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Assessment of the proposed changes regarding heavy vehicles in the statistical pass-by draft standard ISO/DIS 11819-1 (2021)

Michiel Geluykens[1,*], Ablenya Grangeiro de Barros[1], Luc Goubert[2], Cedric Vuye[1]

[1]EMIB Research Group, Faculty of Applied Engineering, University of Antwerp, 2020 Antwerp, Belgium.

[2]Belgian Road Research Centre, Woluwedal 42, 1200 Brussels.

*michiel.geluykens@uantwerpen.be

Abstract
Exposure to excessive (road) traffic noise can result in sleep deprivation, increased stress, and even heart diseases. Accordingly, accurately determining the acoustic quality of different pavement types is crucial for implementing noise-reducing measures such as low-noise pavements. In this regard, the ISO 11819-1:1997 standard, which describes the Statistical Pass-By method for assessing the acoustic performance of road pavements, is currently under revision. The proposed changes include combining two vehicles' categories, currently defined as dual-axles (HD) and multiple-axles (HM) heavy vehicles, into a single category: heavy vehicles (H), by adding 2.7 dB to the maximum sound pressure level (L_{Amax}) of HD vehicles. Additionally, a new method is presented to define the noise versus speed relation of this new caterory. In this work, these changes were evaluated based on a large dataset collected by the authors over 8 months, with an abundance of heavy vehicles (2820) while also accounting for passenger cars (2896). The average difference in L_{Amax} between HD and HM vehicles ranged between 2.1 – 2.3 dB, meaning that the draft standard may overestimate this difference. Furthermore, while the draft standard prescribes a coefficient of 25 for the L_{Amax} variation with speed for the road surfaces here investigated, we observed a lower speed dependency, with a coefficient of 20.5 on average. Lastly, we proposed and investigated the introduction of a new vehicle category containing delivery vans. It appears that vans can form a vehicle category with consistent noise behaviour and could thereby aid in describing the pavements' acoustic performance, ultimately contributing to reducing the measurement duration. The noise produced by vans presents a similar spectra shape and coincident noise levels as passager cars at 1000 to 2000 Hz third-octave bands.

Keywords: Road traffic noise, SPB, heavy vehicles, ISO 11819-1

1 Introduction

Road traffic noise is the largest contributor to environmental noise in urban areas. Excessive road traffic noise exposure is linked to non-auditory adverse health outcomes such as the incidence of ischemic heart diseases, cortical awakenings and self-reported sleep disturbance, among others [1][2][1]. In short, it decreases one's quality of life, and furthermore, the Environmental Noise Guidelines for the European Region indicate that over one million healthy years of life are lost yearly due to traffic-related environmental noise in Western Europe. With the increase in traffic and densely built-up areas, more and more people are exposed to (road) traffic noise [3]. In order to abate this problem by various means, there must first be a solid base for assessing road traffic noise and its influencing factors.

Several standardized methods already exist for this purpose, for example, UNECE R.117 contains requirements for the determination of sound emissions of tyres, and uses the same coast-by measurement principle as in ISO 13325:2019. ISO 11819-2:2017 describes the Close ProXimity method (CPX), the On-Board Sound Intensity method is described in AASHTO T 360-16:2016, and ISO 11819-1 defines the

Statistical Pass-By method (SPB), which all serve to evaluate the the acoustical quality of the pavement. In more detail, in ISO 11819-1 the maximum A-weighted noise levels' L_{Amax}' of passing vehicles, also called 'pass-bys' are captured together with the respective vehicle speed at the roadside under free-flow traffic conditions [4]. The currently active standard, ISO 11819-1:1997, is under revision (ISO/DIS 11819-1, 2021) [5].

