Submitted by the expert of OICA

Informal document **GRBP-74-XX**
74th GRBP, 15-17 September 2021
agenda item 3.

(OICA/ACEA/ATEEL) Study on future sound limits values for type-approval for vehicles of category M & N-

74th GRBP

TFVS-04-10

Study on Future Sound Limit Values for Type Approval for Vehicles of Category M & N

Final Study Results

September 2021

Content

Introduction

The sound emission type approval limits for various vehicle categories have continuously been reduced in the past years, becoming more and more challenging for the automotive industry with increasing trade-offs due to regulatory requirements and customer expectations.

While vehicle manufacturers understand and support the necessity to lower the environmental road traffic noise, it is important to dive deeper into the complex aspects of road traffic noise, before any revision of future vehicle sound limits can be discussed.

In this context, ACEA has tasked ATEEL to perform a study to investigate current sound emission levels of M- and N-category vehicles and propose possible new sound level limits and/or alternative measures.

About ATEEL

ATEEL Group consists of an international **Technical Service** providing certification of motor vehicles and their components as well as an **independent Consulting Company** focused on services around certification.

- Technical Service accredited in accordance with ISO/IEC 17020 which officially proves a competent conformity assessment body
- We are engineers with a passion for technical innovation
- Our customers appreciate the trusting, constructive cooperation and our superior homologation processes

Executive Summary 1/2

Objective

- Analyse the feasibility of further limit value reductions and their effectiveness in real traffic conditions

Work Done

- Review of the current status of sound emission type approval values (2020 vs. 2010)
- Industry consultation on current state of the art and technical feasibility of potential limit value reductions
- Development of a calculation tool to review the impact of limit value reductions and alternative measures in real traffic

Key Findings

- Necessary noise reduction efforts on tyres can have negative impacts on key tyre performance characteristics
- UN R51 Phase 3 appears to be feasible for most categories, but without a significant improvement to tyre technology, reductions beyond Phase 3 would result in an severe trade off to tyre safety, at least for categories M1 and N1
- Reductions in UN R51 do not lead to the same reduction in real traffic situation – especially for speeds significantly above 50 km/h – since UN R51 targets only urban driving
- Market penetration delays the effect of reduction measures: most significant on powertrain, less on tyres – only improvements on the road surface show an immediate impact on the entire vehicle fleet
- Efforts made for tyre noise reductions are limited to OE tyres and unfold their potential only on ISO road surfaces

Conclusions

Introducing a limit value reduction beyond Phase 3 would result in considerable changes in current mobility as many types of vehicles would not be approvable any more

Further reductions only seem feasible if tyre technology makes it possible to significantly improve tyre noise performance without compromising tyre safety

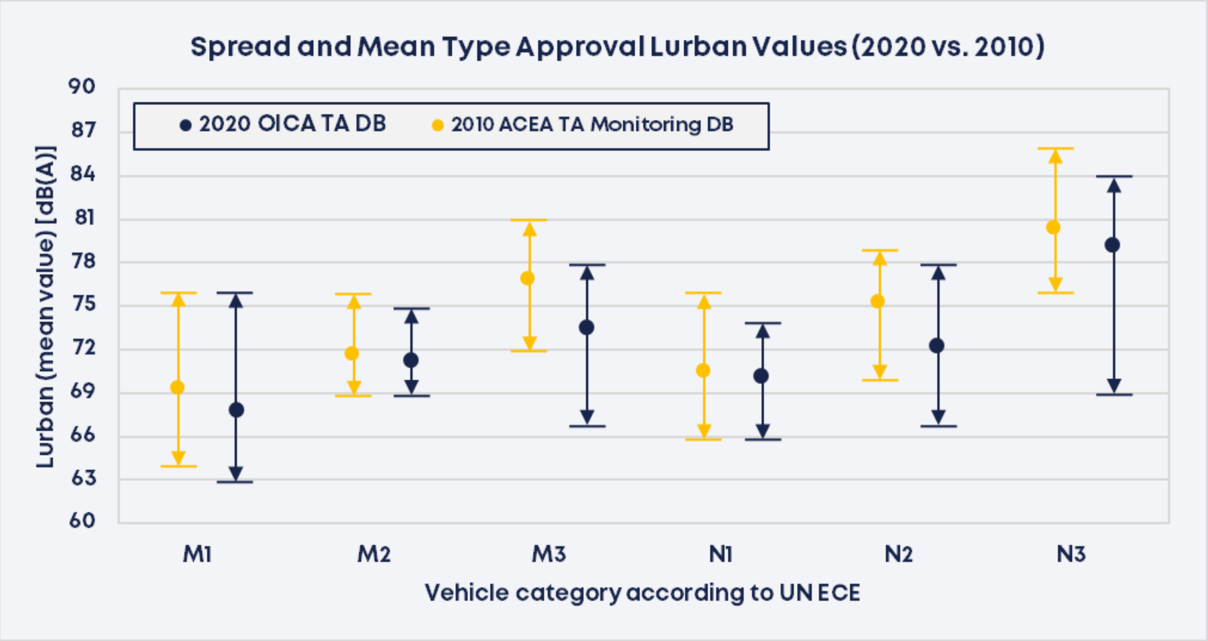
Resurfacing of roads with "quiet asphalt" as well as local speed limits in critical areas would have an immediate positive impact for all existing vehicles

Harmonisation of the implementation period of noise, tyre and emission regulations is necessary to minimise regulatory conflicts and conflicts of interests

Database Analysis

Number of valid data sets see Annex II

Database Analysis – OICA TA Database 2020 vs. ACEA Monitoring Database 2010



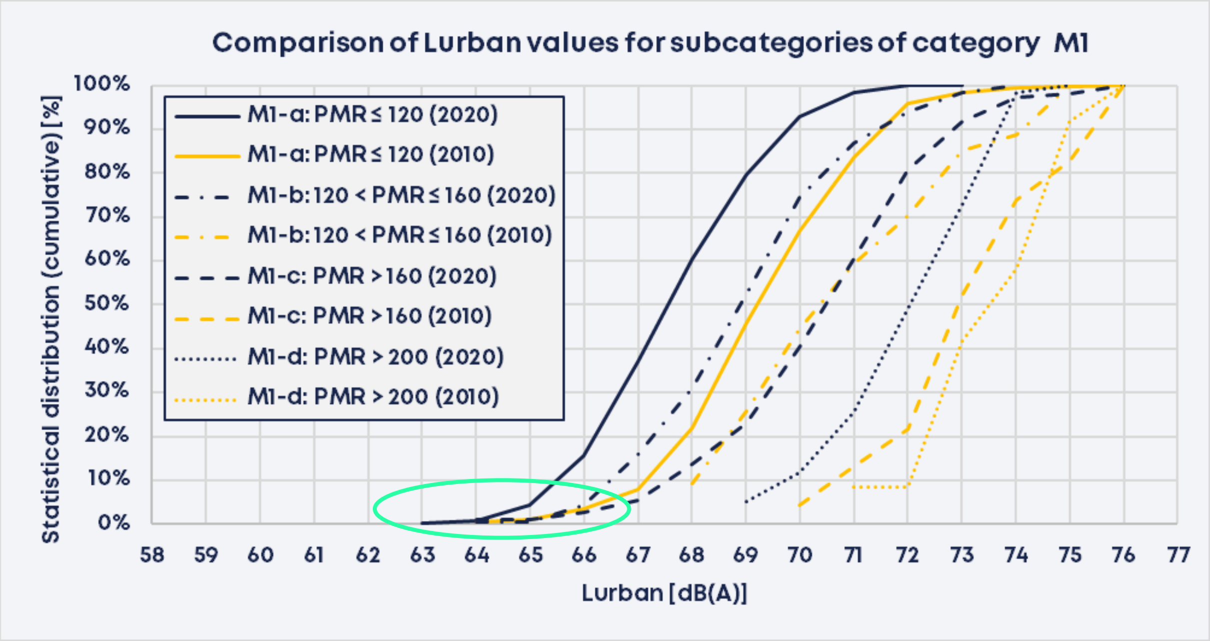
Overview of all categories

- Mean value (50% cumulative) improvements 2020 in comparison to 2010:

✓ M1: -1.5 dB(A)
✓ M2: -0.4 dB(A)
✓ M3: -3.3 dB(A)
✓ N1: -0.4 dB(A)
✓ N2: -3.0 dB(A)
✓ N3: -1.1 dB(A)

→ Noticeable variance in sound level improvements for different categories due to various contributing aspects, e.g. emission standards, technology, testing method, limit values

Database Analysis – OICA TA Database 2020 vs. ACEA Monitoring Database 2010

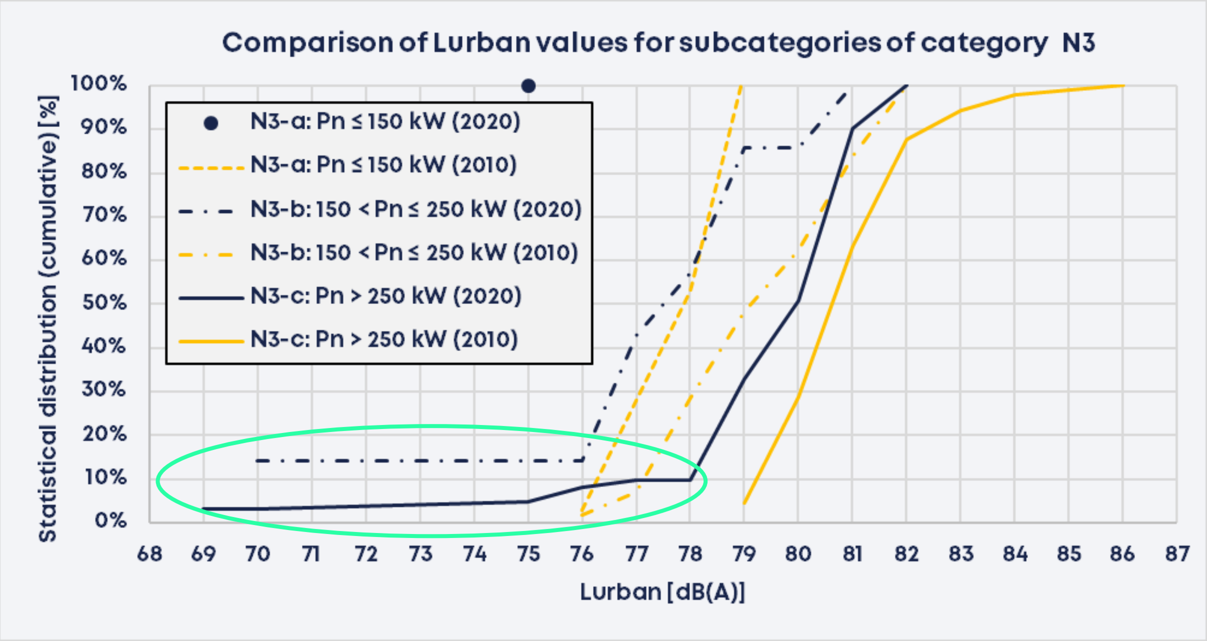


Main findings for category M1

- Mean values improvements:
  - ✓ M1-a: -1.6 dB(A)
  - ✓ M1-b: -1.5 dB(A)
  - ✓ M1-c: -2.5 dB(A)
  - ✓ M1-d: -1.5 dB(A)
- Consequences of electrification:
  - ✓ Higher PMR
  - ✓ Higher acceleration leads to higher gears in TA tests
  - ✓ More electric modes in TA

→ Minimal progress for the most quiet vehicles (likely reason: no constraint from limit value and limited by technical feasibility)
→ High performance vehicles of M1-c have become over-proportionally more quiet

Database Analysis – OICA TA Database 2020 vs. ACEA Monitoring Database 2010

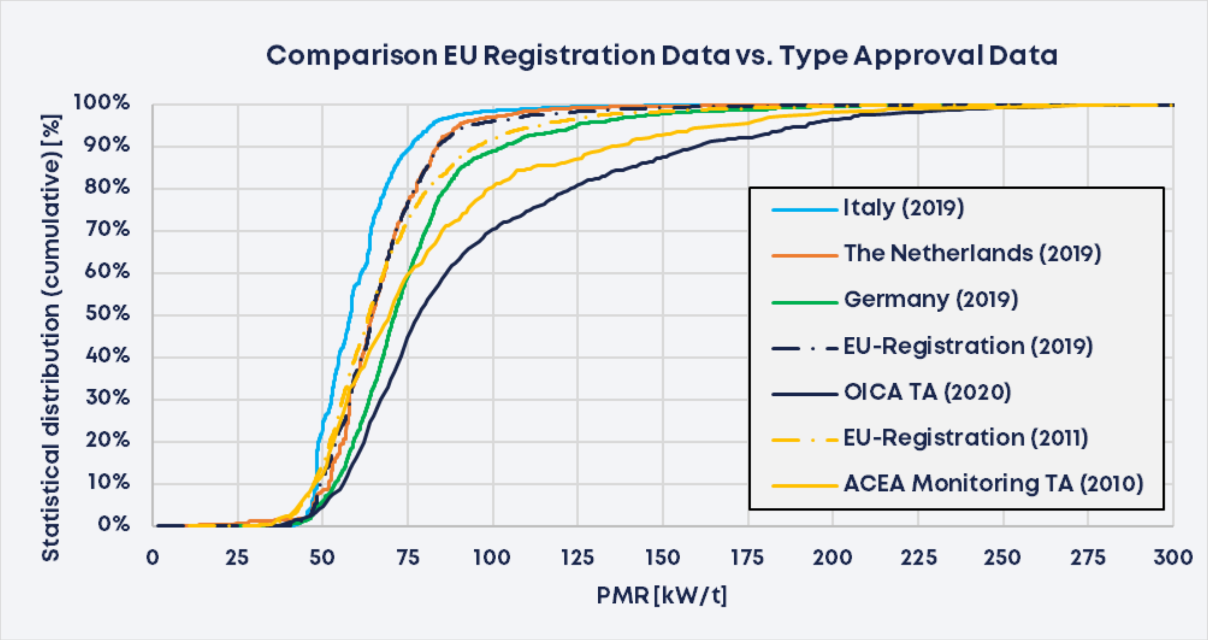


Main findings for category N3

- Mean values improvements:
  - ✓ N3-b: -1.6 dB(A)
  - ✓ N3-c: -0.7 dB(A)
- Not enough data sets (2020) for analysis of N3-a (Pn ≤ 150 kW)
- N3-a (2010) with only a 3 dB(A) spread from min to max value possibly showing the borderline of technical feasibility
- Increased share of electrified vehicles compared to ICE vehicle in TA data (2020)

→ Lower sound levels in type approval testing due to impact of EVs
→ Less improvements for class N3-c; class N3-a integrated into class N3-b, therefore big improvements for class N3-b

