Considerations for transportation policies mitigating the negative impact of vehicle noise

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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

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More than 100 million people in Europe are exposed to day-evening-night noise levels above the WHO recommended levels and road traffic noise is a particular public health problem across many urban areas

	High annoyance	High sleep disturbance	Ischaemic heart disease	Premature mortality ([a])	Reading impairment in children
Road					
Inside urban areas	12 525 000	3 242 400	29 500	7 600	
Outside urban areas	4 625 500	795 500	10 900	2 500	
Railway					
Inside urban areas	1 694 700	795 500	3 100	800	
Outside urban areas	1 802 400	962 900	3 400	900	
Aircraft					
Inside urban areas	848 300	168 500	700	200	9500
Outside urban areas	276 000	84 600	200	50	2800
Industry					
Inside urban areas	87 200	23 400	200	50	
Outside urban areas	No data	No data	No data	No data	
All ([b])	**21 859 100**	**6 478 300**	**47 900**	**12 100**	**12 300**

Estimated number of people suffering from various health effects due to environmental noise in 2017, EEA-33 (excluding Turkey)

https://www.eea.europa.eu/publications/health-risks-caused-by-environmental

More than 18 million people were highly annoyed and 5 million were highly sleep disturbed by environmental noise in Europe in 2017

- WHO definition of health
  - *'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'*
- **Annoyance & sleep disturbance**
  - Good indicators for measuring adverse health impacts of transportation noise
  - Account for the bulk of the burden of disease linked to noise

- Target of the EU Zero Pollution Action Plan (ZPAP)
  - to reduce the share of people chronically disturbed by transport noise by 30% by 2030, compared with 2017
  - Estimated based on populations exposed to 55dB L_{den} and 50dB L_{night}
  - However, this number is **likely underestimated**
    - People can experience annoyance and sleep disturbance below the thresholds
    - Children up to 17 years not included

https://www.eea.europa.eu/en/analysis/indicators/health-impacts-of-exposure-to-1?activeAccordion=546a7c35-9188-4d23-94ee-005d97c26f2b

Over 500,000 children's reading skills impaired by transport noise in Europe, with the largest impact from road

		Outside urban areas	Inside urban areas	Total
Reading ability impairment	Road	116,500	341,000	457,500
	Rail	41,800	38,600	80,400
	Aircraft	5,000	2,900	7,900
	Total	**163,300**	**382,500**	**545,800**
Behavioural difficulties	Road	11,200	39,700	50,900
	Rail	3,100	4,600	7,700
	Aircraft	200	400	600
	Total	**14,500**	**44,700**	**59,200**

https://www.eea.europa.eu/en/newsroom/news/childrens-reading-skills-impaired-by-noise

Many noise indicators are based on average sound $L_{eq,}$ but maximum sound L_{max} is important

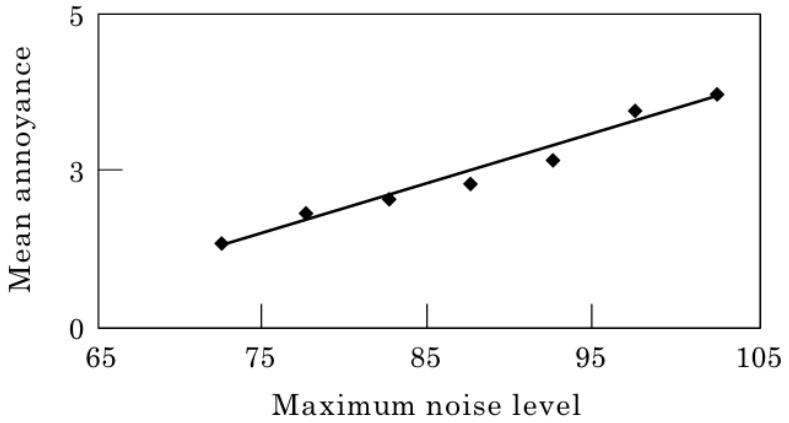


Figure 7. Relationship between average annoyance and personal noise exposure expressed as maximum noise level in 5 dB(A) classes.

- Importance of prioritizing the loudness of individual vehicles (Sato et al., 1999)
  - Strong relationship between the average annoyance and the noise exposure expressed as maximal noise level
- L_{eq} not sufficient to account for complex effects of frequency components and their temporal development (Raggam et al. 2007)
  - Loudness and roughness strongly correlated with discomfort and an increase in heart rate

https://internoise2018.org/assets/documents/21_Sato_Yano_Bjorkman_and_Rylander.pdf
https://www.sciencedirect.com/science/article/abs/pii/S1438463906000903

Increase in psychoacoustic annoyance with higher sound pressure levels

- Motor vehicle sounds analyzed using psychoacoustic parameters like loudness, sharpness (timbre), roughness, fluctuation, tonality
- Psychoacoustic annoyance increases at a faster level from above a sound pressure level of 95 db(A)
- Attributed to various psychoacoustic dimensions that have a stronger effect at higher sound pressure levels

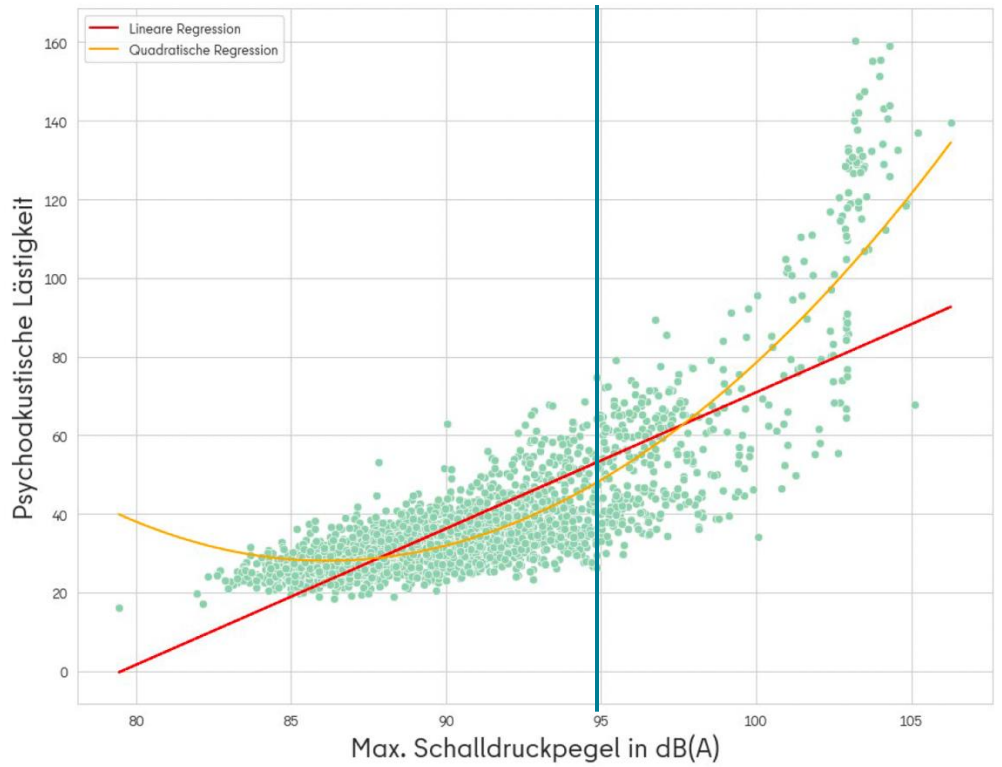
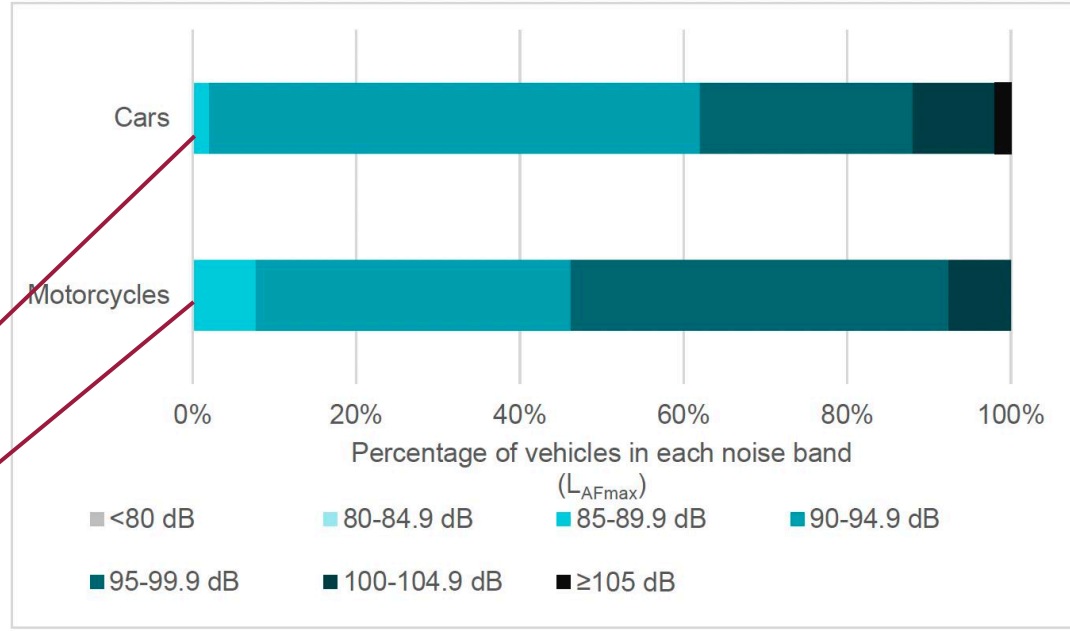