The overall noise emitted by a vehicle passage is the combination of the contributions from several noise mechanisms, commonly categorised under power unit noise, aerodynamic noise and tyre/road noise [6]. Power-unit noise is the mechanical and combustion noise resulting from vehicle propulsion; aerodynamic noise originates from the turbulent airflow around the body (at higher speeds), and lastly, the tyre/road noise is generated by the interaction between the tyre and the pavement. Aerodynamic noise is negligible concerning noise emissions to the environment, and tyre/road noise is dominant over power unit noise already at moderate speeds (about 30 km/h for cars and 50 – 60 km/h for heavy vehicles). For this reason, the pavement plays a critical role in the generation of road traffic noise. Tyre/road noise itself is a convoluted combination of various generation and amplification mechanisms that result in noise in different, but often overlapping, frequency ranges[7]. However, the noise generation differs amongst vehicles on the roads, and moreover, it is also dependent on temperature and vehicle speed [8]. This complicates using free-flowing traffic conditions for the purpose of acoustic characterisation of pavements, as in ISO 11819-1. To some extent, the noise emissions are similar for certain vehicle types. By defining vehicle categories containing specific types of vehicles, it is assumed in ISO 11819-1 that the noise behaviour of the vehicles in each category is sufficiently similar to describe the pavement's acoustic performance. The allocation of vehicles to the categories is made visually, therefore the category descriptions are based on vehicle appearance. The standard describes the following categories; Passenger cars (P), Dual-axled Heavy vehicles (HD) and Heavy vehicles with more than two axles (HM) [4]. These categories are then separately analysed further; first, the L_{Amax} is corrected for temperature. Next, in order to exclude the impact of speed on the measurement, a linear regression is applied to the temperature corrected L_{Amax} and logarithm of the speed of the vehicle pass-bys in the same vehicle category. Finally, the formula of the resulting regression line, see Eq. 1, is used to calculate the L_{Amax} at a reference speed, which represents the acoustic performance of the pavement for that specific category. This value can be used to compare pavements directly, or to calculate the Statistical Pass-By Index (SPBI), a value where the contribution of the different vehicle categories is weighted.

$$L_{\mathrm{Amax}} = \mathrm{A} + \mathrm{B} * \log(v) \qquad (1)$$

To ensure the accuracy of the method, sufficient data is needed to construct the linear regression model. For this reason, the current ISO 11819-1 sets a minimum number of 100 pass-bys for passenger cars and 30 for both HD and HM. Additionally, the vehicle categories of HD and HM combined, also called 'Heavy vehicles', should contain at least 80 pass-bys. However, reaching these minima often proves difficult, specifically regarding the HD and HM categories. While there usually is an abundance of passenger car vehicles, the number of valid HD and HM pass-bys is much lower, and often one of the categories is almost absent which extends the duration of the measurement [9]. Lowering the minima therefore would be of great practical and economic interest. For this reason, methodological changes are included in a new draft version of the ISO standard. Most notably, the minimum required number of heavy vehicles is reduced to 40, and the individual minimum for these categories is abolished [5].

However, only reducing the minimum number of vehicles would compromise the statistical accuracy of the method. For this reason, the draft standard proposes a new approach for processing the data for these categories. Firstly, the data of HD and HM are combined into a single category after the HD pass-bys are 'normalised' to HM pass-bys by adding 2.7 dB to their L_{Amax} levels. Still, the spread of pass-by speeds within the heavy vehicles category is generally lower compared to the passenger car category, and simultaneously, the variation in L_{Amax} is larger, which results in large uncertainties when applying the linear regression method [9]. To solve this issue, Eq. 1 relating L_{Amax} and the logarithm of speed is constructed not using the linear regression analysis. Instead the slope, also referred to as speed coefficient 'B', is assumed to be a predefined semi-generic value selected based on the pavement type. The intercept 'A' is calculated as the arithmetic average of the noise levels corrected to a reference speed using the speed coefficient. Lastly, another change included in the draft standard is a more strict description of vehicles for the HD category with a newly imposed lower limit on Gross Vehicle Mass (GVM) of 8 tons. This aims to increase the compatibility of HD and HM categories for their combined analysis by reducing the variation among the vehicles, and thus the sound emission profiles, within this category. However, this lower limit also excludes more vehicles from the measurement. In this study, a large dataset of SPB measurements was collected according to the ISO/DIS 11819-1 draft standard and utilized to evaluate the proposed changes compared to the original standard ISO 11819-1:1997. Furthermore, the possibility of also considering the pass-bys of vans, currently excluded from the data analysis, is explored.