Comparison Type Approval Data vs. EU Registration Data



EU reg. data for category M1

- Type approval data distribution is not representative for EU registration average which has a tendency to lower PMR
- ✓ In TA data each model has an equal weighting. The regis-tration shows the number of sold and registered vehicles of each model
- ✓ Vehicles with high PMR (e.g. sports cars) are less often regis-tered than low PMR vehicles and thus overrepresented in TA
- Notable differences in reg. data between individual countries

→ Registration data used to determine the realistic share of vehicles per category in real traffic
→ TA data used to calculate the representing average sound level values for each vehicle category

Industry Consultation

Conclusion after conducting interviews with light-duty and heavy commercial vehicle manufacturers

- Central aspect for all manufacturers is the technical feasibility of a limit value reduction beyond R51.03 phase 3:
  - ✓ Phase 3 is already being considered in development but is still providing major challenges
  - ✓ With current technology, **a reduction beyond phase 3 is not possible – even most EVs would not be able to comply** due to the negative effect of higher weight on tyre rolling sound
  - ✓ There is no technology known or in development that would provide a significant sound reduction
  - ✓ Consequently lower limits would result in a significant change of vehicle mobility and serious restriction to OEM's portfolio's
- The limiting factor for reducing exterior noise mentioned by all manufacturers for M1, N1 is the tyre/road interaction:
  - ✓ Reduction of rolling noise results in the **trade off with** other tyre properties such as **safety/grip**, wear, particulate matter, rolling resistance
- Cost are no longer the central aspect concerning a further limit value reduction of UN R51.03:
  - ✓ Majority of manufacturers unable to provide cost statements in lack of a technical solution for further limit value reductions
  - ✓ Few were able to give an estimation but with different assumptions and level of detail

Industry Consultation – Vehicle Manufacturers 2 / 2

Conclusion after conducting interviews with light-duty and heavy commercial vehicle manufacturers

- Amplified due to only WOT testing, the powertrain is still the main contributor for M2, M3, N2, N3 (valid for ICE vehicles):
  - ✓ Encapsulations for powertrain would result in a thermal challenge for trucks – buses are already encapsulated
  - ✓ tyre/road noise will receive a stronger focus with lower limit values, alternative propulsion and/or higher test speeds
- Proposals made to improve noise certification concerning regulatory aspects which will be analysed in the final report, e.g.
  - ✓ Reduction of measurement uncertainties within the test procedure
  - ✓ Better consideration of alternative propulsion types, e.g. ICE on/off, consolidated power, etc.
  - ✓ Implausible 3 dB(A) step (R51.03 phase 2) for M3 between M3-a ($P_n \leq 150$ kW) and M3-b (150 kW < $P_n \leq 250$ kW) will force some OEMs to integrate subcategory M3-a into M3-b with the purpose to benefit from higher limit value
- Concerns about interactions between regulations which will also be analysed in the final report, e.g.
  - ✓ Collision with minimum sound level in UN R138
  - ✓ Double regulation of tyre due to UN R117
  - ✓ Technical impact of EU7 and GSR

Conclusion from tyre manufacturer interview

- C1/C2:
  - ✓ During tyre development multiple key tyre attributes have to be considered
  - ✓ -1 dB(A) reduction (based on UN R117 testing) for passenger car tyres feasible to **achieve phase 3 limits**
  - ✓ For an enforcement beyond phase 3, **no improvement expected from tyres due to the negative impact on safety**
  - ✓ Difference between **best tyre and slick tyre approx. 1-2 dB(A) in terms of noise emissions**
  - ✓ Tyres with low noise for exterior sound are not considered a selling argument unlike safety-, fuel consumption and tread wear performance
  - ✓ Replacement tyres meeting requirements under UN R117 which are not necessarily same level as demanded for OE applications resulting in higher exterior sound emissions
- C3:
  - ✓ Key attributes are high mileage & fuel economy
  - ✓ Due to the limited design parameters of rib tyres the opportunities to improve noise performances are very limited
  - ✓ Retreading of tyres has no impact to noise emissions (ETRTO Study 2019)
- Regulations:
  - ✓ Alignment of UN R51 (30 km/h or 50 km/h) and UN R117 (80 km/h) in terms of testing speed are not seen as useful; optimal potential for noise reduction is at a speed where the tyre becomes dominant (80 km/h)
  - ✓ GSR: Worn tyre wet grip; Improve aquaplaning by opening grooves → negative impact on noise

Impact Analysis on Real Traffic

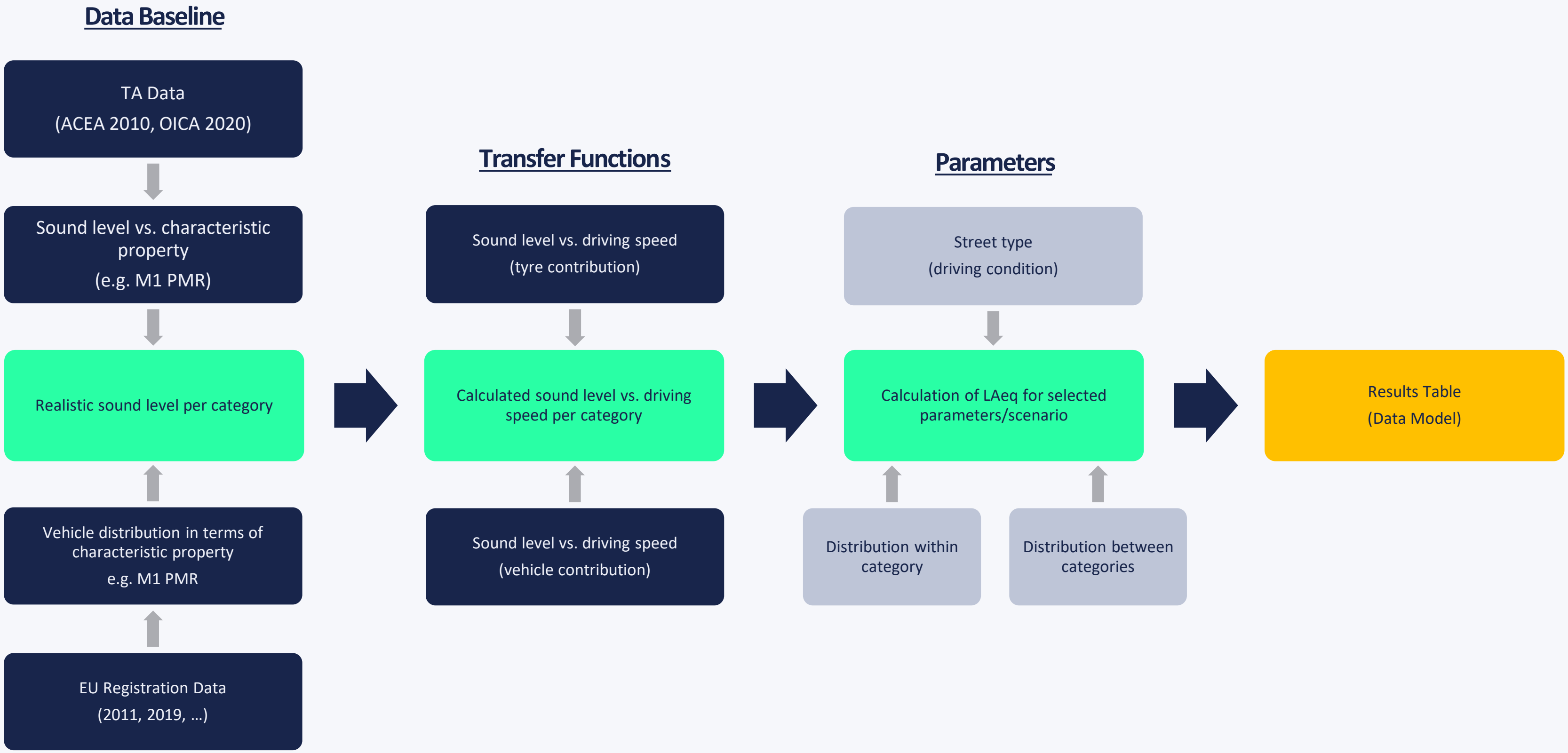
Impact Analysis on Real Traffic – Demands on the Calculation Model

