forum acusticum 2026
8-12 September · Graz, Austria

AMENDMENT PROPOSAL FOR NOISE EMISSION DATA OF MOTORCYCLES AND MOPEDS IN CNOSSOS-EU

Michael Dittrich[1], Heinrich (Heinz) Steven[2]

[1]*Department of Acoustic Signatures and Noise Control, TNO, The Hague, The Netherlands*
[2]*HS Data Analysis and Consultancy, Heinsberg, Germany*

This paper is a revised version of the authors' submitted manuscript that was peer-reviewed by at least two anonymous reviewers.

Abstract

A proposal is made for revised sound source levels for motorcycles and mopeds in the CNOSSOS-EU traffic noise calculation model, which are considered too low. For motorcycles they are partly below those for cars. L-vehicles have comparatively high impact in terms of annoyance and health effects on affected residents, while comprising a small percentage of overall traffic.

The proposed amendment includes the factors for propulsion noise for constant speed, for acceleration/deceleration conditions and for gradients. Vehicle tampering and driving behaviour are taken into account with an increased sound level and weighting for the percentage of vehicles in the fleet with tampering and/or high rev driving.

The analysis is based on several measurement data sources and on vehicle noise modelling, taking driving cycles, engine speed and tampering into account.

Keywords: *Vehicle noise, motorcycles, mopeds, source terms, CNOSSOS-EU*

1. Introduction

In the EU project LENS [1], an analysis was made of potential noise mitigation solutions for noise from L-vehicles, which include motorcycles, mopeds, trikes and quads. One of the recommendations was to update the sound source emission factors for the EU traffic noise calculation model CNOSSOS-EU in Directive 2015/996 [2],[3]. The CNOSSOS-EU model is prescribed for noise mapping, assessment of numbers of annoyed and sleep disturbed people, and to derive noise action plans at local level, as required by the Environmental Noise Directive (END) 2002/49/EC [4]. Noise mapping calculations are based on long term L_{den} and L_{night} sound levels, which tend to average out individual loud peaks.

This paper is based on an analysis documented in [5] of several measurement data sets and on vehicle noise modelling taking vehicle operating conditions, including engine speed, and driving cycles into account (refs [6]-[11]).

2. Justification

There are several reasons why the CNOSSOS sound emission factors should be modified:

a) The sound source levels are unrealistically low, below cars at many speeds, and should better reflect real sound emission of L-vehicles.
b) The correction for accelerating conditions near crossings and roundabouts are zero and therefore too low.
c) The correction for gradients is zero and therefore too low.
d) Vehicle tampering and driving behaviour are not taken into account, leading to underestimation of the noise emission.

Although L-vehicles are less numerous than cars, they have several characteristics which make them increasingly relevant for environmental traffic noise calculations, increasing their contribution to the long term noise level (L_{den}):

- L-vehicles, especially motorcycles, have become more powerful and potentially louder over time in real traffic;
- Depending on driving behaviour, including high engine speeds, and tampering, they can produce excessive sound levels;
- The size of the motorcycle fleet has increased and continues to grow, with very little electrification;
- Other vehicle types have become quieter and will continue to do so, including electrification and reduced rolling noise due to quieter tyres and quiet road surfaces;

Corresponding author: *michael.dittrich@tno.nl.*

- L-vehicles have more dynamic driving behaviour compared to other vehicles, partly driving higher speeds than the road speed limits [7].
- Tampering devices and methods that can increase power and noise are widely available.

Although for motorways and busy arterial roads, the contribution of L-vehicles is relatively small in the total, for main roads, residential roads and rural roads this may not always be the case. In some situations they may actually be the main source of complaints due to high single event sound levels. The proposed modifications may help to better quantify L-vehicle contribution, without actually considering single events. It would even be justifiable to consider penalties in the sound source level of L-vehicles due to the sound characteristics including fluctuation, impulsiveness, tonality and low frequency which are less prominent for other vehicle types. Even the dose-effect relationship could be adjusted, based on earlier studies [12],[13]. Neither of these are yet examined here but would merit further consideration.