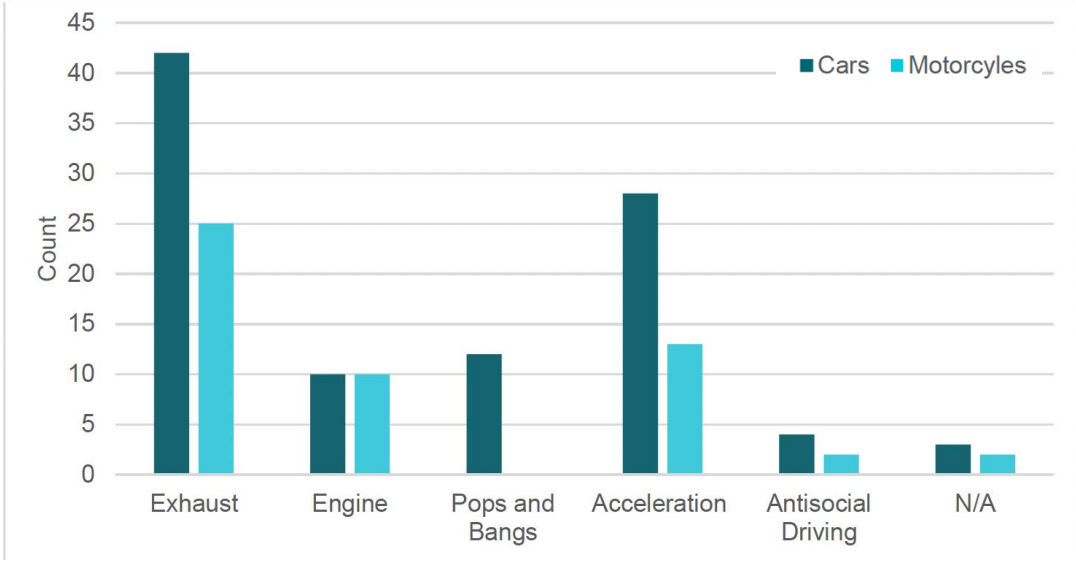
Abbildung 9: Zusammenhang zwischen dem maximalen Schalldruckpegel L_{AFmax} (in Dezibel (A-bewertet)) und der psychoakustischen Lästigkeit nach Di et al. (2016) für alle erfassten Kraftfahrzeuge. In rot (linear) und orange (quadratisch) sind Regressionsmodelle eingezeichnet, die den mathematischen Zusammenhang von maximalen Schalldruckpegel und psychoakustischer Lästigkeit exemplarisch approximieren.

Report analyzing the loud vehicles detected by the noise flasher and their noise impact potential (January 2025) https://www.berlin.de/sen/uvk/_assets/umwelt/laerm/laermminderungsplanung-berlin/projekte/laermblitzer-auswertebericht-berliner-pilotstudie_2025.pdf?ts=1738311674
Jäggi et al : Jäggi, J., Heutschi, K., & Wunderli, J. M. (2022). Herleitung eines Schwellenwerts für übermässig laute Fahrzeuge. https://www.aramis.admin.ch/Default?DocumentID=71239&Load=true

Subjective testing shows there are more dimensions to noise-induced discomfort than just high sound pressure levels

- UK DfT's subjective testing on the roadside
  - Participants considered all vehicles measured at 95db L_{AFmax} and above "excessively noisy"
  - However, some audio characteristics were considered "excessively noisy" at even lower levels
  - Cars at 85.5db L_{AFmax} with pops and bangs and a low rumble from exhaust modifications
  - Motorcycles at 88.6db L_{AFmax} with hard acceleration





UK DfT, Work order T0218 roadside vehicle noise measurements: phase 3 part C (https://www.gov.uk/government/publications/noise-camera-technology-roadside-trial)

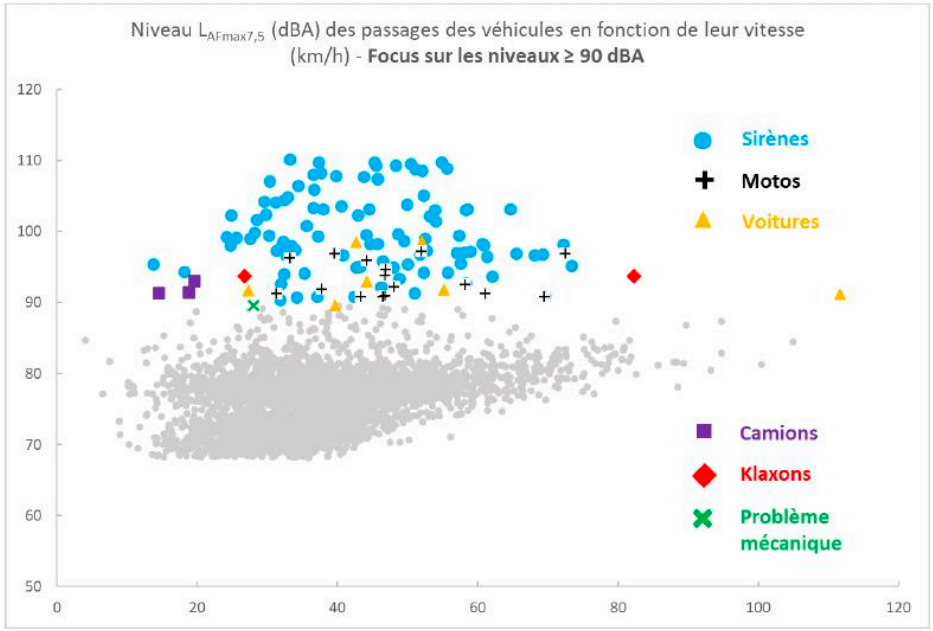
Studies show intermittent noise causes more annoyance than continuous noise despite the need for further studies

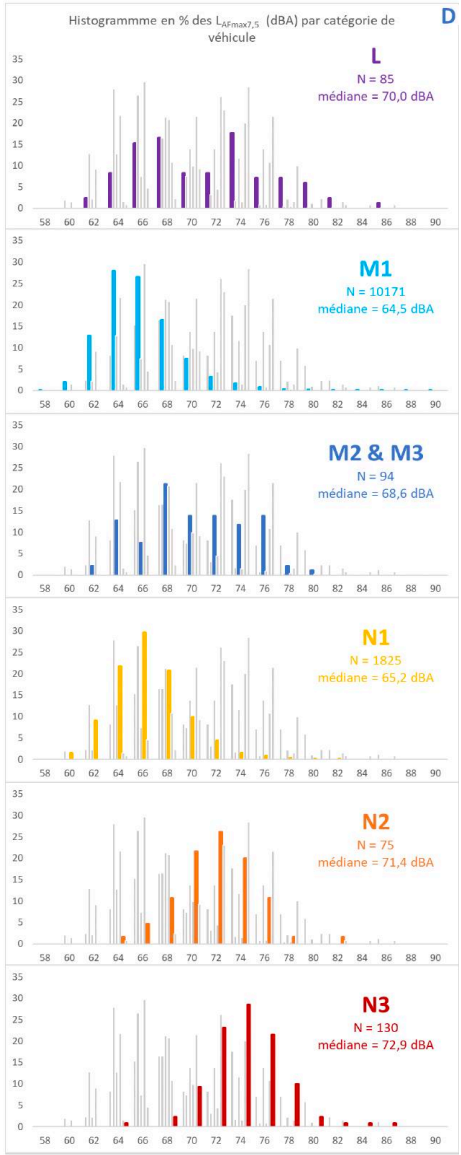
- Intermittent noise: situations with dominant single noise events (“noise peaks”) and relatively calm time periods in between
- Evidence of negative health impact of nocturnal intermittent noise:
  - Increase in arterial stiffness (reflecting endothelial dysfunction) as a result of a chronic exposure to nocturnal intermittent train or road traffic noise (Foraster et al., 2017)
  - Association of a long-term exposure to nighttime road traffic noise with subclinical atherosclerosis, especially in participants with early arterial calcification (Starke et al., 2023)
  - Association of the temporal pattern of noise, like intermittency, with cardiovascular mortality (Vienneau et al., 2022)
- Specifically for road traffic, more frequent noise peaks elicit stronger annoyance (Brink et al., 2019)
  - More highly annoyed by motorway or urban road traffic (perception of noise 6 dB(A) higher)
  - May be due to the effect of different durations of noise-free intervals between events
  - Heterogeneity of acoustical composition of single noise sources not considered in models yet

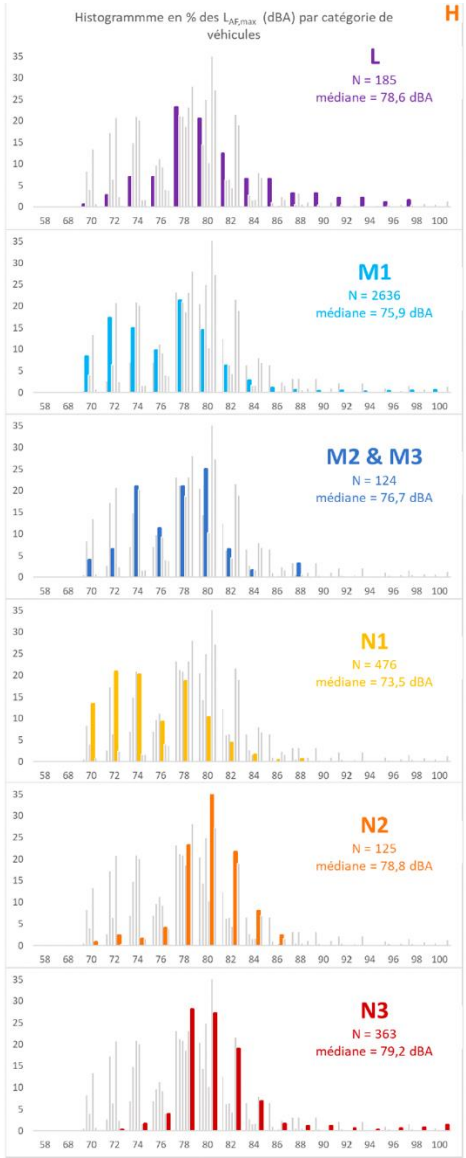
Muenzel et al., 2024 (https://www.ahajournals.org/doi/10.1161/CIRCRESAHA.123.323584#sec-6)
Foraster et al., 2017 (https://pubmed.ncbi.nlm.nih.gov/28934719/)
Starke et al., 2023 (https://www.sciencedirect.com/science/article/pii/S0013935123006072#cebib0010)
Vienneau et al., 2022 (https://www.sciencedirect.com/science/article/pii/S0160412021005997?via%3Dihub)
Brink et al., 2019 (https://www.sciencedirect.com/science/article/pii/S016041201831897X?via%3Dihub#ab0010)

In general, real-world noises from motorcycles and trucks are the loudest

- Brussels noise monitoring (2024) shows (median):
  - Motorcycles (L): passenger car (M1) + 2.7 – 5.5 dBA
  - N2 trucks: passenger car (M1) + 2,9 - 6,9 dBA,
  - N3 trucks: passenger car (M1) + 3,3 - 8,4 dBA.