- Ability to show the effectiveness of various **limit value scenarios** under real traffic conditions:
  - ✓ Scenario 1: Freeze limit values after complete implementation of **phase 2**
  - ✓ Scenario 2: Launch of **phase 3** as given by EU Regulation
  - ✓ Scenario 3: Further reduction of limit values **beyond phase 3**
- Development of a calculation tool to allow a differentiated consideration of the two major partial sound sources: powertrain and tyre
- Flexibility to consider different driving conditions as well as fleet market composition, market penetration, degree of electrification, etc.
- Maximum transparency for user and reader for a better comprehension of the underlying correlations; assumptions and correction factors are based on relevant and sufficient data

Main Focus

- ✓ **Relative progress of real road traffic noise** as a result of the assumed noise reductions per category, scenario and driving condition
- ✓ **Calculations based on pure emission model (LAeq)** incorporating the investigated categories M and N

Impact Analysis on Real Traffic – Model Structure



Impact Analysis on Real Traffic – Parameters

Street type (Driving Conditions)

- 5 street types in terms of driving speed from 10 - 120 km/h: Residential, Urban Main, Extra Urban*, Rural**, Motorway
- Driving speed defined differently for every category, e.g. M1 → 120 km/h, N3 → 90 km/h on Motorways
- Individual speed limits can additionally be defined per category
- Intermittent (acceleration/deceleration) or free flowing traffic with constant speed
- Tyre/road conditions, e.g. type of asphalt, aftermarket/replacement tyres, atmospheric conditions like rain, temperature
- Constant or changing traffic density/volume

* Extra Urban = max. speed 70 km/h
** Rural = max. speed 90 km/h

Distribution within vehicle category

- Share of vehicles with different limit value scenarios: phase 1, phase 2, phase 3, beyond phase 3
- Variable share of pure electric vehicles in certain categories

Distribution between vehicle categories

- Different rates of market penetration over time until 2040 based on fleet average age: Very Fast, Fast, Medium, Slow
- Share of category aligned to selected street type and time of day (Day or Night)

Impact Analysis on Real Traffic – Characteristics of the Calculation Model

Baseline for sound emission values

- "Baseline" for the calculation tool is the average of sound pressure values per category extracted from the TA data, weighted by the EU registration numbers
  - ✓ The data shows that the representative sound level for each category is lower than the respective valid limit value
  - ✓ The necessary improvement to comply with the next level of limit values is therefore in average lower than the step between the limits

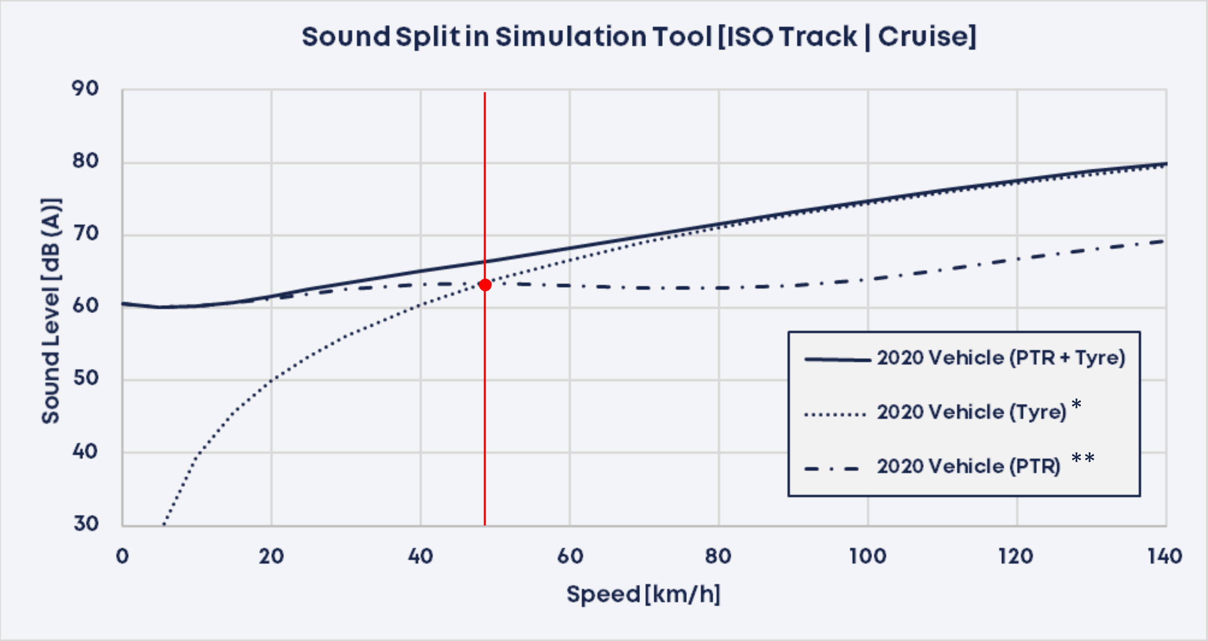
Emission modelling and LAeq

- Our newly developed calculation tool uses these representative sound values per category and combines them (weighted with various parameters) to one resulting sound value – referred as LAeq in this study
- This approach of a pure emission model puts the focus back on the vehicle and is independent of individual surroundings (e.g. reflections of facades or other vertical obstacles)

Real road

- Tyre/road noise contribution for the calculation model is extracted from TA values and not derived from tyre labels
- For the calculation of tyre/road sound emissions on real roads we assume a constant 3 dB(A) offset in accordance to CNOSSOS
  - ✓ This represents typical roads worse than ISO surface
  - ✓ It does not account for old or patched roads, wet surfaces, very cold conditions or aftermarket tyres which would further increase the tyre/road noise