Situations where L-vehicles can affect the long term L_{den} levels are those with relatively high numbers and high sound emission due to driving behaviour and tampering. Sound exposure for residents is also increased in streets with buildings on both sides, along popular rural touring roads, in valleys, at road junctions, on hills, and near tunnel entrances and viaducts. High sound levels carry over longer distances and can penetrate more easily into dwellings. With better source data for L-vehicles, it is expected that more representative noise exposure calculations can be made, which in turn can be used as a basis for END action plans that also include L-vehicles. The effect of motorcycle sound levels on the equivalent traffic noise sound level has been evaluated in [14] and [15] showing that L_{den} levels can be affected by the source levels, numbers and speeds of L-vehicles, besides the other traffic sources.

3. Motorcycles and mopeds in CNOSSOS-EU

The CNOSSOS model calculates the long term average sound levels L_{den} and L_{night} along roads, based on traffic flow rates, speeds, vehicle sound source data, road surface and gradient and other factors. The current CNOSSOS sound power source data includes five vehicle categories including (1) cars and light vehicles, (2) medium heavy vehicles, (3) heavy vehicles, (4) powered two-wheelers, with 4a for mopeds and 4b for motorcycles, and (5) an open category. Category 4 is only assigned propulsion noise, whereas categories 1, 2 and 3 include both tyre noise and propulsion noise.

The sound power level for propulsion noise $L_{WP,i,m}$ for vehicle category m and octave band i is calculated with

$$L_{WP,i,m}=A_{P,i,m}+ B_{P,i,m} \times (v_m-v_{ref})/v_{ref} + \Delta L_{WP,i,m} \qquad (1)$$

where $A_{P,i,m}$ and $B_{P,i,m}$ are tabulated coefficients (see Table 1 as in [2] Table F-1) for each octave band and vehicle category, v_m is vehicle speed and v_{ref} is a reference speed of 70 km/h. For this analysis, the pass-by sound pressure level L_{pAFmax} at 7.5 m distance is obtained by subtracting 29.5 dB (including divergence and ground effect for point sound power source, fitted as the yellow curve in Fig. 1).

Table 1. Coefficients for propulsion noise of category 4 vehicles, for free flowing traffic conditions.

		Octave band frequency [Hz]							
Cat		63	125	250	500	1k	2k	4k	8k
4a	A_P	93.0	93.0	93.5	95.3	97.2	100.4	95.8	90.9
	B_P	4.2	7.4	9.8	11.6	15.7	18.9	20.3	20.6
4b	A_P	99.9	101.9	96.7	94.4	95.2	94.7	92.1	88.6
	B_P	3.2	5.9	11.9	11.6	11.5	12.6	11.1	12.0

$\Delta L_{WP,i,m}$ is a sum of correction coefficients for road surface absorption, gradient and acceleration/deceleration:

$$\Delta L_{WP,i,m} = \Delta L_{WP,road,i,m} + \Delta L_{WP,grad,i,m} + \Delta L_{WP,acc,i,m} \qquad (2)$$

For acceleration and deceleration, the correction is given as

$$\Delta L_{WP,acc,i,m} = C_{P,m,k} \times \max(1-|x|/100 \, ; 0 \,) \qquad (3)$$

where x is the distance in metres to the nearest crossing or roundabout and k is an index for crossing (1) or roundabout (2). For L-vehicles (m=4), C_P is zero. For cars, the C_P is between 3 and 6 and for medium and heavy vehicles between 7 and 9. The gradient correction $\Delta L_{WP,grad,i,m}$ for L-vehicles is zero, whereas for other vehicle types it is a function of slope and speed. The road surface correction $\Delta L_{WP,road,i,m}$ is zero for L-vehicles.