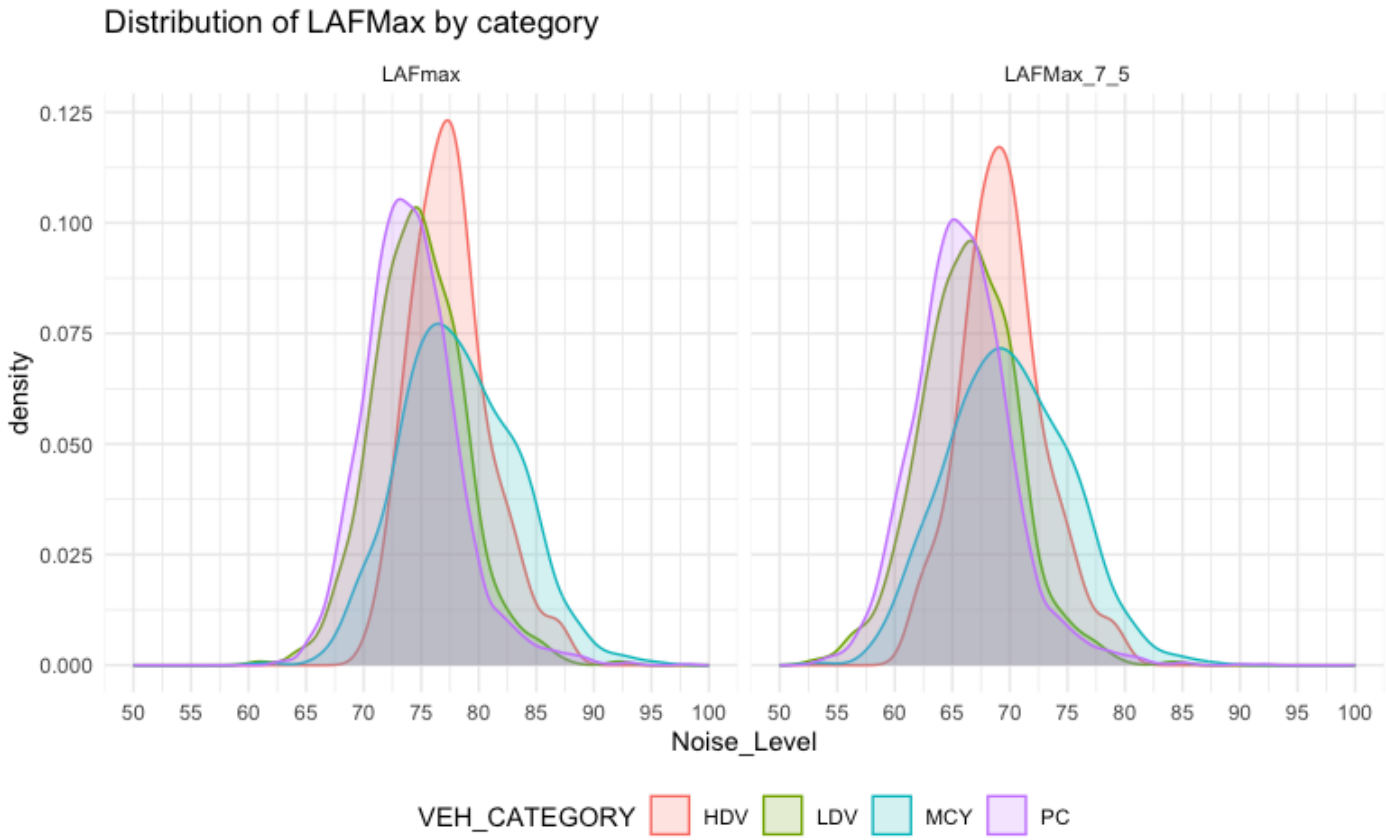






EXPÉRIMENTATION DE DEUX RADARS SONORES EN RÉGION DE BRUXELLES-CAPITALE (2024):https://document.environnement.brussels/opac_css/doc_num.php?explnum_id=11268

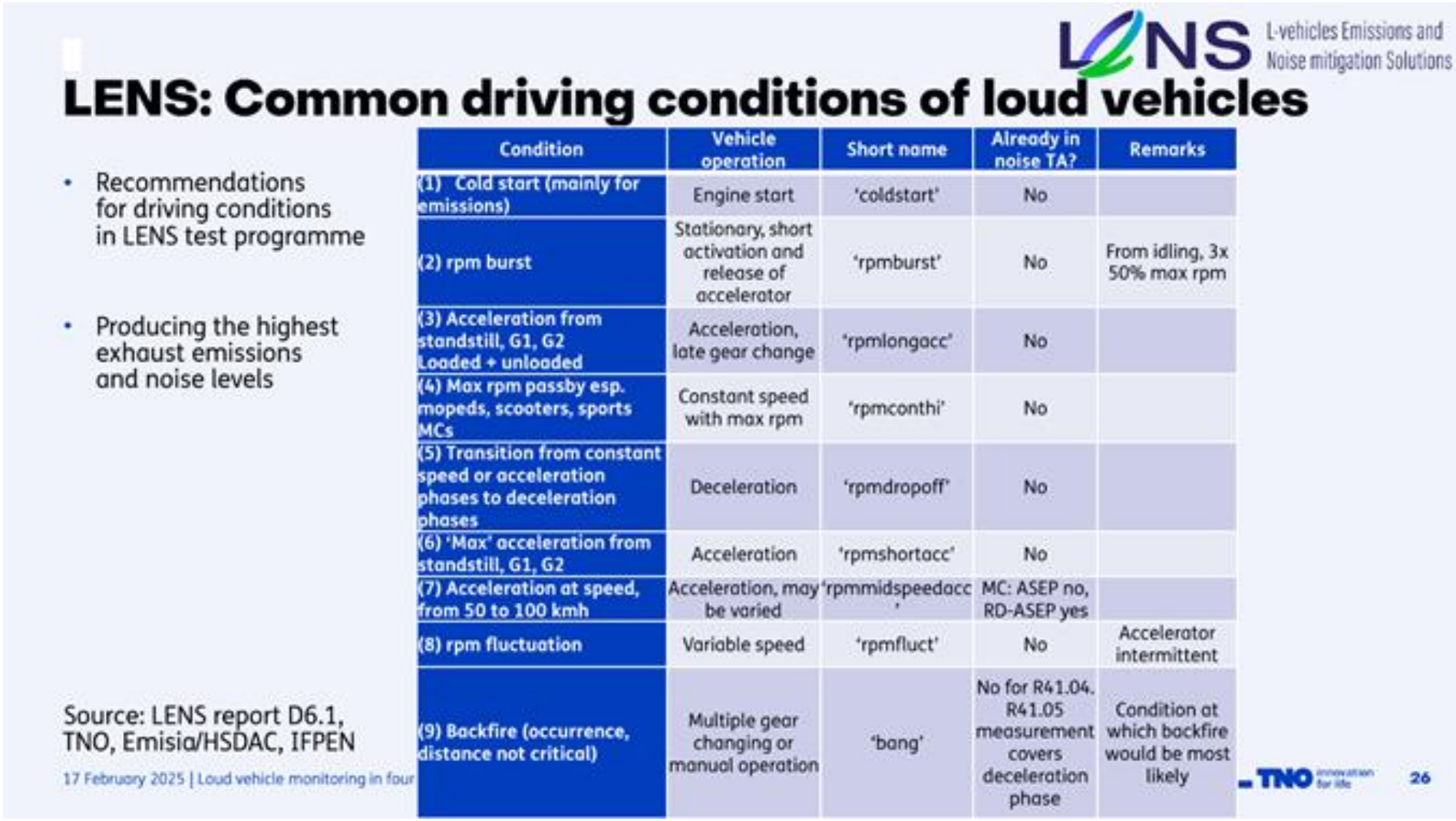
In general, real-world noises from motorcycles and trucks are the loudest



- Motorcycles and HDVs show up to 4 dBA higher median noise levels than passenger cars
- At measurement distance (2-3m), motorcycles have a median level over 78dB(A)
- Top 5% high-emitters have median close to 85dB(A)

Data collected as part of the NEMO project provided by OPUS RSE

Common driving conditions of L-vehicles leading to loud events are not yet covered by regulations



LENS L-vehicles Emissions and Noise mitigation Solutions

LENS: Common driving conditions of loud vehicles

- Recommendations for driving conditions in LENS test programme
- Producing the highest exhaust emissions and noise levels