2 Materials and methods

2.1 Statistical Pass-By (SPB)

The influence of the pavement on traffic noise is evaluated through wayside noise measurements according to ISO/DIS 11819-1. The overall vehicle noise is measured, which is more representative of the real-world impact of traffic noise compared to tyre/road noise captured in the CPX-method. To measure the noise levels, a sonometer setup is placed at 7.5 m from the centre of the measured traffic lane at a height of 1.2 or 4.0 m, or both. In this study, only a single microphone at 1.2 m was used, connected to a sonometer type 2260 by Brüel and Kjaer, see Figure 1. Since the pass-by noise is greatly impacted by vehicle speed, it is captured by a tachometer also placed at the roadside; a model KR-10 SP was used in this study. Moreover, the speed of the pass-bys needs to be checked actively as only vehicles approaching at a constant speed should be measured; accelerating/decelerating causes additional engine or breaking noise, which is not desired when assessing the pavements acoustic performance. The sonometer and tachometer are connected to a data acquisition system plugged into a laptop, where the real-time noise level and speed can be evaluated, and the pass-by data can be saved. In order to capture the acoustic spectra in third-octave bands, a second sonometer, an NTi XL2, was set up in parallel for the second half of the measurement campaign. The two devices were individually calibrated and their accuracy was checked through a round-robin test at each measurement site. Lastly, also temperature impacts the noise levels. In more detail, higher temperatures result in lower noise levels, regarding passenger cars, this effect is as large as 1dB per 10 °C [8]. For this reason, the air temperature was captured every 15 min. with an accuracy of 0.1 °C and the measured L_{Amax} were temperature corrected according to ISO/DTS 13471-2:2021. In a previous work, we established that this temperature correction is appropriate for this dataset [8].

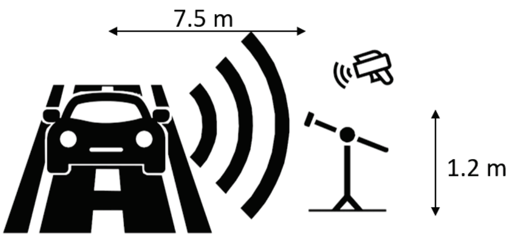

Figure 1: SPB method setup.

2.2 Locations

In the SPB method, the overall vehicle noise is captured at the roadside, therefore, acoustic reflections of surfaces in the vicinity of the microphone can affect the measured noise levels. In this regard, the acoustic behaviour of the ground surface between the measured lane and microphone position is of great importance. For this reason, the standard sets requirements regarding the acoustic properties of this surface area and other objects that disturb the acoustic free-field around the microphone [4], [5]. In this study, SPB measurements were repeatedly performed at three locations, which were carefully selected to fulfil these requirements. However, a few minor deviations were unavoidable. Furthermore, as the goal of this study was to evaluate the changes made in the draft standard, and the majority of these changes are regarding the heavy vehicle categories, the locations for this study were specifically selected for their large share of heavy vehicles in the traffic volume. Due to safety concerns, the maximum speed limit at the selected locations was 70 km/h. However, the average speeds during the measurements were remarkably lower, especially for the heavy vehicle categories. Lastly, the pavement either consisted of an AC or SMA type. All available data about the measurement sites is presented in Table 1.

Table 1: Overview of measurement locations.

	Location 1			**Location 2**			**Location 3**		
Address	Keetberglaan, Zwijndrecht, Belgium			Krijgsbaan, Zwijndrecht, Belgium			Stuivenbergvaart, Mechelen, Belgium		
	 Scale: 1 square = 1 cm			 Scale: 1 square = 1 cm			 Scale: 1 square = 1 cm		
Asphalt type	Stone Mastic Asphalt (SMA-10)			Stone Mastic Asphalt (SMA-10)			Asphalt Concrete (AC)		
Max. aggregate size	10 mm			10 mm			14 mm		
Mean Profile Depth	1.2 mm			1.0 mm			1.8 mm		
Surface between lane and mic.	Asphalt parking lane			Cobblestone parking lane Concrete bike lane			Concrete block pave bike lane and sidewalk		
Remarks regarding acoustically free field	• Very thin bushes on the opposite side of the road • Small ditch behind the microphone, banking was covered by grass • Highway near, background noise levels were checked			• Vegetation and houses across the street at approximately 20 and 30 m from the microphone position			• Highway near, background noise levels were checked • small ditch behind the microphone position		
Speed limit	70 km/h			70 km/h			70 km/h		
Vehicle category	P	HD	HM	P	HD	HM	P	HD	HM
Avg. speed	63 km/h	55 km/h	53 km/h	51 km/h	46 km/h	45 km/h	51 km/h	47 km/h	46 km/h
N° pass-bys	773	101	1855	898	137	384	1225	57	286
Measurement count	7 days			5 days			6 days		