Impact Analysis on Real Traffic – Model Basis



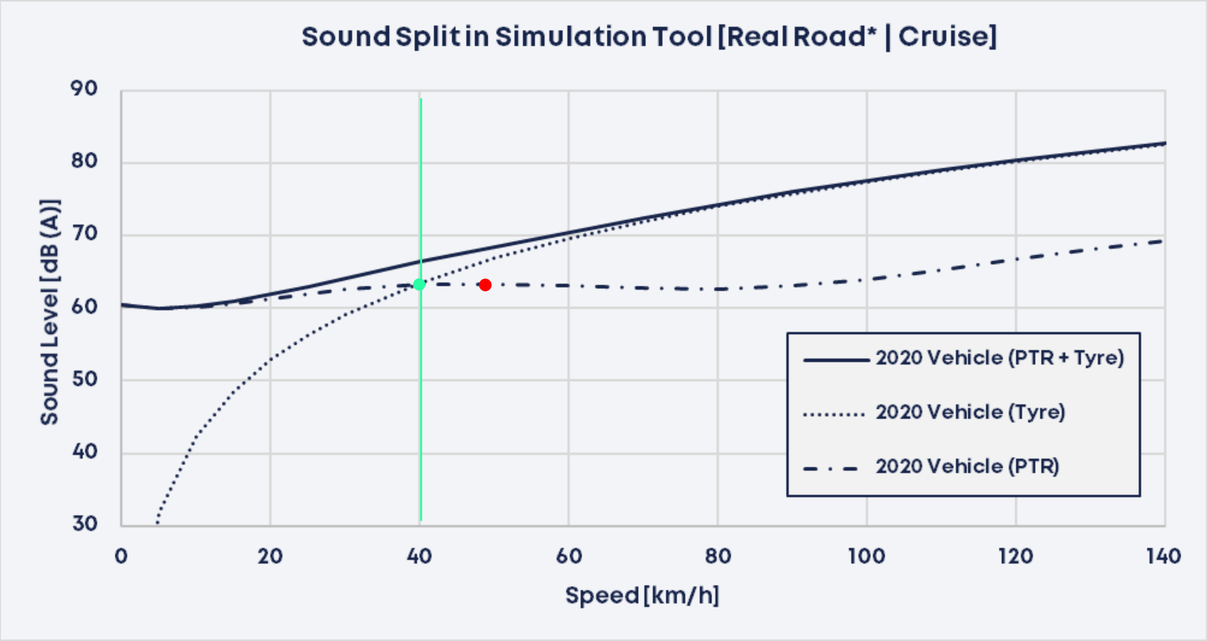
Example M1 ICE – ISO Track

- Typical 2020 M1 ICE vehicle according OICA TA DB in cruise condition (free flowing)
- PTR** curve mainly driven by engine speed – effects of typical gear shift peaks smoothened by averaging of multiple vehicles
- Main contributor changes approx. at 45 km/h from powertrain to tyre
- Overall sound emission is primarily affected by the dominant sound source

→ To reduce the sound level over entire speed range both contributors, tyres* and PTR** have to be reduced simultaneously

* Tyre = tyre contribution ** PTR = powertrain contribution

Impact Analysis on Real Traffic – Model Basis



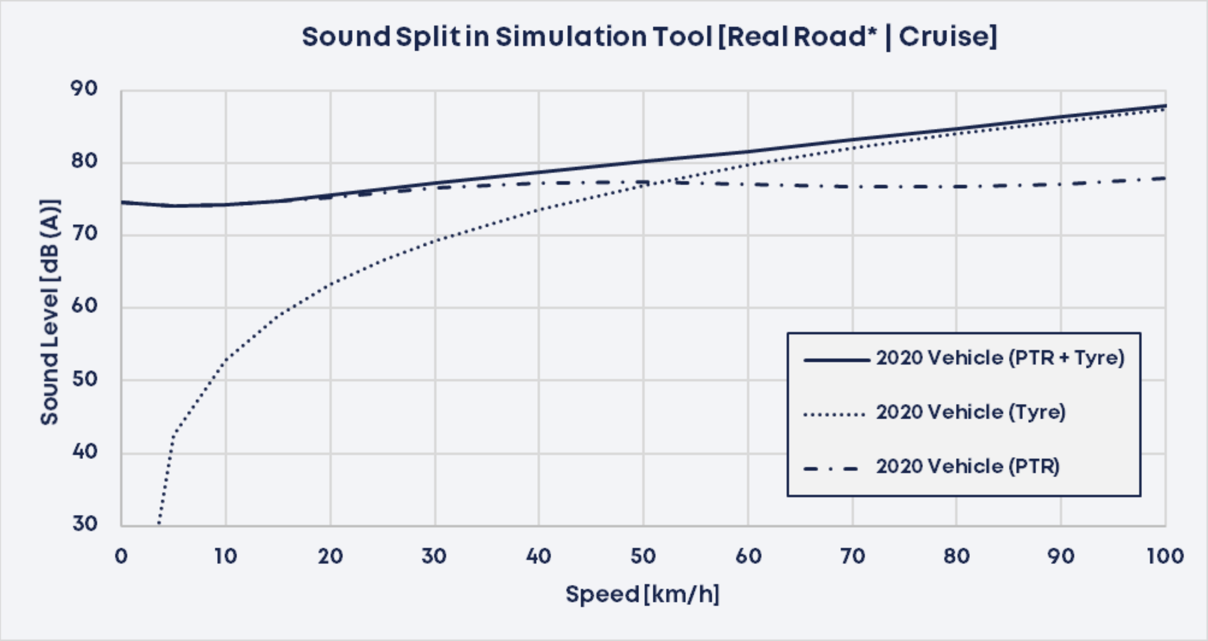
Example M1 ICE – Real Road*

- +3 dB(A) offset for tyre/road interaction compared to ISO track to represent real road conditions similar to CNOSSOS
- The contribution of the tyre road interaction becomes dominant earlier than on the ISO track
- The crossing point between powertrain and tyre contribution is shifted towards lower speeds

→ A further reduction of only the powertrain would shift the balance further towards the tyres, even for lower driving speeds

* Real road surface is assumed to be +3 dB(A) vs. ISO (similar to CNOSSOS)

Impact Analysis on Real Traffic – Model Basis



Example N3 ICE – Real Road*

- The tyre sound level is derived from tyre limit values and a representative and realistic truck & trailer configuration with 5-axles
- In contrast to real traffic, TA tests focus on powertrain noise using a 2-axle configuration to minimize tyre sound contribution

→ Very low dynamics from PTR over speed range (reason: very low range of engine speeds variation due to high number of gears)
→ Tyre becomes dominant sound source at speeds above 50 km/h

* Real road surface is assumed to be +3 dB(A) vs ISO (similar to CNOSSOS)

Impact Analysis on Real Traffic – Scenarios and Assumptions

	Scenario 1	Scenario 2	Scenario 3
Description	Freeze after Phase 2 Baseline	Launch of Phase 3 as given by UN R51.03	Beyond Phase 3 -2 dB (A) vs. Phase 3
Feasibility	Possible Already in place (N2 from 01.07.2022 onwards)	Largly possible Already in development, but challenging	Critical, fictional Technical limit already reached in Phase 3

Category	Current Status				Optimisations vs. Baseline				Optimisations vs. Baseline			
	PTR [dB (A)]		Tyre [dB (A)]		PTR [dB (A)]		Tyre [dB (A)]		PTR [dB (A)]		Tyre [dB (A)]	
	ICE, HEV	BEV	ICE, HEV	BEV	ICE, HEV	BEV	ICE, HEV	BEV	ICE, HEV	BEV	ICE, HEV	BEV
M1	baseline		baseline		-1.0	0.0	-1.0	-1.0	-3.5	0.0	-2.0	-2.0
M2	baseline		baseline		-2.0	0.0	-1.0	-1.0	-4.0	0.0	-2.0	-2.0
M3	baseline		baseline		-1.0	0.0	-0.5	-0.5	-3.0	0.0	-1.0	-1.0
N1	baseline		baseline		-1.0	0.0	-1.0	-1.0	-3.0	0.0	-2.0	-2.0
N2	baseline		baseline		-2.0	NA*	-0.5	NA*	-5.0	NA*	-1.0	NA*
N3	baseline		baseline		-2.5	NA*	-0.5	NA*	-5.0	NA*	-1.0	NA*

Explanations:

- **Scenario 1** means staying with the current Phase 2 limits (baseline = derived from TA and registration data)
- **Scenario 2** assumes achievable improvements on tyres and PTR
- **Scenario 3** assumes tyre noise reductions leading to significantly reduced safety performances
- The remaining efforts in order to achieve the limit values of each scenario has been assumed to come from the PTR

With the available technology the assumed reductions in Scenario 3 are not confirmed and do not seem to be achievable
Therefore all further analyses based on Scenario 3 are purely fictional due to technical feasibility issues !