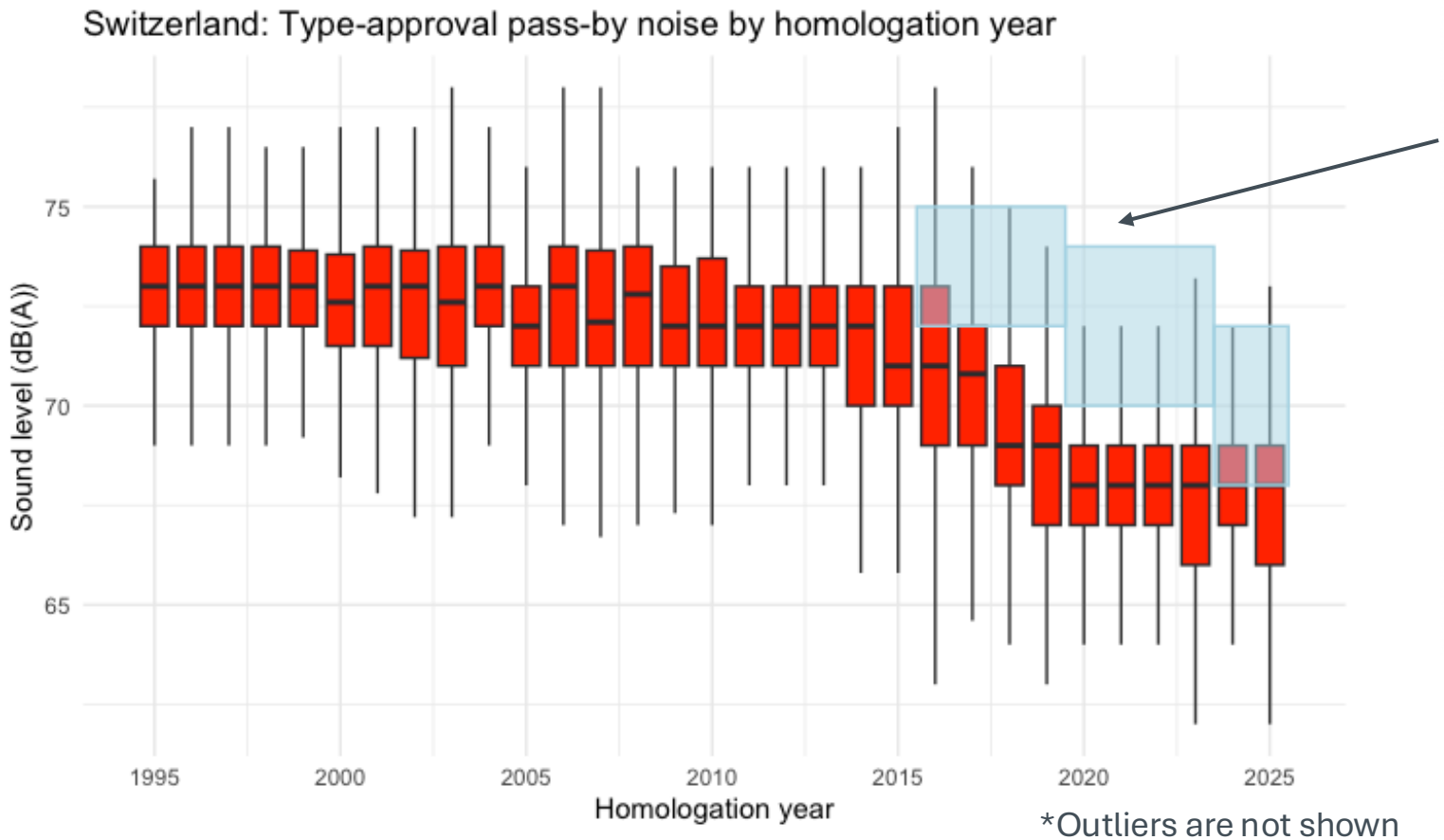
Condition	Vehicle operation	Short name	Already in noise TA?	Remarks
(1) Cold start (mainly for emissions)	Engine start	'coldstart'	No	
(2) rpm burst	Stationary, short activation and release of accelerator	'rpmburst'	No	From idling, 3x 50% max rpm
(3) Acceleration from standstill, G1, G2 Loaded + unloaded	Acceleration, late gear change	'rpmlongacc'	No	
(4) Max rpm passby esp. mopeds, scooters, sports MCs	Constant speed with max rpm	'rpmconthi'	No	
(5) Transition from constant speed or acceleration phases to deceleration phases	Deceleration	'rpmdropoff'	No	
(6) 'Max' acceleration from standstill, G1, G2	Acceleration	'rpmshortacc'	No	
(7) Acceleration at speed, from 50 to 100 kmh	Acceleration, may be varied	'rpmmidspeedacc'	MC: ASEP no, RD-ASEP yes	
(8) rpm fluctuation	Variable speed	'rpmfluct'	No	Accelerator intermittent
(9) Backfire (occurrence, distance not critical)	Multiple gear changing or manual operation	'bang'	No for R41.04. R41.05 measurement covers deceleration phase	Condition at which backfire would be most likely

Source: LENS report D6.1, TNO, Emisia/HSDAC, IFPEN

17 February 2025 | Loud vehicle monitoring in four

TNO innovation for life 26

For LDVs, pass-by noise limits were introduced in 2016, but some are still type-approved to higher levels

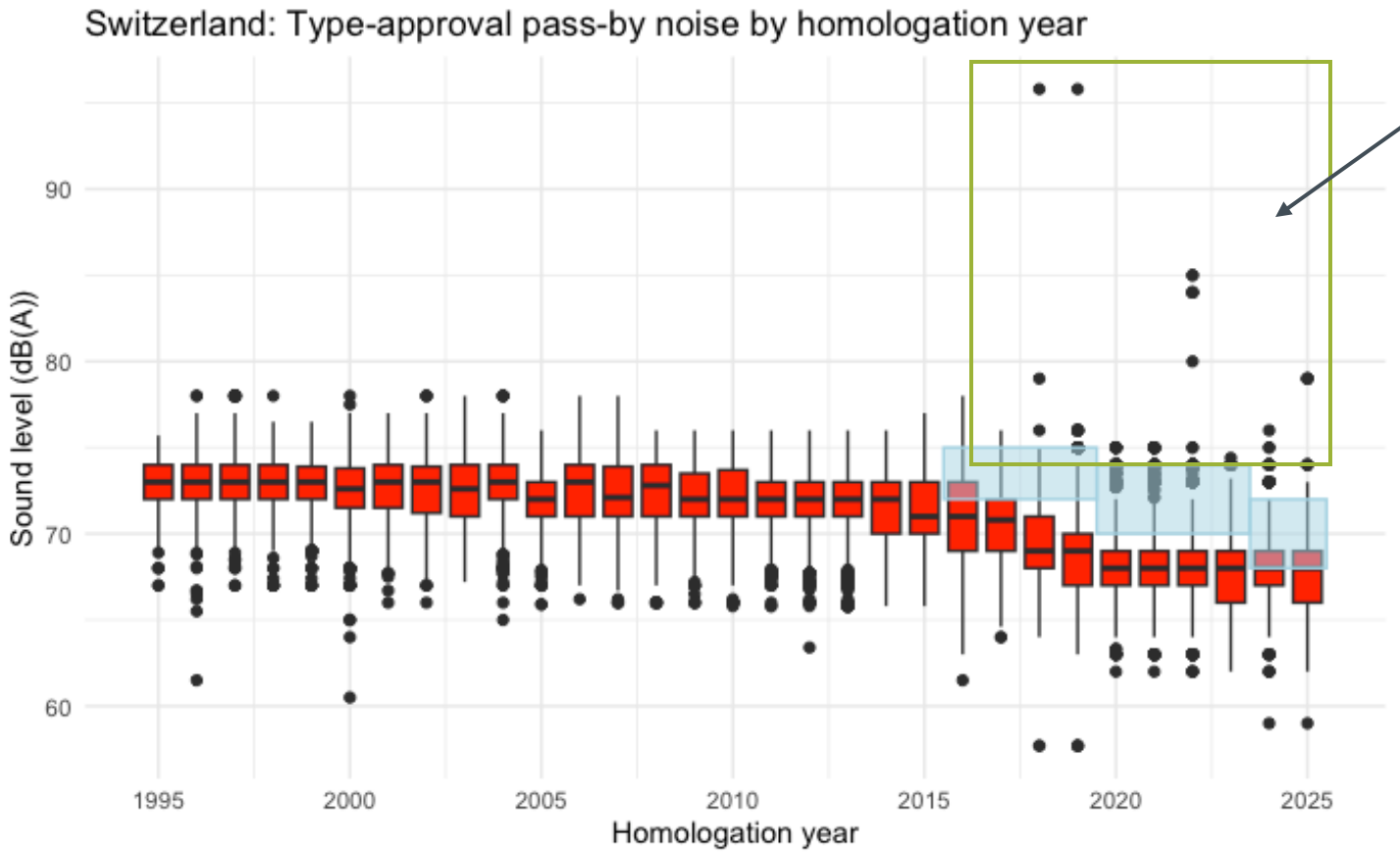


*Outliers are not shown

Vehicle category	*Vehicles used for the carriage of passengers*	*Limit Values (dB(A))*		
		Phase 1	*Phase 2*	*Phase 3*
M_1	PMR ≤ 120	72	70	68
	120 < PMR ≤ 160	73	71	69
	PMR > 160	75	73	71
	PMR > 200, no. of seats ≤ 4, R-point height < 450mm from the ground	75	74	72
M_2	$M \leq$ 2.5 t	72	70	69
	2.5 t < M ≤ 3.5 t	74	72	71
	M > 3.5 t; $P_N \leq$ 135 kW	75	73	72
	M > 3.5 t; P_N > 135 kW	75	74	72
M_3	$P_N \leq$ 150 kW	76	74	73
	150 kW < $P_N \leq$ 250 kW	78	77	76
	P_N > 250 kW	80	78	77
Vehicle category	*Vehicles used for the carriage of goods*	*Phase 1*	*Phase 2*	*Phase 3*
N_1	$M \leq$ 2.5 t	72	71	69
	M > 2.5 t	74	73	71
N_2	$P_N \leq$ 135kW	77	75	74
	P_N > 135 kW	78	76	75
N_3	$P_N \leq$ 150 kW	79	77	76
	150 kW < $P_N \leq$ 250 kW	81	79	77
	P_N > 250 kW	82	81	79

Data source: open type-approval data from Swiss Bundesamt für Strassen (ASTRA) https://opendata.astra.admin.ch/ivzod/2000-Typengenehmigungen_TG_TARGA/2200-Basisdaten_TG_ab_1995/