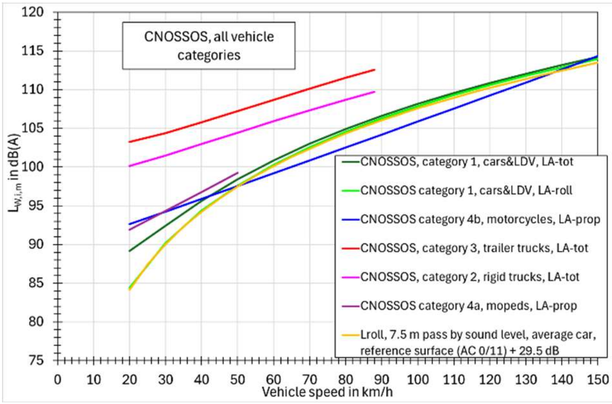

Figure 1. A-weighted sound power level for CNOSSOS vehicle categories for current emission data for free flowing conditions. The yellow curve shows the comparison with rolling noise of an average car measured at 7.5 m distance.

The A-weighted sound power levels for the CNOSSOS vehicle categories are set out in Fig. 1. For comparison, the sound power curve for rolling noise for cars is shown in green and yellow, derived from measurements of rolling noise at 7.5 m and used in the ROTRANOMO model [11], with a correction of 29.5 dB between sound pressure level and sound power level. It is apparent from these curves that

- the motorcycle curve (blue) is below the car curve (green) between 45 and 140 km/h and far below the curves for medium and heavy vehicles;
- above 30 km/h, mopeds (magenta) have higher noise emissions than motorcycles (blue).

Neither is in line with the results of noise measurements in real traffic [7],[8] or the type approval limits including older L-vehicles.

4. Analysis

4.1 Datasets and modelling

In order to cover the wide range of L-vehicles and driving conditions as identified in LENS [6],[7],[8], existing measurement data sets were used [9], [10] together with calculations with the ROTRANOMO/TRANECAM model for vehicle noise emission [11]. The measurement datasets included on-road driving cycles for which speeds were registered, from which noise emission could be derived with the ROTRANOMO model. Also pass-by measurements were available for various driving conditions.

ROTRANOMO allows prediction of vehicle noise emission based on vehicle type, speed, engine speed, gear, acceleration and loading. When calibrated to pass-by measurements of known vehicles, the sound emission can be calculated for any given driving cycle if the speed time history is known. The ROTRANOMO/TRANECAM model was originally developed in an EU framework project in 2002 [11] and was updated several times since then, financed by the EU Commission, the German and the Norwegian government. The latest update, dedicated to two-wheelers, was performed within the LENS project. It contains all noise related type approval legislation steps up to the 3rd step of the current noise regulation 540/2014/EU, coming into force 2026/2028.

4.2 L-vehicle subcategories

Motorcycles in category 4b include a wide range of vehicles, all with engine capacity from 50 cc up to 1500 cc and higher. This actually includes scooters (distinguished by their wide footplate), which like mopeds often have a CVT transmission, and a maximum speed up to 100-120 km/h vs. 50 km/h or lower for mopeds. In contrast, most motorcycles generally have manual sequential gears, higher power, and maximum speeds exceeding 200 km/h for some models. Motorcycles above 250 cc, also known as L3e-A2/A3 vehicles, have different sound characteristics and are therefore proposed as a new CNOSSOS category 4c. Motorcycles below 250 cc are also known as L3e-A1 vehicles, proposed as a new CNOSSOS category 4b.

In order to analyse sound emission for a sufficient range of conditions, both on-road driving data, pass-by data at different constant speed and acceleration conditions are required, besides measurements on tampered vehicles, all for a variety of vehicles. The ROTRANOMO model was calibrated against these measurements, allowing to predict noise emission for given engine speed, gear and load conditions. A default mix is proposed of 45% for new category 4b and 55% for new category 4c, based on LENS data from 2025.
In order to make results for different rated engine speed values and idling speed values comparable, the engine speed values were normalised to the span between idling speed and rated engine speed. Cruise sections are cycle intervals where the acceleration values were between -0.1389 m/s² and +0.1389 m/s², acceleration sections are cycle parts with a > 0.1389 m/s² (0.1389 m/s = 0.5 km/h/s). Further details are given in [5].