* No data available for part source contributions to build a reliable model for the calculation tool

Impact Analysis on Real Traffic – Market Penetration Speed

Consideration of 4 different market penetration speeds:

- ✓ Slow: ø Age 12 years
- ✓ Medium: ø Age 10 years
- ✓ Fast: ø Age 8 years
- ✓ Very Fast: ø Age 5 years

Example M1 - Selected Market Penetration Speed: Medium

- **Share per phase based on average age of the whole fleet**
- E.g. an average vehicle age of 10 years of whole market will lead to an exchange of 5% per year
- This exchange rate combined with market growth leads to approx. 14 million new vehicle registrations per year

Year	R51.02 & 03 Phas		Scenario 1		Scenario 2		Scenario 3		
	Share								
2019	100%	10.0	0%	0.0	0%	0.0	0%	0.0	10.0
2020	95%	10.5	5%	0.5	0%	0.0	0%	0.0	10.0
2021	90%	11.0	10%	1.0	0%	0.0	0%	0.0	10.0
2022	85%	11.5	15%	1.5	0%	0.0	0%	0.0	10.0
2023	80%	12.0	20%	2.0	0%	0.0	0%	0.0	10.0
2024	75%	12.5	20%	3.0	5%	0.5	0%	0.0	10.0
2025	70%	13.0	20%	4.0	10%	1.0	0%	0.0	10.0
2026	65%	13.5	20%	5.0	15%	1.5	0%	0.0	10.0
2027	60%	14.0	20%	6.0	20%	2.0	0%	0.0	10.0
2028	55%	14.5	20%	7.0	20%	3.0	5%	0.5	10.0
2029	50%	15.0	20%	8.0	20%	4.0	10%	1.0	10.0
2030	45%	15.5	20%	9.0	20%	5.0	15%	1.5	10.0
2031	40%	16.0	20%	10.0	20%	6.0	20%	2.0	10.0
2032	35%	16.5	20%	11.0	20%	7.0	25%	2.5	10.0
2033	30%	17.0	20%	12.0	20%	8.0	30%	3.0	10.0
2034	25%	17.5	20%	13.0	20%	9.0	35%	3.5	10.0
2035	20%	18.0	20%	14.0	20%	10.0	40%	4.0	10.0
2036	15%	18.5	20%	15.0	20%	11.0	45%	4.5	10.0
2037	10%	19.0	20%	16.0	20%	12.0	50%	5.0	10.0
2038	5%	19.5	20%	17.0	20%	13.0	55%	5.5	10.0
2039	0%	20.0	20%	18.0	20%	14.0	60%	6.0	10.0
2040	0%	20.5	15%	18.5	20%	15.0	65%	6.5	10.0

Impact Analysis on Real Traffic – Vehicle Share per Street Type

- Consideration of varying vehicle shares for the 5 street types
- 2 periods of the day weighted differently for calculating LAeq:

✓ Day: 80%

✓ Night: 20%

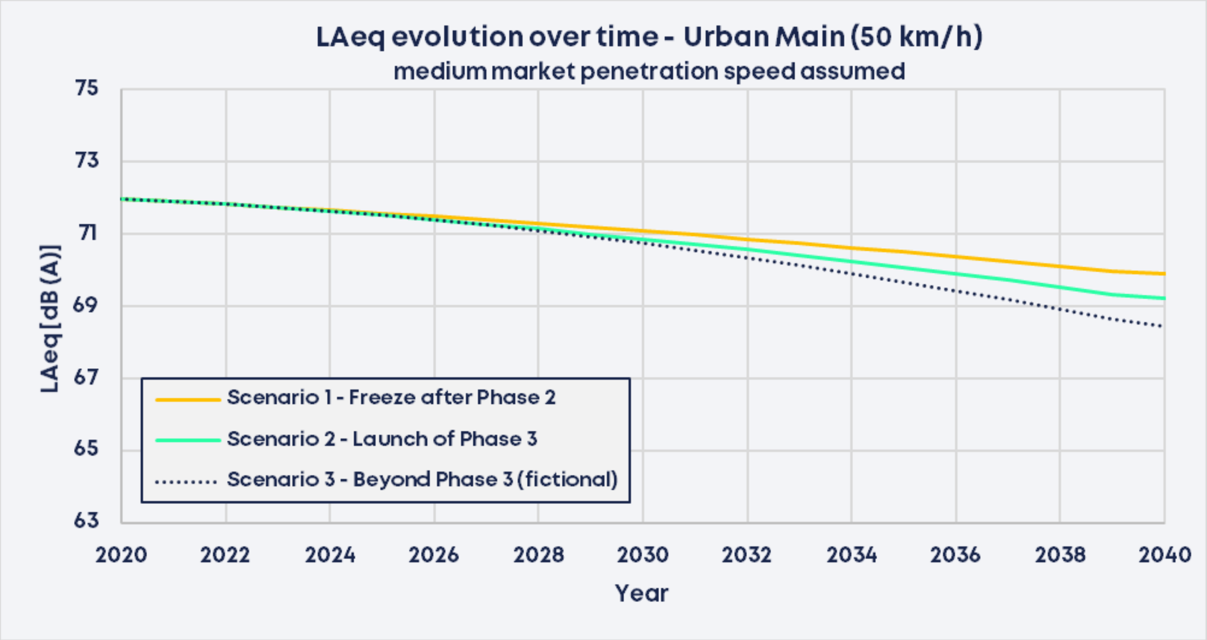
- Overall vehicle share per category assumed to be constant over the years
- BEV share rate per category acc. to Bloomberg Study*

Street Type	Year	Category	Day		Night	
			ICE, HEV	BEV	ICE, HEV	BEV
Urban Main [50 km/h]	2020	M1	80,5%	1,0%	87,2%	1,0%
		M2	0,8%	0,2%	0,1%	0,0%
		M3	0,8%	0,2%	1,0%	0,3%
		N1	14,4%	0,1%	9,6%	0,1%
		N2	1,9%	NA**	0,7%	NA**
		N3	0,1%	NA**	0,0%	NA**
	2040	M1	53,8%	27,7%	58,3%	29,9%
		M2	0,3%	0,7%	0,0%	0,1%
		M3	0,3%	0,7%	0,4%	0,9%
		N1	10,8%	3,8%	7,2%	2,5%
		N2	1,9%	NA**	0,7%	NA**
		N3	0,1%	NA**	0,0%	NA**