… and they're mostly sports cars and SUVs

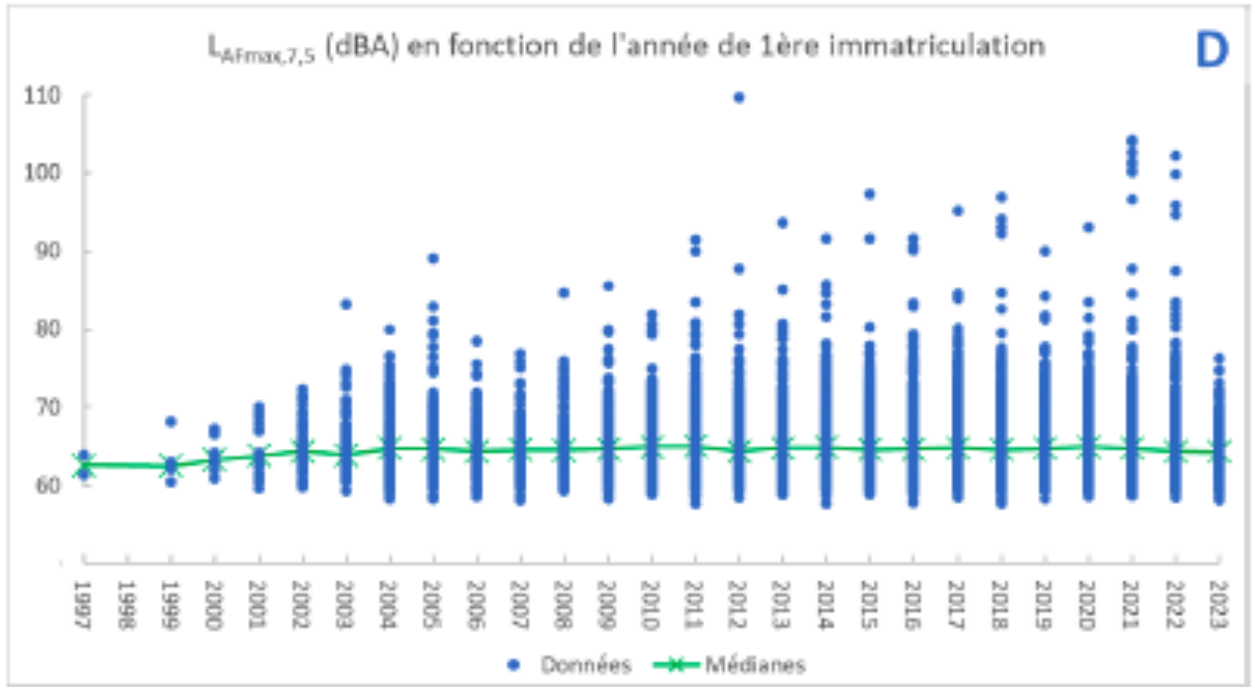


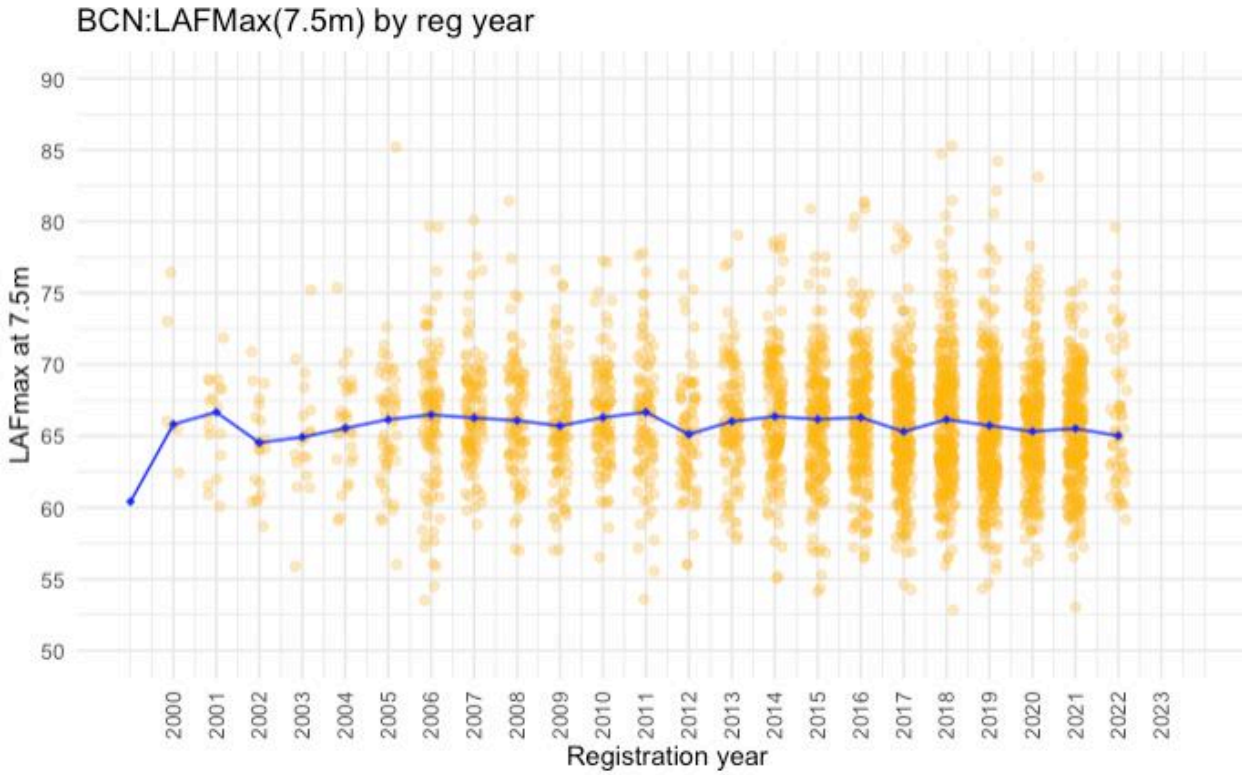
ASTON MARTIN	DBS GT Zagato
AUDI	SQ7 4.0TDI
BENTLEY	Bentayga Speed
MORGAN	Midsummer
MORGAN	Plus Four
MORGAN	Plus Six
MORGAN	Super Sport
FERRARI	296 GTS
FERRARI	812 Competizione
FERRARI	812 CompetizioneA
FERRARI	Daytona SP3
FERRARI	Purosangue
FERRARI	Roma Spider
JEEP	Wrangler 3.6
JEEP	Wrangler Unl. 3.6
CATERHAM	Seven 485 CSR
CATERHAM	Seven 485 S3
CATERHAM	Seven 485 SV
JAGUAR	F-Pace SVR
LAND ROVER	RR Sport SVR
LAND ROVER	RR Sport5.0LSVR
LAND ROVER	RR Sport5.0LV8
LAND ROVER	RangeRoverS V8
JAGUAR	F-Pace SVR
LAMBORGHINI	724 Huracàn
MASERATI	GT2 Stradale
MASERATI	MC20
MC LAREN	Artura Coupe
MC LAREN	Artura Spider
MERCEDES-BENZ	211 CDI

Data source: open type-approval data from Swiss Bundesamt für Strassen (ASTRA)
https://opendata.astra.admin.ch/ivzod/2000-Typengenehmigungen_TG_TARGA/2200-Basisdaten_TG_ab_1995/

Real-world data show little improvement with newer cars

Brussels (2024)





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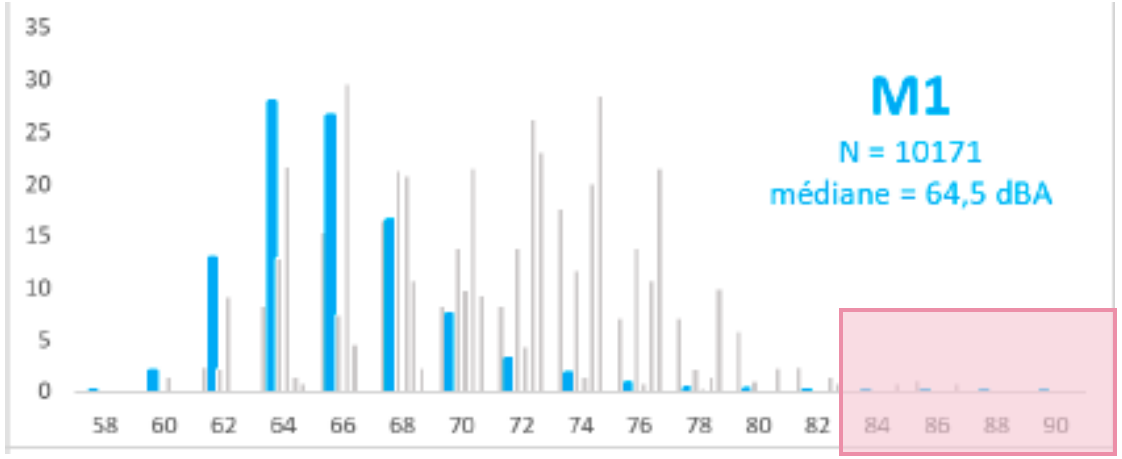
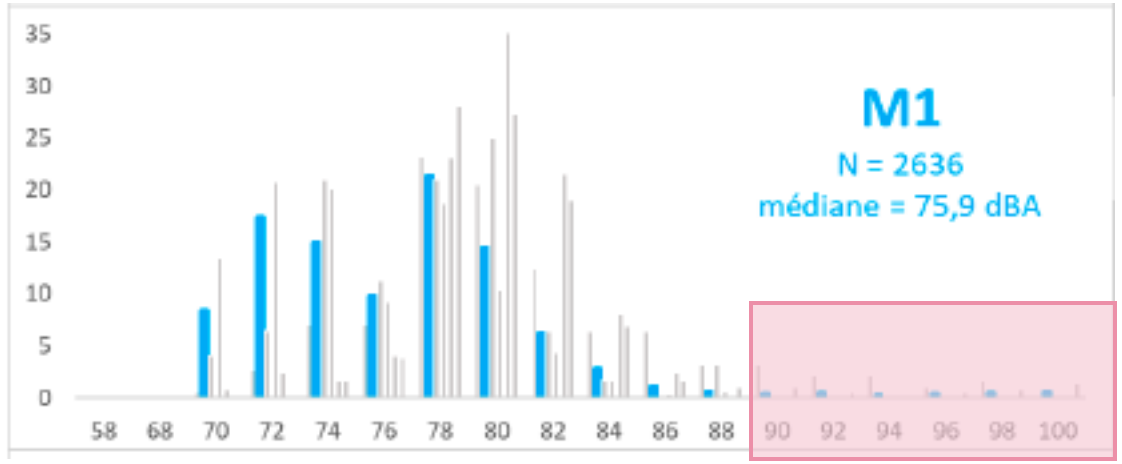
Data collected as part of the NEMO project provided by OPUS RSE: https://nemo-cities.eu/

