other heavy vehicle configurations with more than 9 axles (HV6) (Peng et al., 2019). In the modern application of CoRTN, all heavy vehicle axle configurations with unladen weight greater than 3.5 tonnes (HV1–HV6) are aggregated into a single-category (Highways England, 2011). FHWA-TNM and CNOSSOS-EU represent heavy vehicles as two distinct categories corresponding to 2 axle rigid trucks (HV1) and multi-axle trucks (HV2–HV6). As such, Eq. (1) can be simplified to two vehicle categories for CoRTN comprising light vehicles (LV) and heavy vehicles (HV1–HV6). Similarly, Eq. (1) can be simplified to three vehicle categories for FHWA-TNM and CNOSSOS-EU comprising light vehicles (LV), 2 axle rigid trucks (HV1) and multi-axle trucks (HV2–HV6).

2.3 24-hour composite noise indicators

24-hour composite noise indicators corresponding to the day-night level, L_{dn}, and day-evening-night level, L_{den}, are expressed as follows (EC, 2000; FTA, 2018):

$$L_{\mathrm{dn}} = 10\log_{10}\left(\frac{1}{24}\left(15 \times 10^{L_{\mathrm{Aeq,day}}/10} + 9 \times 10^{(L_{\mathrm{Aeq,night}}+10)/10}\right)\right) \tag{2}$$

$$L_{\mathrm{den}} = 10\log_{10}\left(\frac{1}{24}\left(12 \times 10^{L_{\mathrm{Aeq,day}}/10} + 4 \times 10^{(L_{\mathrm{Aeq,evening}}+5)/10} + 8 \times 10^{(L_{\mathrm{Aeq,night}}+1\ )/10}\right)\right) \tag{3}$$

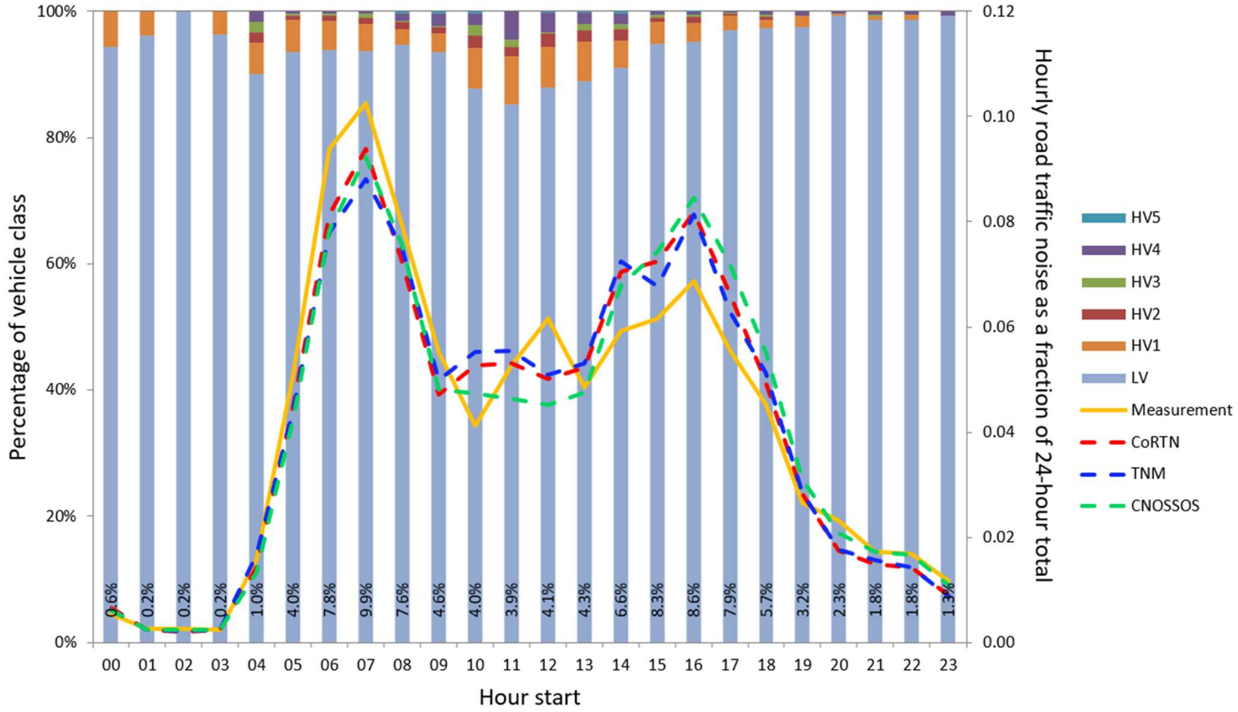
where $L_{\mathrm{Aeq,day}}$, $L_{\mathrm{Aeq,evening}}$ and $L_{\mathrm{Aeq,night}}$ correspond to the equivalent continuous sound pressure levels specified over the relevant assessment time periods identified in Table 1. In Eqs. (2) and (3), night-time contribution of noise includes a penalty factor to take into account the equivalence in daytime and night-time noise disturbance prevalence rates in a general population for which $L_{\mathrm{Aeq,night}}$ is lower than $L_{\mathrm{Aeq,day}}$ by 10 dB (EC, 2000). In Eq. (3), the evening period is also distinctively identified and includes a penalty factor.