4.3 Motorcycles up to 250 cc (4b)

These are mainly L3e-A1 vehicles with rated power values up to 11 kW, power to mass ratio values < 50 W/kg and maximum vehicle speed up to 115 km/h. The majority are scooters. In LENS, RDE measurements were performed for a series of different L3e-A1 motorcycle types [8],[9]. For 9 of these types the engine speed measurement results were exact enough to use them in the ROTRANOMO model for pass-by sound emission modelling. The total amount of driving time was 39 hours and the total driving distance was 1800 km. Fig. 2 shows pass-by levels calculated with ROTRANOMO for motorcycles below 250 cc, based on engine speed sampling, for constant speed (blue) and acceleration conditions (red). Also the linear fitted curves are shown.

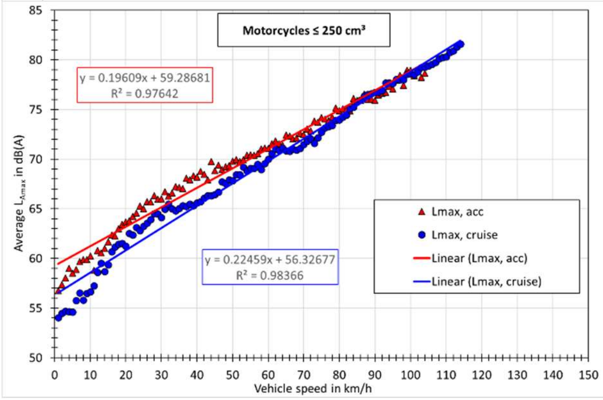

Figure 2. Average L_{pAFmax} sound levels at 7.5 m distance vs vehicle speed, modelled with ROTRANOMO for motorcycles below 250 cc, compliant with current noise type approval regulations, for constant speed and acceleration conditions.

In Fig. 3, the derived sound power curves are shown. These include 7 dB increase for the effect of tampering based on the silencer study [10], and verified in LENS [15], which is 2 dB if weighted for 15% of the fleet. The 15% corresponds to the LENS field survey on tampering (report D5.3 and D6.4 [15]).

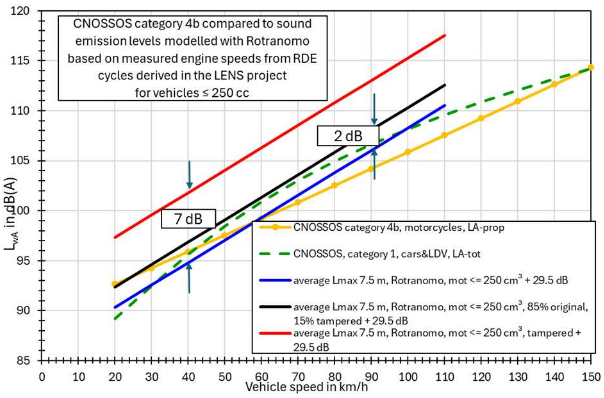

Figure 3. Average CNOSSOS sound power curve for existing category 4b (in blue) compared to sound power levels for motorcycles up to 250 cc, modelled with ROTRANOMO. Tampered vehicles have on average a 7 dB higher level than compliant vehicles. For 15% tampering rate this is 2 dB (black curve).

4.4 Motorcycles above 250 cc (4c)

RDE measurements also were performed for a series of different motorcycle types within the LENS project. For 6 of these with more than 250 cc, the engine speed measurement results during 29 hours and 1500 km of driving were exact enough to be used in the ROTRANOMO model for pass-by sound emission modelling. Fig. 4 shows calculated pass-by sound levels for constant speed and acceleration conditions, with linear fitted curves.