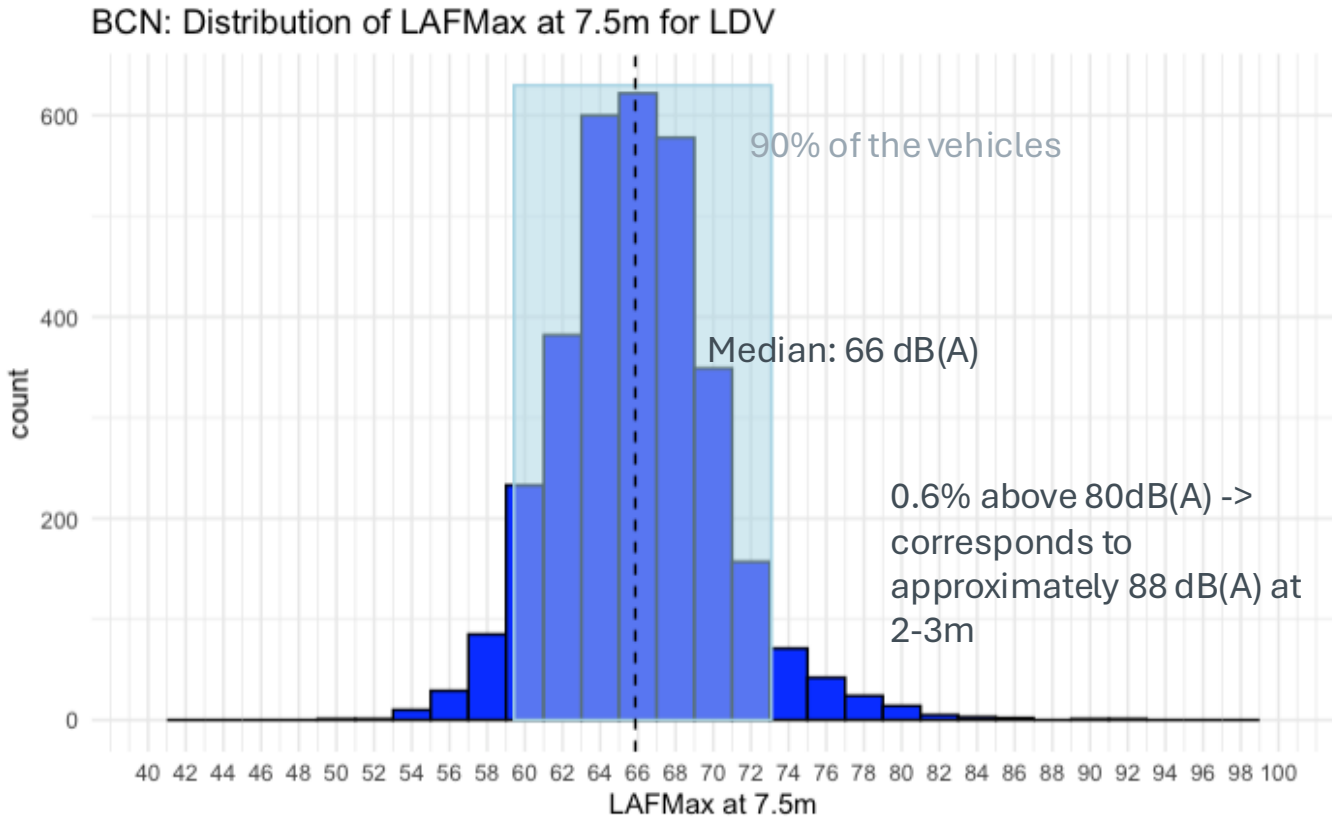
Real-world data show high noise levels are coming from <1% of vehicles

Brussels (2024) - dBFlash



Brussels (2024) – Hydre (BruitParif)





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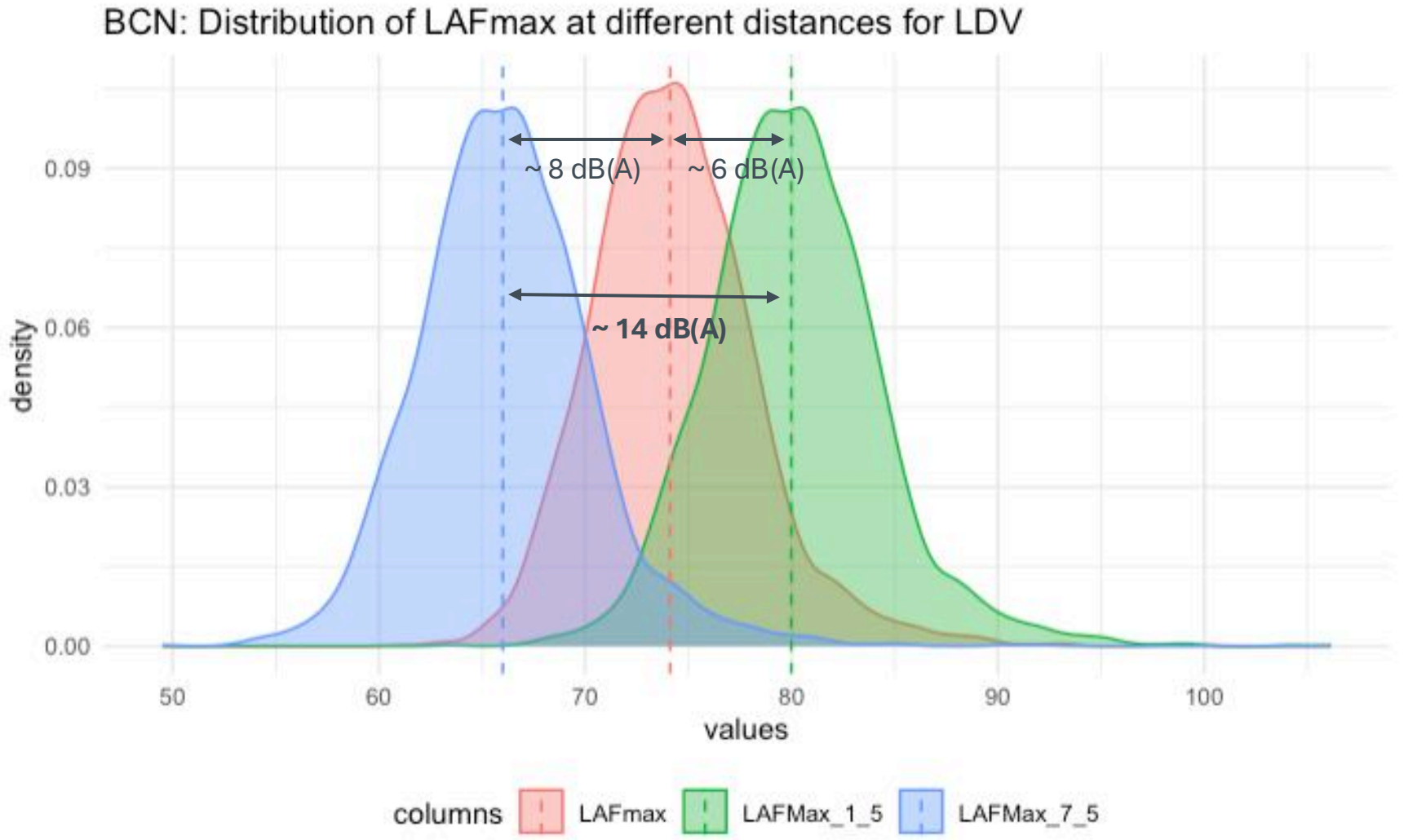
In reality, pedestrians in urban areas are exposed to higher noise levels than type-approval levels



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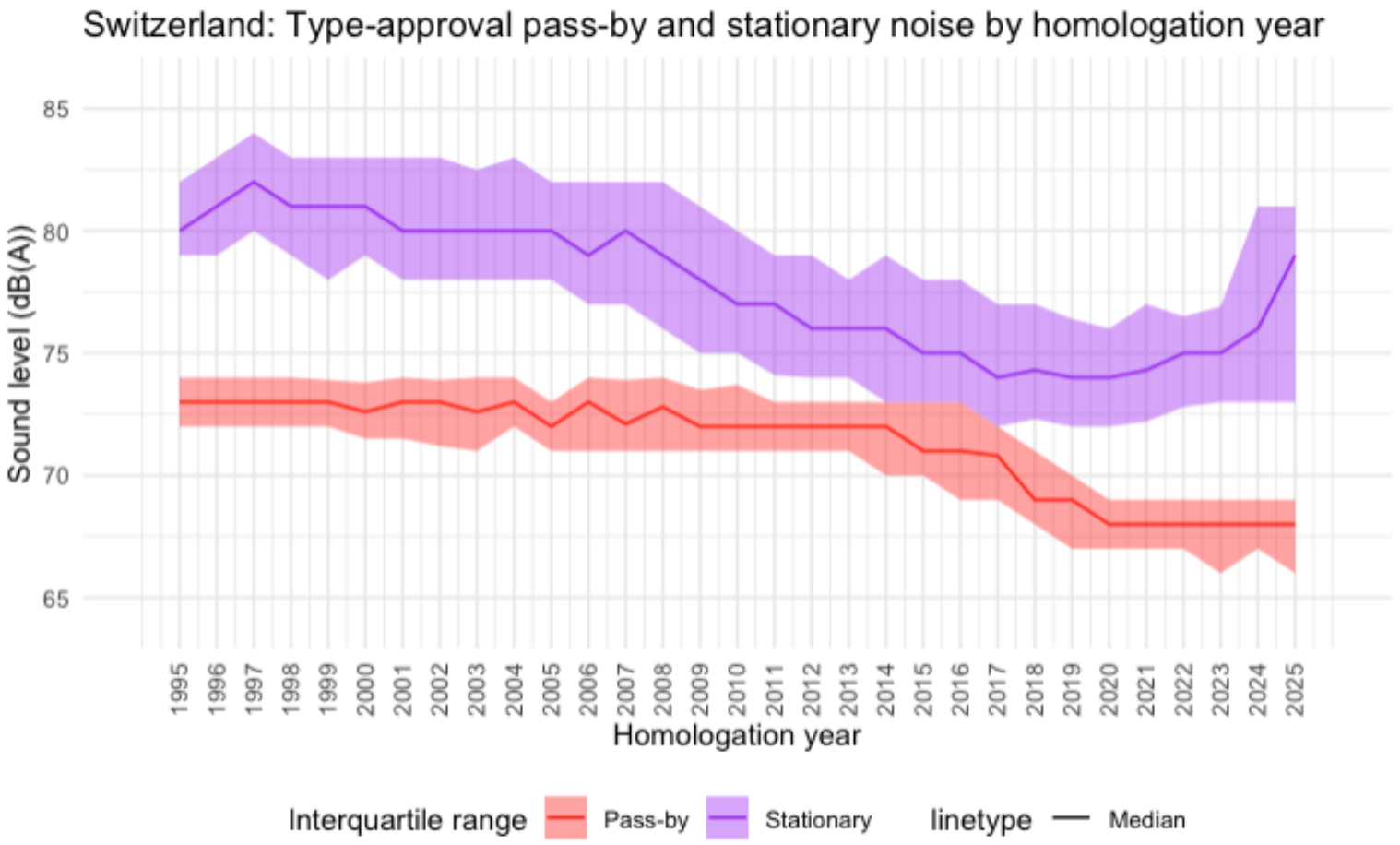
Type-approval stationary noise levels for LDVs, however, have not decreased over time and there is no limits on stationary noise