* Source: Electric Vehicle Outlook 2021, BloombergNEF

** No data available for part source contributions to build a reliable model for the calculation tool

Impact Analysis on Real Traffic – LAeq evolution over time

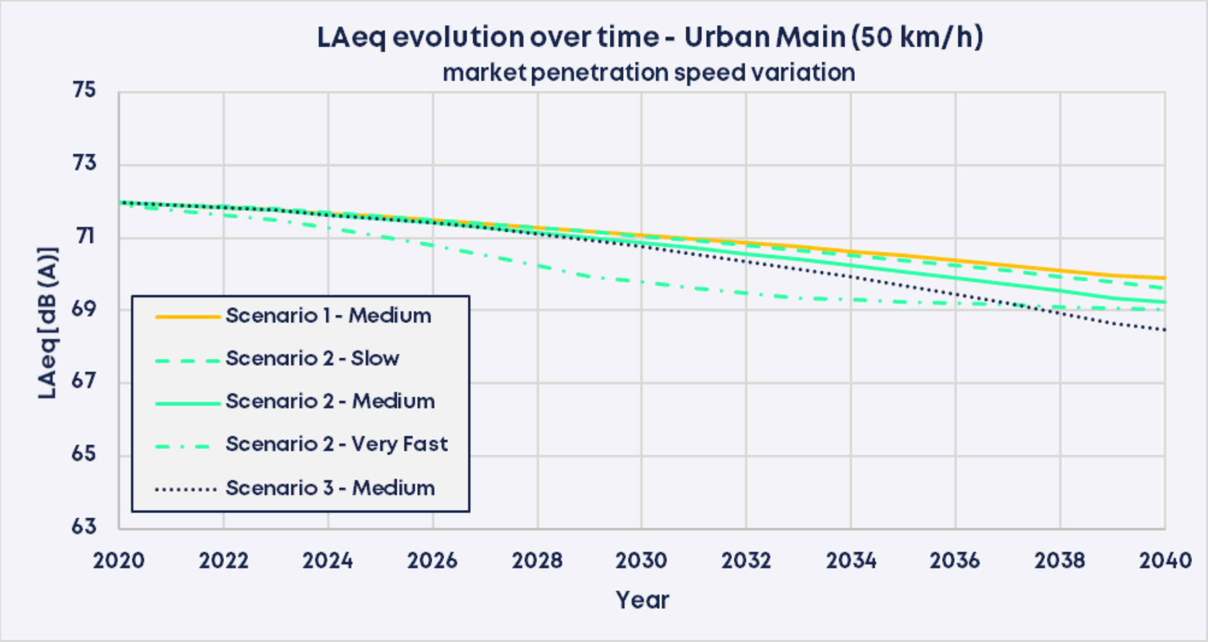


Comparison of LAeq values - all vehicle categories (Real Road)

- **Theoretical** calculated LAeq improvement 2020 vs. 2040 for Scenario 1: -2.0 dB(A)
  (Possible change of traffic volume neglected in the calculation model)
- Scenario 2 vs. Scenario 1 in 2040: Δ = -0,7 dB(A)
- Scenario 3 vs. Scenario 2 in 2040: Δ = -0,8 dB(A) (fictional)
- Steady reduction over time, as newer vehicles replace the noisier old ones

→ Even with Scenario 1 (keep phase 2 until 2040) a steady decrease in LAeq can be observed as a result of vehicle fleet renewal

Impact Analysis on Real Traffic – Market Penetration Speed variation



Comparison of LAeq values - all vehicle categories (Real Road)

- **Theoretical** impact to the result in 2040 by comparing the effects of varying market penetration rate:
  (Possible change of traffic volume neglected in the calculation model)

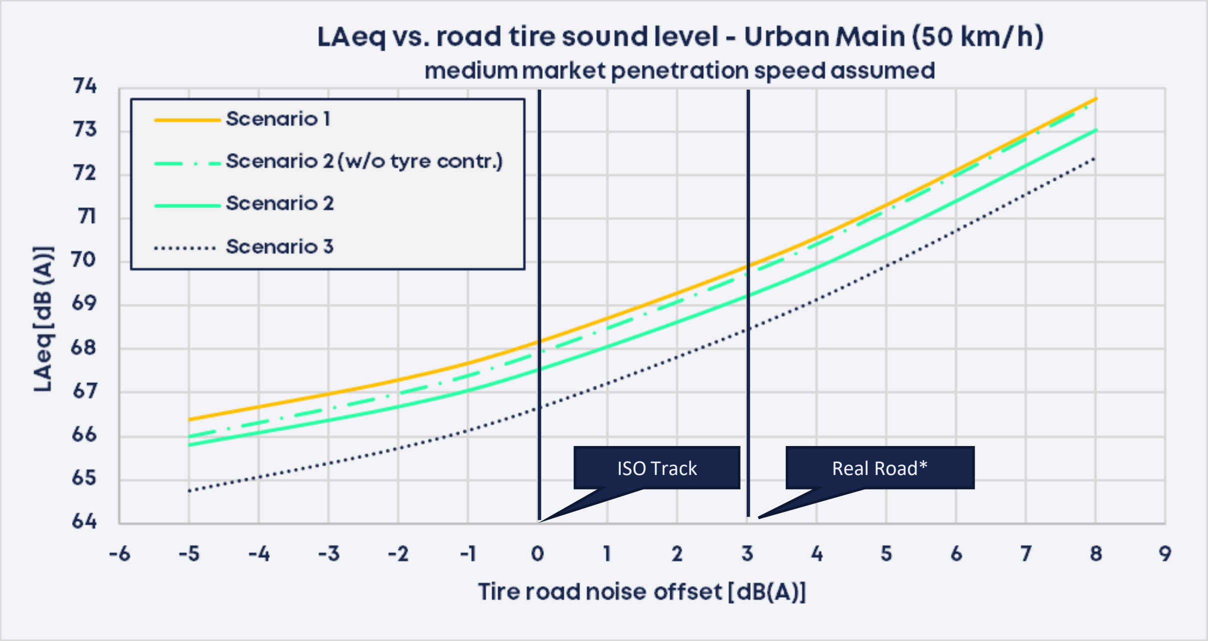
✓ +0.4 dB(A) for Slow vs. Medium

✓ -0.2 dB(A) for Very Fast vs. Medium
→ only 0.6 dB(A) difference between Slow and Very Fast

- Steady reduction over time, as newer vehicles replace the noisier old ones

→ Measures for accelerated market penetration such as incentives for new technologies lead to lower LAeq value in a shorter period of time, provided that there are realistic production and infrastructure capacities

Impact Analysis on Real Traffic – LAeq vs. road tyre sound level



Comparison of LAeq values – all vehicle categories [in 2040]

- Approx. efficiency of PTR or tyre measures in relation to varying offsets to ISO track from -5 dB(A) to +8 dB(A):

✓ PTR: 25% - 5%
✓ Tyre: 25% - 85%
✓ Road: 30% - 85%

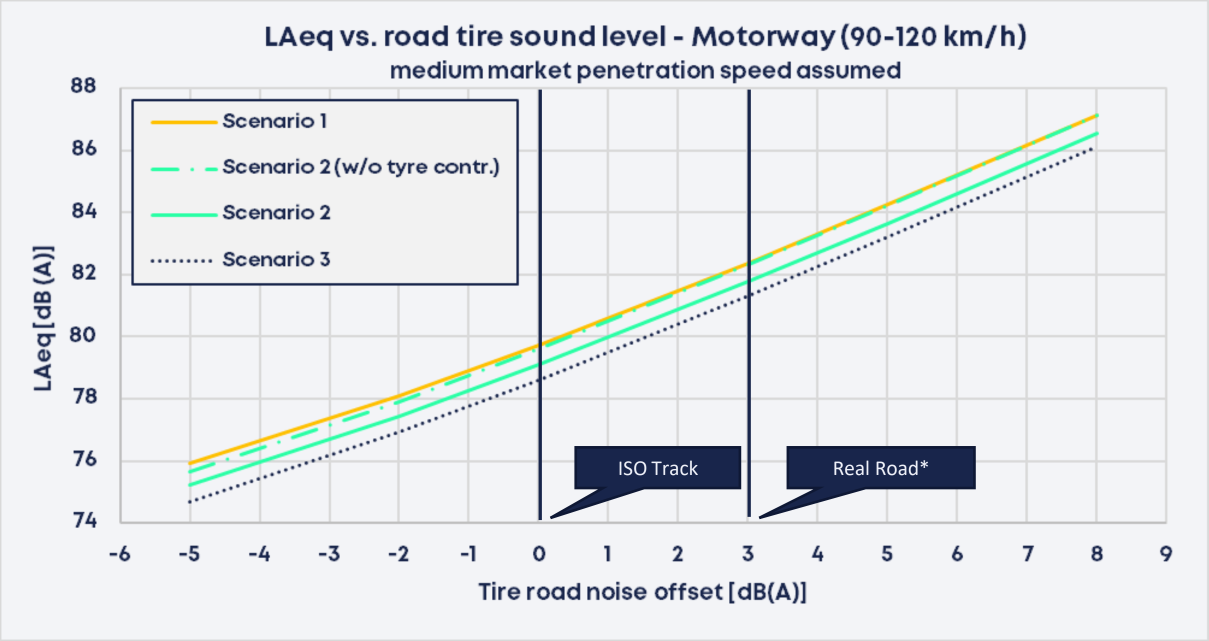
- Reasons for deviating tyre/road interaction in real traffic vs. ISO Track (homologation cond.):