3 HOURLY VARIATION IN TRAFFIC NOISE LEVELS

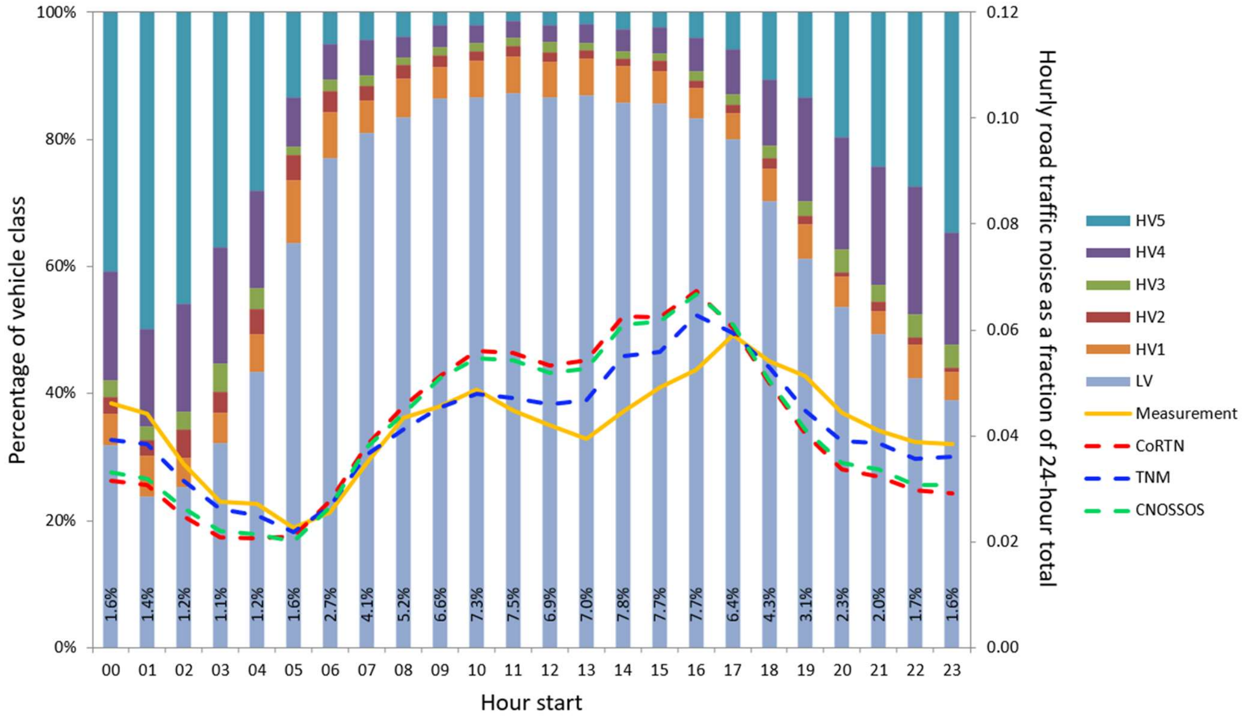
The variation in measured and calculated hourly noise level contribution as a fraction of a 24-hour day (indicated by the vertical axis on the right hand side of each figure) using the three principal road traffic noise models corresponding to CoRTN, FHWA-TNM and CNOSSOS-EU are compared for an urban arterial road (Figure 1(a)) and an interstate freight route (Figure 1(b)). The respective variations in hourly traffic volume contribution (indicated by the vertical rotated text on each bar in the figure) and vehicle composition (indicated by the vertical axis on the left hand side of each figure) are also shown. Measured hourly speeds are not reported. However, the range in measured hourly speeds is less than 10 km/h at both sites, which is typically observed under free-flowing conditions. Results for HV6 are not shown due to their significantly reduced presence compared to HV1 to HV5 across the New South Wales road network.