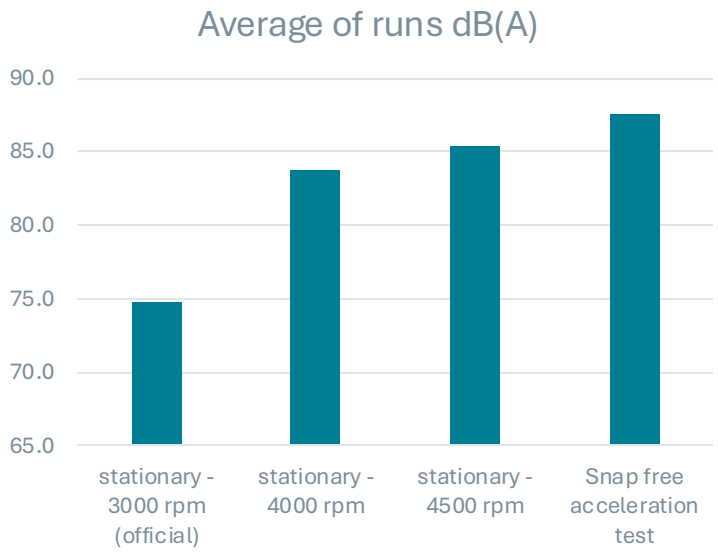
Data source: open type-approval data from Swiss Bundesamt für Strassen (ASTRA) https://opendata.astra.admin.ch/ivzod/2000-Typengenehmigungen_TG_TARGA/2200-Basisdaten_TG_ab_1995/

Stationary noises type-approved to over 100 dB(A) since 2016 are mostly from sports cars

Marke	avg_stationary	n	models
FERRARI	105.9	104	LaFerrari Aperta, GTC4 Lusso, GTC4 Lusso T, 812 Sup…
BMW	103.0	60	M4 Coupé, M4 Cabrio, X5 M, X6 M
MERCEDES-BENZ	104.4	16	CLA45 AMG 4m, A 45 AMG 4m
JAGUAR	109.9	14	F-Type SVR AWD, F-Type 3.0s/c, F-Type S3.0s/c
ALPINE	101.2	11	A110, A110 R
LOTUS	103.6	11	Elise Sport 220, Elise Cup 250, Exige Cup 430, Elise S…
MASERATI	103.7	10	Quattroporte ?, Ghibli Modena SQ4, Grecale Trofeo
ASTON MARTIN	100.7	7	Vanquish S, Vanquish Z., VanquishS Vol, VanquishZ V…
BUGATTI	103.0	7	Chiron, Divo, Chiron Pur Sport, Chiron SuperSport, W…
AUDI	107.0	4	R8 5.2FSI, R8 Spyder 5.2FSI
HYUNDAI	109.4	4	i30N 2.0 T-GDI
LAND ROVER	103.0	3	RR Sport5.0LSVR
MC LAREN	101.3	3	765LT Coupe, Elva, 765LT Spider
VW	102.0	3	Golf 8 R

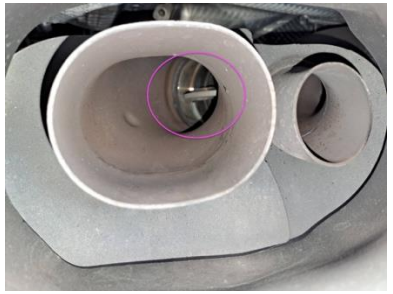
Data source: open type-approval data from Swiss Bundesamt für Strassen (ASTRA) https://opendata.astra.admin.ch/ivzod/2000-Typengenehmigungen_TG_TARGA/2200-Basisdaten_TG_ab_1995/

ICE vehicles in standstill can lead to much higher noise than than declared values outside the official test conditions



Renault Megane diesel 1.5L 2014

Model/year	Porsche 911 Turbo S (2022)	Cayenne Turbo (2019)	Cayman S (2009)
Type-approved value (stationary)	93	85	96
RPM range used for testing	idle – 3500 (Max 6000)	idle – 6000	idle - 7200
Exhaust flap closed	91.8	95.5	106.0
Exhaust flap open	96.7	100.78	110.2



*Values in dB(A) were averaged from 3 testing runs

Equipment used:
PeakTech P 8005 – Hochpräzises Schallpegelmessgerät Klasse 2 30-130 dB – Kalibriertes Dezibel Messgerät mit Aufzeichnung
PeakTech 8010 Schallpegelkalibrator – Präziser Decibel-Meter Kalibrator für Schallpegelmessgeräte, Klasse 2, 94 dB/114 dB, Hohe Genauigkeit für Geräuschpegelmessung und dB-Messgerät

Some e-bus in standstill operation can lead to noise annoyance but there are no vehicle regulations to prevent it

"For some time now, ESWE Verkehr has been receiving feedback from passengers about very loud fan noises in the battery buses currently in use.

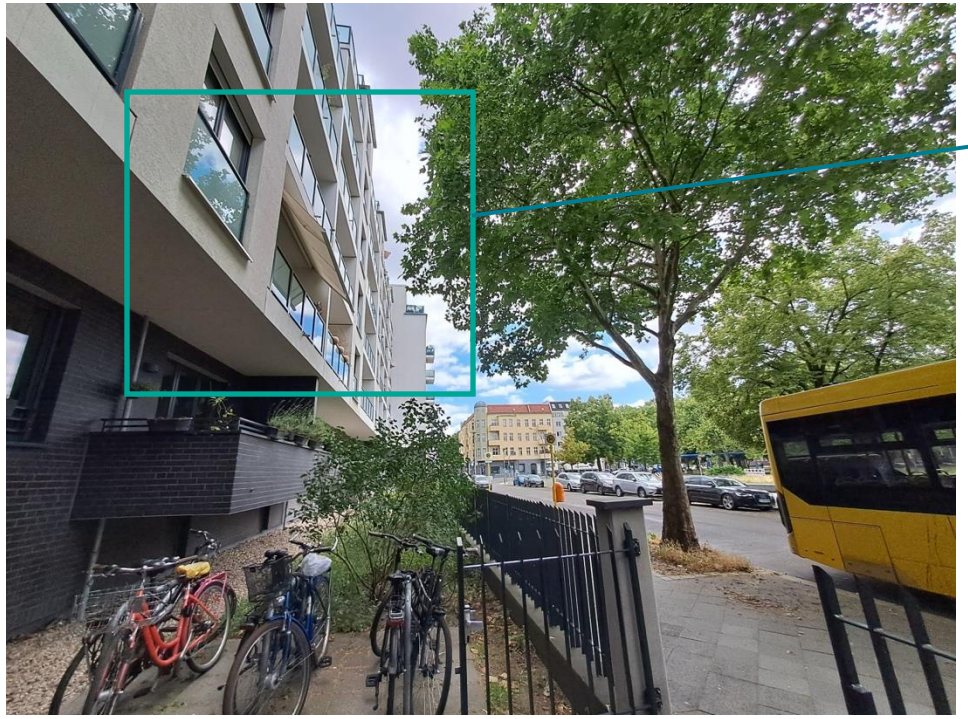
The fan noise occurs both during operation and after the vehicle has been parked, for example at terminus stops. The fan starts up to provide the necessary cooling for the components installed in the vehicle in order to protect them from overheating. At high outside temperatures or after heavy use - for example after driving uphill or downhill, as is often the case in Wiesbaden due to the topography - the components need to be cooled more intensively. The use of the cooling fan is not a malfunction, but a technical necessity."

https://www.eswe-verkehr.de/news/geraeuschentwicklung-bei-batteriebussen-deutlich-reduziert.html

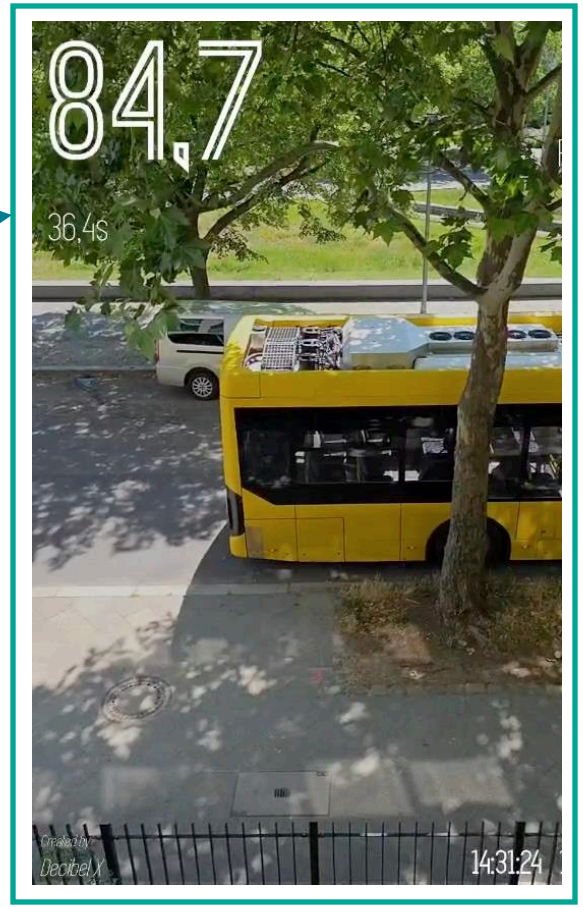
Some e-bus in standstill operation can lead to noise annoyance but there are no vehicle regulations to prevent it

68 dB(A): E-bus noise at standstill

62.2 dB(A): Comparably quieter e-bus



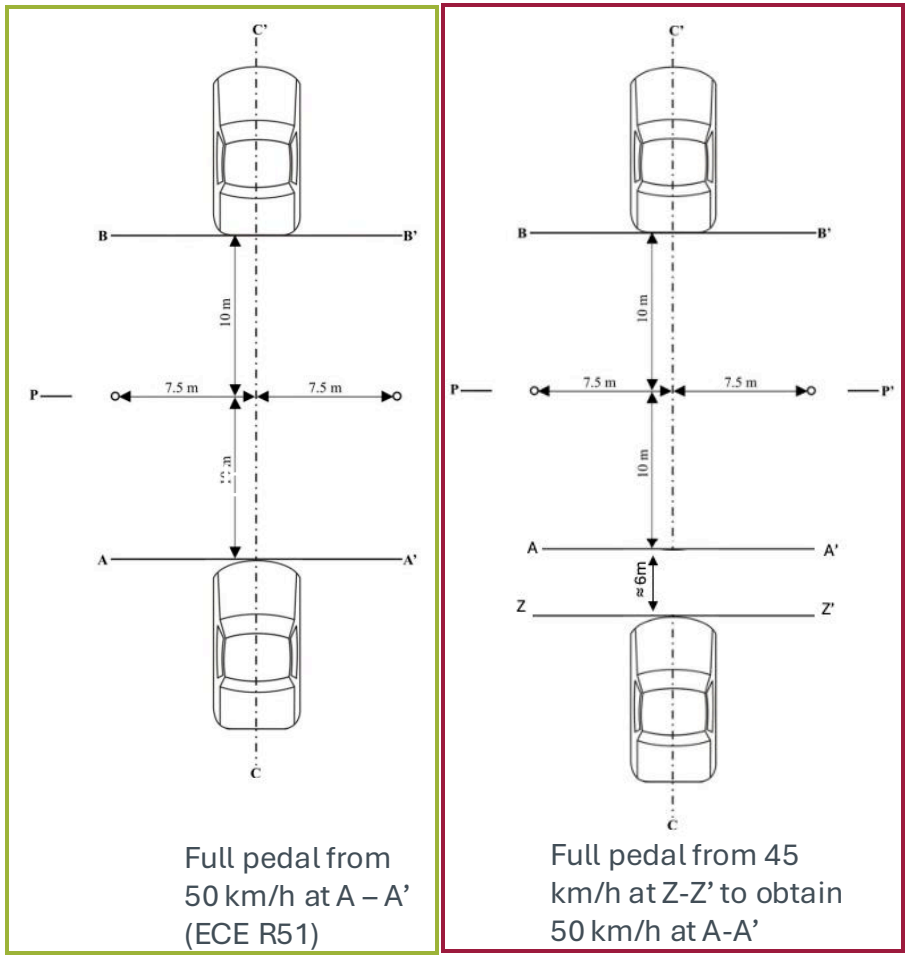
Proximity of bus terminus stops to houses where some inhabitants complain about noise