3 Results and discussion

3.1 Difference in L_{Amax} of vehicle groups HD and HM

To increase the practicality of the SPB measurements, the draft standard proposes to reduce the minimum number of measured vehicles by combining the data of HD and HM categories into a single category named 'Heavy vehicles' (H). However, as the noise-speed behaviour of these categories differs, the data of the HD category is first normalised by adding 2.7 dB to the L_{Amax} value of each pass-by. To evaluate this proposed change, the data of the individual measurement days was combined per location to achieve a robust dataset, from which the difference in L_{Amax} from categories HM and HD was calculated and compared to the proposed 2.7 dB.
First, in Figure 2, the L_{Amax} values of both HD, without the 2.7 dB correction, and HM pass-bys are plotted versus the logarithm of their speed for each location, and a linear regression analysis is perfomed for each vehicle category. From the graphs in Figure 2, the difference in noise behaviour of the HD and HM vehicle categories is directly clear.

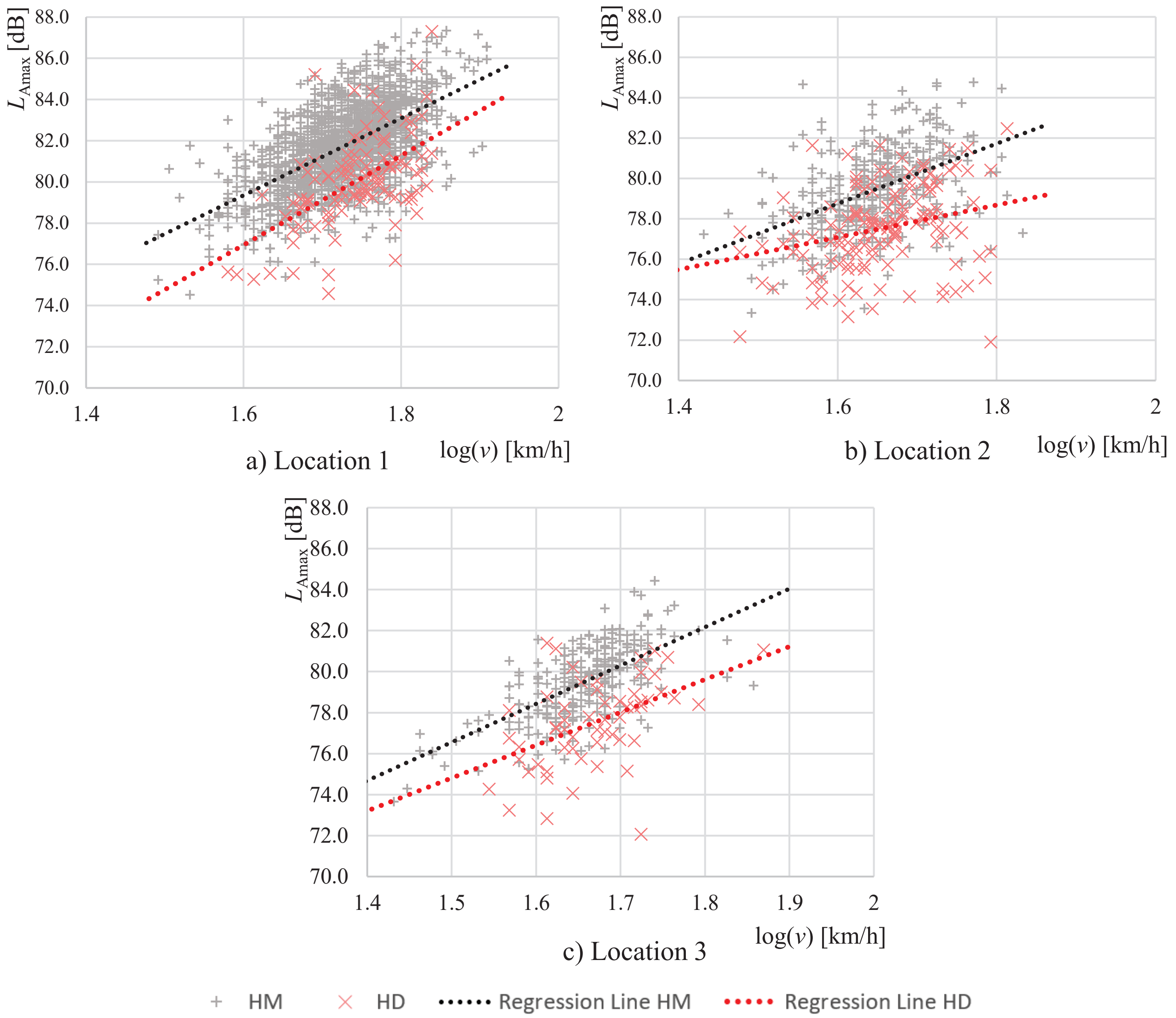

Figure 2: Regression models for HD and HM vehicle categories per location.