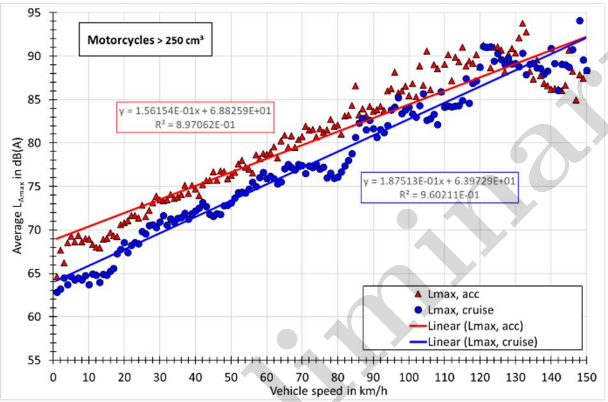

Figure 4. Average L_{pAFmax} sound levels at 7.5 m distance vs vehicle speed, modelled with ROTRANOMO for motorcycles > 250 cc, compliant with current noise type approval regulations, for constant speed and acceleration conditions.

A similar curve (in blue) is introduced, shown in Fig. 5 for constant speed conditions, besides a 7 dB higher curve (in red) for 100% tampering. For the fleet, 15% tampering and 15% high rpm driving are taken into account, resulting in 30% of the fleet, as found in Dutch roadside measurements [7]. These percentages are used as defaults as identified in the LENS project. Averaging the blue and red curves results in a 3.4 dB higher level (black curve). This is around 9 dB above the original CNOSSOS curve (yellow).

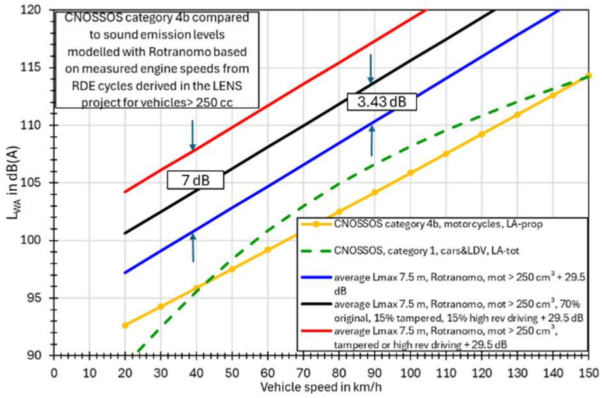

Figure 5. Average CNOSSOS sound power curve for existing category 4b (in blue) compared to sound power levels for motorcycles above 250 cc, modelled with ROTRANOMO. Tampered or high rpm vehicles have on average a 7 dB higher level than compliant vehicles, based on findings from the Silencers project [10]. For 15% tampering rate and 15% high rev driving this is 3.4 dB (black curve).

4.5 Mopeds (4a)

For mopeds, a similar approach was taken, using engine speed measurement data from driving cycles totalling 5.6 hours and 160 km distance. The sound levels derived from engine speeds show a large spread, shown in Fig. 6, including polynomal fitted curves.

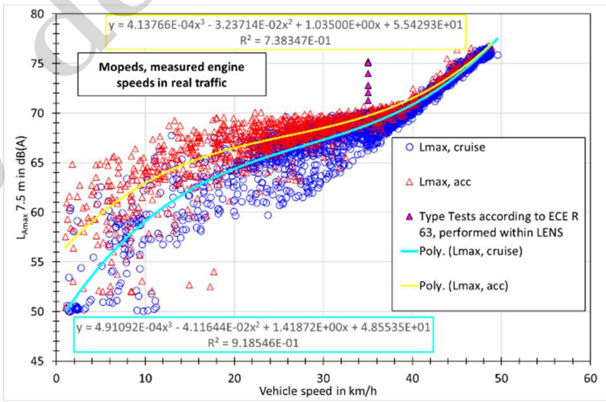

Figure 6. Average L_{pAFmax} sound levels at 7.5 m distance vs vehicle speed, modelled with ROTRANOMO for mopeds, compliant with current noise type approval regulations, for constant speed and acceleration conditions.