Figure 1(a) shows that along an urban arterial road in Western Sydney, vehicle composition is generally consistent across the entire 24-hour, where the hourly traffic volume comprises predominantly of light vehicles. Furthermore, the heavy vehicle mix comprises primarily of 2 axle rigid trucks (HV1) used for local freight services. The characteristic morning peak period (0600 to 0900) and afternoon peak period (1400 to 1800) representative of urban arterial roads are also evident. During these peak periods, minor discrepancies between calculated and measured hourly noise levels can be observed. These discrepancies are attributed to the exclusion of temperature influence on rolling noise emission in the calculation, whereby under-prediction in hourly contribution (up to 20%) is expected during the morning peak period when daily temperature is at a minimum (11ºC) whereas over-prediction (up to 20%) is expected during the afternoon peak period when daily temperature is at its highest (27ºC). Overall, close agreement between calculated and measured hourly noise levels can be observed in Figure 1(a) for the urban arterial road.

In contrast to the vehicle composition on an urban arterial road, Figure 1(b) reveals that a distinctive feature of the interstate freight route through the Mid North Coast of New South Wales is the higher proportion of larger articulated trucks at night (HV4 and HV5). Further, there are no distinct morning and afternoon peak periods. Instead, a significant variation in vehicle composition is observed throughout the 24-hour day, particularly at night when local freight delivery and commuter traffic become less active. In Figure 1(b), close alignment with measured data is observed only for FHWA-TNM due to its ability to more realistically simulate the hourly variation in heavy vehicle noise emission. From Figure 1(b), it can be seen that CoRTN and CNOSSOS-EU apportion up to 30% lower hourly noise contribution than measured results when over 50% of the vehicles comprise HV4 and HV5. Compared to CoRTN, no observable improvement in prediction performance of hourly road traffic noise can be seen using CNOSSOS-EU even though an additional heavy vehicle category is modelled, attributed to under-representation of heavy vehicle sound power levels (Kok and van Beek, 2019; Peng et al. 2019).



(a) Urban arterial road



(b) Interstate freight route

Figure 1: Hourly traffic flow and noise contribution over a 24-hour day along an (a) urban arterial road in Western Sydney and (b) interstate freight route through the Mid North Coast of New South Wales

4 COMPARISON BETWEEN SELECTED NOISE INDICATORS

Noise indicators corresponding $L_{\mathrm{Aeq,period}}$, L_{dn} and L_{den} have been derived from the hourly data reported in Section 3 and are compared in Table 2. Results have been normalised with reference to L_{den}. Comparing the predicted noise levels from CoRTN, FHWA-TNM and CNOSSOS-EU with measured data for the urban arterial road reveals that $L_{\mathrm{den}} - L_{\mathrm{Aeq,period}}$ is within ±0.4 dB for all time periods. The difference between measured and predicted results is also consistently low for the interstate freight route when FHWA-TNM is utilised. In contrast, discrepancies between measured and predicted noise levels become notably higher for CNOSSOS-EU and CoRTN, where the difference in $L_{\mathrm{den}} - L_{\mathrm{Aeq,15h}}$ increases to 1.1 dB and 1.2 dB, respectively. The larger discrepancy observed for CoRTN and CNOSSOS-EU associated with the interstate freight route is primarily attributed to under-estimation of heavy vehicle dominant noise levels across the night-time period in the computation of L_{den} by these calculation methods.