Due to the large amount of data of this study, the regression models are assumed to be an accurate representation of the noise behaviour of the vehicle categories. Therefore, in order to evaluate the proposed +2.7 dB in a quantitative manner, the difference between the vehicle categories' C' was calculated as the difference between the regression lines at the reference speed using Eq. 2:

$$C = (A_{HM} - A_{HD}) + (B_{HM} - B_{HD}).\log v_{ref} \quad (2)$$

where $A_{HD/HM}$ and $B_{HD/HM}$ are the regression line's intercept and slope, respectively, on the HD or HM data, and v_{ref} is the reference speed at 50 km/h (log(50) ≈ 1.7). The C values for each location are presented in Table 2. The values for C at 50 km/h range from 2.1 to 2.3 dB with an average value of 2.2 dB.

Table 2: C values per location.

Location 1	Location 2	Location 3	Average
2.1	2.3	2.3	2.2

Figure 3 also displays the C values over the whole speed range of the datasets. The C values are not constant across the speed range as the regression lines of $L_{A,max}$ vs. log(v) are not parallel. There is a decreasing trend for Location 1, meanwhile an increasing trend is found at Locations 2 & 3.

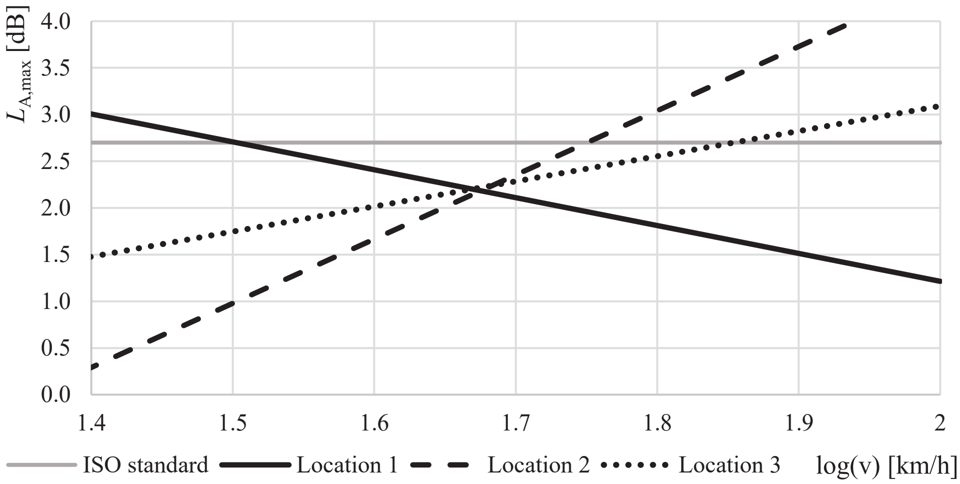

Figure 3: C values per location over the speed range.

The overall average of the C values is 2.2 dB, which is 0.5 dB lower compared to the 2.7 dB proposed in the draft standard. The data used to establish this value has not been published yet. Regarding other literature, [10] reported an average difference of 2.5 dB between the vehicle categories based on a compilation of measurements from different locations. However, there was no detailed information on the pavement type or speed range at the measurement sites. Furthermore, since the report dates from 2015, it did not impose the 8 tonnes lower limit for the HD category imposed by the new draft standard, which affects the selection of vehicles for the HD category. In another study from the UK, HD and HM SPB values were also reported from a series of measurements [11]; the difference between the categories was on average 2.4 dB. However, in that study, the vast majority of the sites were specifically selected because they were paved with low-noise pavements, which acoustic behaviour is very different from the dense asphalt surface considered in this study, and the study was performed at highway speeds. In short, the values reported in the literature were closer to the findings of this study. On the other hand, differences in measurement sites and traffic make the interpretation ambiguous. An overestimation of C by the standard, as the results from this study indicate, would lead to an overestimation of $L_{\mathrm{SPB:H},v}$ at locations where HD vehicles dominate the traffic. However, as the difference is only 0.5 dB, the impact would be limited. Yet, it is still important to further evaluate the correctness of this value, not only for dense asphalt surfaces considered in this study but also for other pavement types. Furthermore, it is necessary to evaluate the speed dependency of the C value in more detail.