The derived new curve in blue is shown in Fig. 7, together with the increase of 7 dB for tampering (red) and a weighted curve of 4.5 dB higher, taking a percentage of 45% tampered vehicles into account (black). The dashed curves are polynomial fits, the solid curves are linear fits. The original CNOSSOS curves for mopeds (yellow) and cars (green dashed) are also shown for comparison. The slope is much higher for the L_{max} ROTRANOMO regression curves than for the current CNOSSOS curve for mopeds (2 dB higher at 20 km/h up to 8 dB higher at 50 km/h). And the sound emission of mopeds exceeds those of the motorcycles above 40 km/h. The proposed curve does not correspond exactly to the curve shown in Fig. 6, but the advantage of keeping the linear dependency compensates the disadvantage of higher deviations from the modelled sound emissions. It results in differences to the current CNOSSOS curve of 1 dB at 20 km/h and 6.5 dB at 50 km/h.

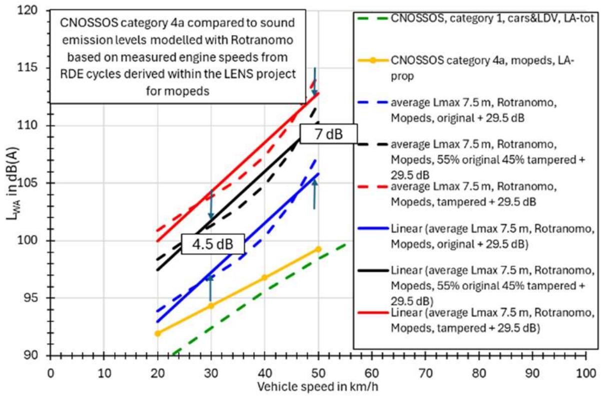

Figure 7. Derived sound power levels for mopeds (blue, compliant), modelled with ROTRANOMO, with higher curves for 100% (red) and for 45% (black) tampered vehicles. Original CNOSSOS curves for mopeds (yellow) and cars (green) are also shown for comparison.

4.6 New CNOSSOS coefficients for L-vehicles

Based on the obtained fitted sound power curves for each vehicle subcategory, measurement spectra of a series of test vehicles [10], both compliant (as original) and tampered, were also used to derive octave band coefficients A_P and B_P, resulting in the proposed values as set out in Table 2. If a fleet tampering percentage is known, the coefficients can be obtained by a weighted energy average of the compliant and the tampered values (T) for A_P and B_P. The default tampering rates are 30% for motorcycles>250 cc, which includes 15% tampering and 15% high rpm driving, 15% for motorcycles ≤ 250 cc, and 45% for mopeds.

Table 2. New proposed coefficients for propulsion noise of category 4 vehicles, for compliant vehicles in free flowing traffic conditions, and for tampered vehicles (T).

	Octave band frequency [Hz]							
	63	125	250	500	1k	2k	4k	8k
4a								
A_P	109.22	99.99	108.68	113.28	110.68	110.47	108.73	94.75
B_P	23.667	10.717	27.454	34.146	30.380	27.615	34.006	18.424
4aT								
A_P	116.22	106.99	115.68	120.28	117.68	117.47	115.73	101.75
B_P	23.667	10.717	27.454	34.146	30.380	27.615	34.006	18.424
4b								
A_P	100.96	101.68	95.66	95.30	95.73	94.63	93.05	89.53
B_P	10.108	8.309	11.438	17.934	16.527	15.547	17.612	18.424
4bT								
A_P	107.96	108.68	102.66	102.30	102.73	101.63	100.05	96.53
B_P	10.108	8.309	11.438	17.934	16.527	15.547	17.612	18.424
4c								
A_P	105.78	112.99	106.85	101.77	98.27	98.70	98.72	96.06
B_P	0.700	8.477	16.639	15.267	12.460	13.615	15.841	16.380
4cT								
A_P	112.73	121.34	120.10	107.87	101.32	99.23	98.82	95.61
B_P	0.700	8.477	16.639	15.267	12.460	13.615	15.841	16.380

4.7 Acceleration/deceleration correction

The C_P coefficients for acceleration and deceleration were derived from the differences in fitted curves for constant speed and acceleration in Figs. 2, 4 and 6 and were checked with test data from several vehicles. These differences are set out in Fig. 8 for mopeds, motorcycles below and above 250 cc.