Potential malfunction leading to high noise levels

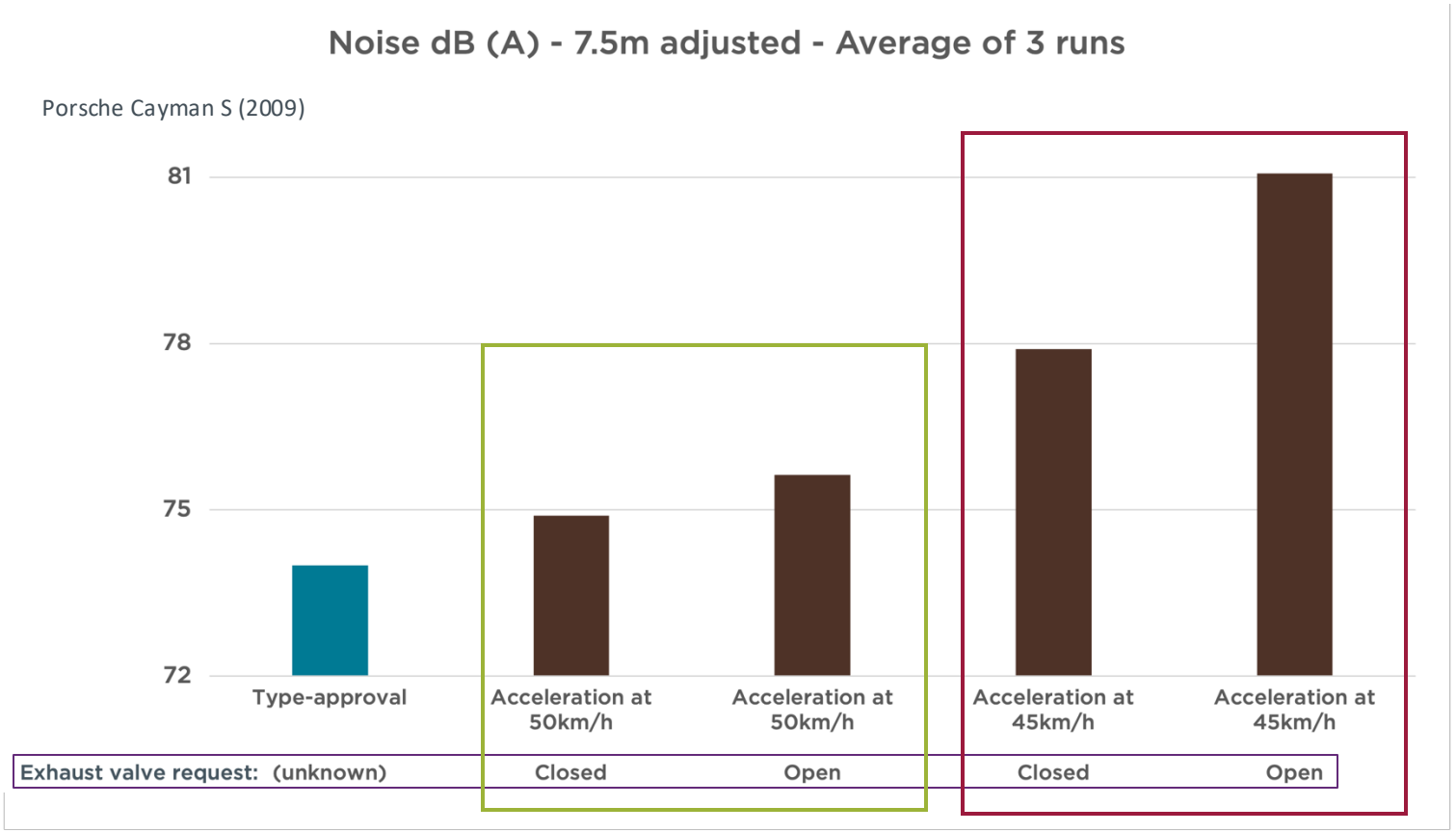
Berlin, June 12th – 19th 2025 with ambient temperatures below 30 deg C

Investigation of noise sensitivity to conditions simulating and altering type-approval testing, showing up to 6 dB difference



Full pedal from 50 km/h at A – A' (ECE R51)

Full pedal from 45 km/h at Z-Z' to obtain 50 km/h at A-A'



For illustration purposes only: Due to a lack of space, the microphone was placed at 5.5 m and the results were downward adjusted to reflect noise at 7.5m.

Note: the tests aimed to approach pass-by type-approval conditions, however, the setup is not strictly compliant with the regulatory requirement as not performed on a test track. The results cannot be used to determine the vehicle's compliance.

Sport Exhaust button

Prohibition of noise defeat device can be strengthened

- *R51 – 6.2.3.1.: The vehicle manufacturer shall not intentionally alter, adjust, or introduce any mechanical, electrical, thermal, or other device or procedure solely for the purpose of fulfilling the sound emission requirements as specified under this Regulation which is not operational during typical on-road operation.*
- "Solely" can be used to argue a device is used for multiple purposes (e.g. protect components, performance), in addition to meeting noise test requirements and bypassing the prohibition.
- "which is not operational during typical on-road operation" may not be sufficient to prevent a device from not operating during on-road operation, because it could be, but only a small subset of real-world conditions, which are hardly encountered in practice.

Our proposal:

The vehicle manufacturer shall not design, calibrate, program, or operate any mechanical, electrical, electronic, thermal, software-based, or other device or procedure with the purpose or effect of defeating or circumventing the noise type-approval tests, or of modifying sound emissions under type-approval conditions in a way that does not reflect operation in real traffic.

A Not-to-Exceed could be a change of paradigm

Context:

- Test procedures, including RD-ASEP, do not fully cover loud noise events in real-world cases like hard throttle or dynamic driving.
- No test exists limiting noise at zero speed and standstill (e.g. high engine rpm, cooling fans, etc).
- Establishing a Not-To-Exceed limit in a range of operating conditions has proven to be effective for regulating vehicle pollutant emissions
- The approach pushes manufacturers to identify the true peak noise conditions — not just what happens in standardized testing.

Steps:

- Manufacturers declare testing conditions of max pass-by noise (at 7.5 m), and at standstill (at 0.5 m)
- Noise levels cannot exceed a certain level (e.g. pass-by noise 85 dB (A)), including outside of the type-approval tests.

To do:

- Establish limits to cap the impact of noise on health and annoyance at distances with the vehicles in operating conditions reflecting the use in urban environment (i.e, 95 db at 7.5 m may be over 110 db at 1 meter distance)

Examples of efforts to limit transport-related noise around the world

- Paris, France: automated noise cameras ticketing vehicles emitting over **85dB(A)** in ≤ 50 km/h zones
- Belgian Highway Code: all motor vehicles to limit noise to **95dB(A)** at the source
- Kensington and Chelsea boroughs in London: 74dB(A) to trigger noise camera to tackle supercars and antisocial behaviors
- New York City: roadside sound meters and cameras to detect noise violation of vehicles emitting over 85dB(A) at 50ft –or nearly **91dB(A)** at 7.5m
- New Zealand: objective testing (ISO 5130) limit at **90dB(A)** for vehicles (2008 and before) and vehicles (after 2008)
- Amsterdam: Fine for vehicles 5dB over permitted noise levels
- Pilot testing in the UK: recommended thresholds of **95dB(A)** L_{AFmax} (for all vehicle groups and speed limits) with **85dB(A)** L_{AFmax} as a camera trigger level

Threshold suggested in the literature

- A uniform threshold of maximum level of 82 dB(A) (Jäggi et al. 2022)
  - Representative acceleration and speeds of up to 50km/h in urban traffic
  - Measurement surcharge of 1 dB from the technical test of the type approval, cold weather, acoustically unfavorable tires and surfaces (since R41.02 or R51.02)
  - Does not take into account higher sensitivity at night

- 82 db (A) at 7.5m can exceed 95 db (A) for pedestrians at much closer distance (1.65 m and conservatively assuming no reverberation from buildings)

Jäggi et al : Jäggi, J., Heutschi, K., & Wunderli, J. M. (2022). Herleitung eines Schwellenwerts für übermässig laute Fahrzeuge. https://www.aramis.admin.ch/Default?DocumentID=71239&Load=true

Pathways to lower noise impact from transport

Type-approval

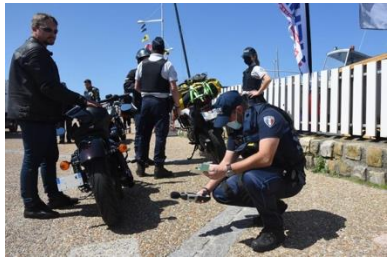
- Real-driving conditions (e.g. those leading to peak noise)
- Defining a Not-to-Exceed limit for noise in a wide range of conditions
- Forbidding physical/software defeat devices

In-service conformity

- Checking noise of in-use vehicles
- Allowing third-party testing
- Ensuring the durability of noise levels
- Monitoring noise from vehicle groups

Lifetime conformity

- Detecting individual tampering/malfunctions
- Enforcing noise limits, with periodic technical inspection, noise radars, etc.



Thank you for your attention!

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ON CLEAN TRANSPORTATION