3.2 Evaluation of speed coefficients for H

Generally, the H category presents a much larger range of L_{Amax} while simultaneously covering a much smaller speed range. This spread of data results in large uncertainties on the $L_{\mathrm{Amax}} - \log(v)$ relation in the linear regression model. To solve this problem, an alternative method for processing the data using semi-generic speed coefficients is proposed in the draft standard. There are three coefficients for three surface types: dense asphalt, open asphalt and concrete pavements, and these semi-generic speed coefficients are the equivalent of the slope' B' of the regression line in the $L_{\mathrm{Amax}} - \log(v)$ regression model. As this study consists of a remarkably large number of HM pass-bys, the dataset allows to perform the regression analysis on the pass-bys of the individual measurement days. The proposed speed coefficient for dense asphalt is then compared to the equivalent slope of the regression lines in this study. With regard to the previous section, where it was found that the average SPL difference between HD and HM was smaller compared to what is proposed in the standard, only the data of HM has been considered in this section.
The B values from this study range from 14.9 to 27.7 dB/log(km/h) with a mean value of 20.5 dB/log(km/h), one outlier at -2.7 was removed, see Table 3. A one sample t-test was performed to check if the mean B value of this study is different from the provided coefficient of 25 in the standard. The result is strongly significant with a p-value <0.001. This indicates that at these specific measurement sites the proposed value is not applicable. Nevertheless, the effect of the difference in speed coefficients on the subsequent calculations is negligible. As indicated in the draft itself, a variation of +/-5 in B results in 0.25 dB over 10 km/h.

Table 3: B and R^2 values from the linear regression on the data of individual measurement days.

Meas. day	B	R^2	Location	Meas. day	B	R^2	Location
1	14.9	0.26	1	10	15.5	0.27	1
2	25.6	0.55	1	11	20.0	0.51	3
3	20.3	0.46	3	12	26.6	0.71	3
4	19.8	0.37	3	13	20.5	0.40	2
5	17.5	0.35	3	14	16.8	0.41	3
6	23.0	0.47	2	15	27.7	0.61	2
7	21.0	0.43	2	16	19.4	0.34	1
8	-2.7*	0.01	2	17	21.2	0.45	1
9	19.0	0.34	1	18	20.0	0.42	1

*Removed from the one sample t-test as an outlier

3.3 Vans as an alternative category

Vans are currently not included in any of the vehicle categories, neither in the original ISO 11819-1:1997, nor the ISO/DIS 11819-1:2021 draft. This is because the purpose of the standard is to evaluate the impact on the acoustic performance of the pavement; as the impact is different for various vehicles, with light and heavy vehicles at the extreme ends, the standard primarily focusses on these two vehicles types. Furthermore, the impact on noise behaviours of cars and trucks is more relevant since the first makes up the majority of the traffic composition, while the latter results in the highest L_{Amax} values. Meanwhile, 'medium' vehicles, such as vans, are not considered to be of interest. Nonetheless, in urban landscapes, the presence of vans is becoming increasingly more significant due to a broad range of activities such as postal, courier and delivery services, construction, etc. Vans are visually different from passenger cars in appearance due to their larger size and different build, and moreover, a van category 'V'could also be easily distinguished from the HD category by vehicle length, height and tyre size. Images of typical vehicles assigned to these categories are presented in Figure 4.

Figure 4: Images of typical vehicles assigned to the P, V and HD categories in this study.

Interestingly, a linear regression on L_{Amax} and the logarithm of speed on the data of each individual measurement day presented on average higher R^2 values for vans compared to the HD and HM vehicle categories, see Table 4. In this application, the R^2 indicates how much variation of L_{Amax} is explained by the variation in speed, thus the higher R^2 values indicate that the regression model for the V category better describes the acoustic behaviour of the pavement compared to the HD and HM categories. While it is true that the linear regression method will no longer be applied to the HD and HM vehicle categories in the ISO/DIS 1119-1:2021 draft, the R^2 values remain a good indicator for the uncertainty when using the proposed alternative method. For this reason, considering vans as an alternative vehicle category may yield valuable information that potentially could aid in reducing the measurement length. The noise behaviour of this alternative vehicle category in relation to the other vehicle categories will be explored in the next section.

Table 4: R^2 values per vehicle category.