Table 2 shows that the variation in $L_{\mathrm{den}} - L_{\mathrm{dn}}$ is mostly the same for both the urban arterial road and interstate freight route. In contrast, $L_{\mathrm{den}} - L_{\mathrm{Aeq,8h}}{}^{\mathrm{b}}$ associated with an 8-hour time period from 2200-0600h resulted in the highest variation between road types, from 9.4 dB for an urban arterial road to 6.5 dB for an interstate freight route. The variation in $L_{\mathrm{den}} - L_{\mathrm{Aeq,period}}$ is also notable when the $L_{\mathrm{Aeq,period}}$ indicator captures mostly traffic noise occurring in the daytime period. Interestingly, the variation in $L_{\mathrm{den}} - L_{\mathrm{Aeq,period}}$ between road types is significantly reduced for $L_{\mathrm{Aeq,9h}}$ (2200-0700h) and $L_{\mathrm{Aeq,8h}}{}^{\mathrm{a}}$ (2300-0700h). The results in Table 2 suggest that road traffic noise occurring between 0600-0700h is the most critical when computing the L_{den} composite indicator.

Table 2: Comparison between $L_{\mathrm{Aeq,period}}$, L_{dn} and L_{den} noise indicators

Comparison between noise indicators	Urban arterial road				Interstate freight route			
	Measured (dB)	Predicted (dB)			Measured (dB)	Predicted (dB)		
		CoRTN	TNM	CNOSSOS		CoRTN	TNM	CNOSSOS
$L_{\mathrm{den}} - L_{\mathrm{dn}}$	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0
$L_{\mathrm{den}} - L_{\mathrm{Aeq,24h}}$	4.5	4.2	4.2	4.2	5.7	5.0	5.5	5.1
$L_{\mathrm{den}} - L_{\mathrm{Aeq,18h}}$	3.6	3.3	3.3	3.2	5.5	4.4	5.1	4.5
$L_{\mathrm{den}} - L_{\mathrm{Aeq,16h}}$	3.2	2.9	2.8	2.9	5.4	4.2	5.0	4.4
$L_{\mathrm{den}} - L_{\mathrm{Aeq,15h}}$	3.4	3.0	3.0	3.0	5.3	4.1	4.9	4.2
$L_{\mathrm{den}} - L_{\mathrm{Aeq,9h}}$	7.2	7.5	7.5	7.5	6.6	7.0	6.8	7.0
$L_{\mathrm{den}} - L_{\mathrm{Aeq,8h}}{}^{\mathrm{a}}$	7.1	7.3	7.3	7.4	6.7	7.1	6.8	7.0
$L_{\mathrm{den}} - L_{\mathrm{Aeq,8h}}{}^{\mathrm{b}}$	9.4	9.6	9.5	9.5	6.5	7.0	6.7	6.9

Note: 8-hour time period (a) from 2300 to 0700 or (b) from 2200 to 0600

5 SUMMARY

In this work, measured noise levels at roadside locations along an urban arterial road and an interstate freight route as well as predicted noise levels from three road traffic models, expressed in terms of equivalent continuous sound levels and 24-hour composite noise indicators, are compared. The contributions of road traffic noise are calculated as a function of hourly traffic volume and vehicle composition. Compared to measured results, FHWA-TNM simulates the hourly variation in road traffic noise with greater accuracy compared to CoRTN and CNOSSOS-EU, particularly along the interstate freight route where vehicle composition varies significantly throughout the 24-hour period. Further, the findings in this work indicate that road traffic occurring in the morning shoulder period from 0600h to 0700h significantly affects the comparison between equivalent continuous noise levels and day-evening-night composite noise indicators for assessment of road traffic noise.

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