It is proposed to use the average of the values between 10 km/h and 30 km/h for the coefficients $C_{p,m,k}$, for crossings and the average of values between 20 km/h and 40 km/h for roundabouts. The resulting coefficients $C_{p,m,k}$ are set out in Table 3. This also includes a simplified proposal 4bc, which weights the corrections for the portions of the fleet, 45% for 4b and 55% for 4c.

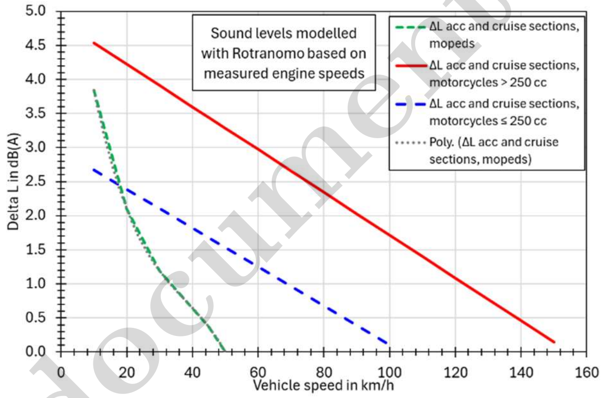

Figure 8. Derived differences between sound levels at acceleration and at constant speed for categories 4a (green dashed, and dotted for polynomal fit), 4b (blue dashed) and 4c (red solid).

Table 3. Proposed values for C_P correction for acceleration/deceleration conditions in Table F-3 in 2015/996.

Category	C_P in dB Crossings	C_P in dB Roundabouts
4a Mopeds	2.4	1.3
4b Motorcycles ≤ 250 cc	2.4	2.1
4c Motorcycles > 250 cc	4.2	3.9
4bc = 45% 4b, 55% 4c	3.4	3.1

4.8 Gradient correction

As the effect of gradients is included in the ROTRANOMO/TRANECAM model this was used to assess correction values $\Delta L_{WP,grad,m}$ for CNOSSOS. These differ significantly for mopeds and both types of motorcycles due to their design aspects. The proposed formulas are set out in Table 4, with "s" being the gradient as a percentage (10% = 0.1).

Table 4. Proposed correction for gradients for L-vehicles for gradient s as a percentage and speed v in km/h. Outside the specified gradient ranges, $\Delta L_{WP,grad,m} = 0$. v represents the posted speed limit of the road section under consideration.

Mopeds (4a)	
For s ≥ 4% and s ≤ -4%	$\Delta L_{WP,grad,m} = 9.234*s$
Motorcycles ≤ 250 cc (4b)	
For 2% ≤ s < 8%	

$\Delta L_{WP,grad,m}=(-0.2365*s+0.0015)*v+24.914*s + 0.05955$
For s ≥ 8%
$\Delta L_{WP,grad,m} = -0.01742*v + 1.93357$
Motorcycles > 250 cc (4c)
For s>3% and v≤90 km/h
$\Delta L_{WP,grad,m} = (0.14247*s + 0.00023)*v +1.937*s + 0.02725$
For s>3% and v≥100 km/h
$\Delta L_{WP,grad,m} = (-0.087*s + 0.0001)*v +23.6625*s - 0.01578$
For s < 0 and v <= 50 km/h, no correction
For 60 km/h <= v <= 90 km/h
$\Delta L_{WP,grad,m} = (-0.6986*v+92.972)*s^2+(0.1575*v+1.703)*s$
For v > 90 km/h
$\Delta L_{WP,grad,m} =(-0.04845*v+18.209)*s+(0.00059*v - 0.08123)$

5. Conclusions and recommendations

New sound emission coefficients are proposed for CNOSSOS-EU for category 4 vehicles, including mopeds (4a) and two new subcategories for motorcycles upto 250 cc (4b) and above 250 cc (4c). These are significantly higher than the current ones, up to 9 dB higher for category 4c. Separate values are given for compliant vehicles and for tampered vehicles. The effect of tampering is given at 7 dB, but this is lowered to 3.4 dB when average tampering rates in the fleet are taken into account. Defaults are proposed for both the fleet composition (4b:45%, 4c:55%) and for fleet tampering rates, by default 15% for motorcycles and 45% for mopeds. For motorcycles above 250 cc, also high rpm driving behaviour is included for 15% of the fleet, resulting in a total tampering rate of 30%. Different fleet compositions and tampering rates can be used if such information is available from monitoring for example.