	P	HD	HM	V
Mean	0.507	0.298	0.410	0.443
Stdev	0.164	0.245	0.150	0.224
N° pass-bys	2896	295	2525	682

3.4 Comparison of noise behaviour of different vehicle categories

Figure 5 displays the regression lines resulting from the L_{Amax} – log(v) relation for the four different vehicle categories and three measurement locations.

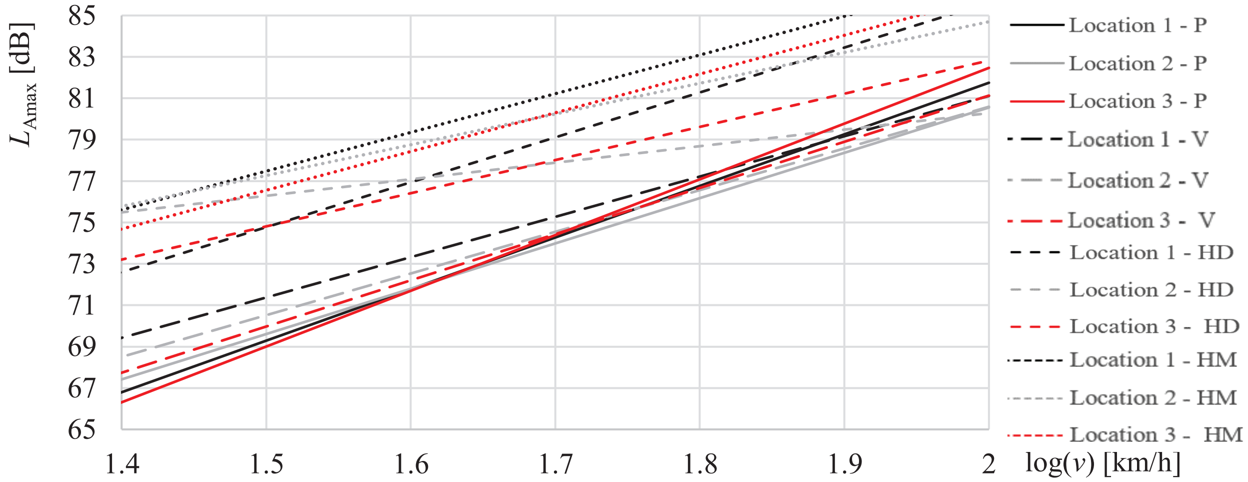

Figure 5: Regression lines for each vehicle class at all locations.

The P category presents the most inclined L_{Amax} vs log(v) relation; thus, for low speeds (below 45 km/h), their noise levels are considerably lower than at higher speeds compared to the other vehicle categories. At low speeds, power-unit noise outweighs tyre/road noise, while at higher speeds, tyre/road noise is dominant in contributing to the overall vehicle noise. In this sense, it can be interpreted that the share of power-unit noise over vehicle noise of P pass-bys, even at low speeds, is consistently smaller than for other vehicle categories. This behaviour is expected due to their smaller engine and other differences in the intake system/exhaust/muffling design.

Even though the regression lines for P pass-bys are slightly steeper than for vans, Figure 5 shows that the two categories produce similar noise levels, mostly at higher speeds. Vans, especially those based on car platforms, may only require passenger rated tyres (tyre class C1, as per the ECE Regulation 117 [12]). Larger commercial vans tend to demand specific van tyres (C2) to cope with the payload of the vehicle, but these tyres have similarities with passenger car tyres, such as tread depth, that may result in a tyre/road noise generation behaviour closer to the C1 than the tyres generally used on heavy vehicles (C3).

The 2.7 dB addition in HD pass-bys noise levels results in a vertical shift of the regression lines in Figure 5. As discussed in Section 3.1, even though this addition will bring the HD pass-bys L_{Amax} to similar noise levels as HM, the L_{Amax} vs log v relation slopes are consistently different, emphasising that a speed-depencendy of this value should be investigated.

To gain more insight in the acoustic behaviour of the different vehicle categories, Figure 6 depicts the average L_{Amax} spectrum from the three locations for the vehicle categories in third-octave bands between 315 Hz and 5000 Hz. To eliminate the speed dependency, and allow a direct comparison among vehicle categories, the noise levels ($L_{\mathrm{Amax,i}}$) for each individual pass-by v_i were normalised to a reference speed of 50 km/h for each vehicle category and location, using the slope B of the regression lines presented in Figure5, before calculating the average noise levels, following Eq.(3).

$$L_{\mathrm{Amax,i,speednormalised}} = L_{\mathrm{Amax,i}} - B * \log\left(\frac{v_i}{v_{ref}}\right) \tag{3}$$

V and P pass-bys present a similar behaviour regarding the value of peak L_{Amax} ranging around the 800-1000 Hz, Additionally, their spectra almost overlap between 1000 and 2500 Hz third-octave bands. This could be attributed to the fact that air-pumping mechanisms [6], induced by displacement of air in/out the tyre tread under its volume changes upon contact with the pavement, are the main tyre/road noise generation mechanism at these frequencies and are similar for vans and passenger car tyres due to similarities in construction.

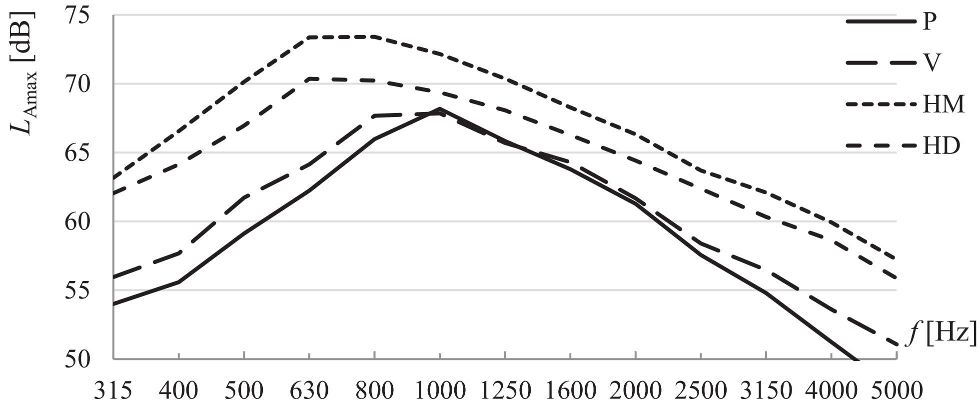

Figure 6: Average spectrum of LAmax, corrected for speed, per vehicle category P (n=616), V(n=166), HD (n=74), and HM (n=905).

HD and HM present similarly shaped spectra, shifted in amplitude by 2.1±0.7 dB on average. These spectra show that these two vehicle groups are impacted by the different tyre/road noise generating mechanisms in a similar manner and, in this sense, may produce a consistent single group by combining HM pass-bys with the normalised HD, as proposed in the ISO/DIS 11819-1 draft standard.
Peaks in noise levels for HM and HD occur at lower frequencies than P and V. A possible explanation for this can be a lower crossover frequency from the dominance of impact mechanisms to air displacement mechanisms for truck tyres (around 500 Hz), compared to car tyres (800-1200 Hz) [6].

4 Conclusions

In this study, a large dataset collected over 18 measurement days at three locations with a large share of heavy vehicles was used to evaluate the changes in ISO/DIS 11819-1 draft standard compared to the original currently active version ISO 11819-1:1997. The following was concluded:

- This study reports a difference in maximum overall noise levels of vehicle pass-bys 'L_{Amax}' between heavy vehicles with two axles (HD), and more than two axles (HM) of 2.2 dB. This is 0.5 dB lower compared to the 2.7 dB proposed in the draft standard. An overestimation of this difference C by the standard, as the results from this study indicate, would lead to overestimation of $L_{SPB:H,v}$, used to describe the acoustical performance of the pavement, at locations where HD vehicles dominate the traffic, although a difference of 0.5 dB entails only a limited impact.
- The slope of the regression line B for the HM vehicle category of all individual measurement days in this study was on average 20.5 dB/log(km/h). A one-sample t-test showed that this result is significantly different from the value of 25, which is proposed in the draft standard as an equivalent value to replace the regression analysis by an alternative data processing method.
- The spectra of the HD and HM vehicle categories indicate that they are similarly impacted by the different noise generating mechanisms, thus producing a consistent vehicle group after the $L_{A,max}$ normalisation for HD vehicles.
- By presenting good R^2 values in the linear regression analysis, vans appear to be an appealing group as an additional vehicle category with relatively consistent noise behaviour and could thereby reduce the measurement duration. Moreover, a deeper look showed that vans present strong similarities with passenger cars (P): regarding L_{Amax}, the two categories produce similar noise levels, mostly at higher speeds where tyre/road noise is dominant. Furthermore, their noise spectra almost overlap from 1000 to 2500 Hz with only limited differences outside this frequency range. A possible explanation is the similarity of the vehicle's tyres resulting in similar tyre/road noise behaviour.

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