For acceleration/deceleration conditions, corrections are proposed of 2.4 - 4.2 dB near crossings and 1.3 - 3.9 near roundabouts. As in the CNOSSOS model, these drop to zero after 100 meters from crossings and roundabouts, it could be reconsidered whether this distance might be extended, especially for motorcycles.

For gradients, new corrections are proposed of up to 1.5 dB, depending on the subcategory, gradient and speed.

The higher noise emission levels will be more noticeable in average L_{den} levels in some situations where L-vehicles are more numerous and/or louder than average. Where this is not the case, it might be preferable to calculate the L_{den} for L-vehicles separately. It should be further considered how penalties for the sound characteristics and dose-effect relationships should be included specifically for L-vehicles, for example in Annex III of the END [4]. This could help better quantify the impact of loud vehicles, and thereby help initiate specific noise action plans for L-vehicles as required by the END. This requires separate study.

6. Acknowledgments

The measurement data for this analysis was available from the EU projects LENS and ROTRANOMO, and a project on silencers for the German Environmental Agency, which is gratefully acknowledged.

References

[1] LENS project, L-vehicles Emissions and Noise mitigation Solutions, EU Horizon project GA No. 101056777, 2022-2025.www.lens-horizoneurope.eu

[2] EU Directive 2015/996 on common noise assessment methods.

[3] EU Directive 2021/1226, amending 2015/996.

[4] Environmental Noise Directive (END) 2002/49/EC and 2020/367 (amended Annex III on assessment methods for harmful effects).

[5] M.G. Dittrich, H. Steven: *Analysis of noise emission data of L-vehicles in CNOSSOS-EU*, TNO Report TNO 2026 R10789, March 2026.

[6] M. Dittrich et al: *Real world driving conditions and requirements for the LENS test programme*, LENS report D6.1, 2023.

[7] M. Dittrich et al: *Monitoring of loud vehicles in Utrecht*, (in Dutch), TNO report 2023 R12599.

[8] A. Garbi et al: *Real world driving patterns to assess LV noise and emissions*, LENS report D3.5, 2025

[9] *LENS noise database of measured vehicles*, Deliverable D4.3, 2025.

[10] H. Steven: *Determination of Noise Emission Levels for a Selection of Replacement Silencers for Motorcycles*, TÜV Nord Mobilität GmbH & CO.KG, Institute for Vehicle Technology and Mobility, by order of the German Federal Environmental Agency, Project No. 202 54 136, November 2006.

[11] *ROTRANOMO project (Development of a Microscopic Road Traffic Noise Model for the Assessment of Noise Reduction Measures*" (Contract no. G3RD-CT-2002-00801, funded by the European Community under the 'Competitive and Sustainable Growth' Programme)

[12] C. Lechner et al, *Effects of Motorcycle Noise on Annoyance—A Cross-Sectional Study in the Alps,* International Journal of Environmental Research and Public Health, 29 February 2020.

[13] D. Schreckenberg et al, *Motorcycle Noise Study Baden-Württemberg, Part I: Long-term noise annoyance in residents living alongside busy motorcycle routes in the southwest of Germany,* Procs. 14 ICBEN Conference,Belgrade, 2023.

[14] Papadimitriou, et al, *Study on Euro 5 sound level limits of L-category vehicles,* Final Report for European Commission, November 2017, ISBN 978-92-79-70064-4.

[15] M. Dittrich et al:, Impact of interventions in decreasing LV noise and pollutant emissions, LENS report D6.4, 2025.