✓ Real road surface
✓ Aftermarket and worn tyres
✓ Rain, snow, …

→ The efficiency of efforts put into the PTR are strongly dependent on the contribution of tyre/road interaction
→ Under real traffic conditions the highest potential for sound level reductions is on the tyre/road interaction side

* Real road surface in calculation model is assumed to be +3 dB(A) vs. ISO (similar to CNOSSOS)

Impact Analysis on Real Traffic – LAeq vs. road tyre sound level



Comparison of LAeq values – all vehicle categories [in 2040]

- Approx. efficiency of PTR or tyre measures in relation to varying offsets to ISO track from -5 dB(A) to +8 dB(A):

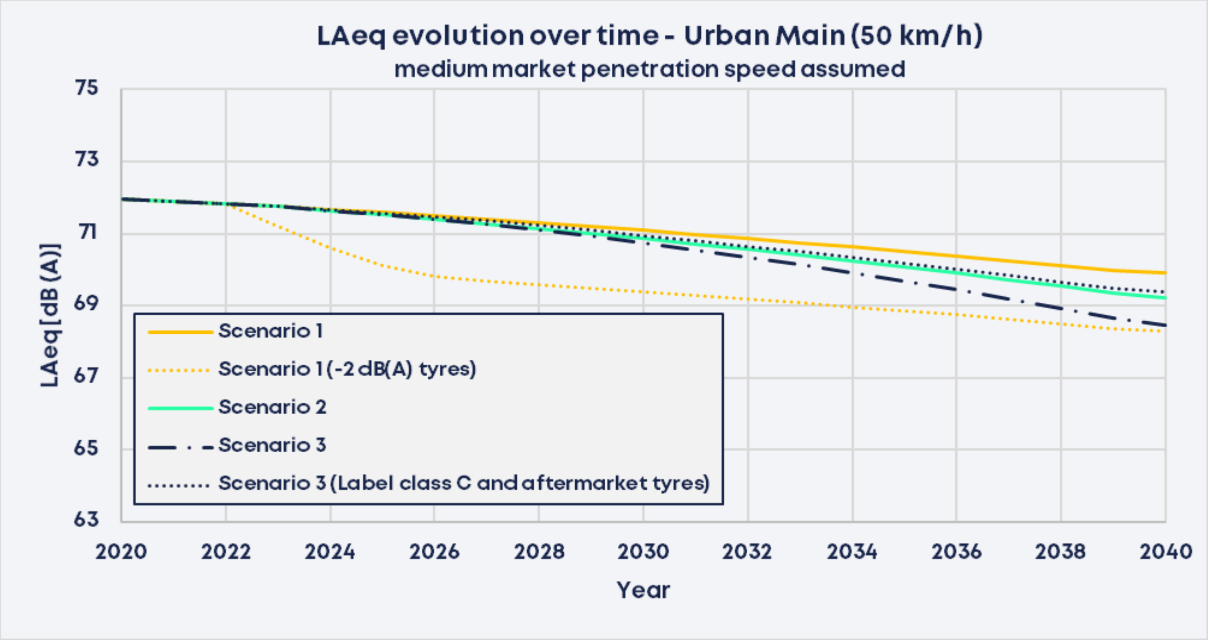
✓ PTR: 20% - 0%
✓ Tyre: 80% - 85%
✓ Road: 85% - 95%

- At higher speeds the efficiency of measures put into PTR decreases since tyre/road interaction becomes more dominant

→ The efficiency of the powertrain sound optimisation measures decreases with increasing driving speed

* Real road surface in calculation model is assumed to be +3 dB(A) vs. ISO (similar to CNOSSOS)

Impact Analysis on Real Traffic – LAeq evolution over time

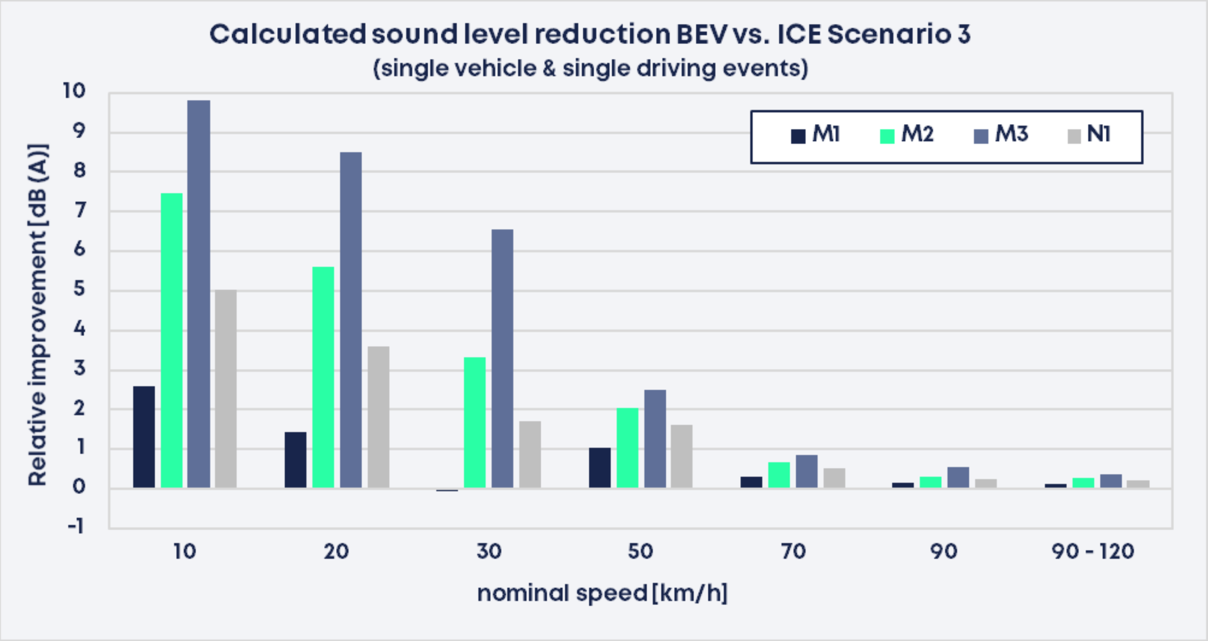


Comparison of LAeq values - all vehicle categories [Real Road]

- If tyres with a rolling noise of -2 dB(A) below the current ones would be equipped to the current vehicle fleet:
  - ✓ Immediate effect on LAeq
  - ✓ Even in 2040 LAeq remains below that of Scenario 3
- Vehicles compliant with Scenario 3 limits will typically be equipped with tyres of label class A. Fitting aftermarket tyres of label class C would result in higher LAeq values compared to Scenario 2

→ In contrast to limit value reductions, the decrease of tyre/road noise has an immediate effect on LAeq., e.g. quiet tyres
→ Biggest and quickest benefit to real traffic noise can be achieved by reducing the tyre/road sound emission

Impact Analysis – Vehicle comparison ICE vs. BEV in discrete traffic scenarios



Comparison of improvements for electric vehicles [Real Road]

- AVAS sound emission assumed as average between min. and max. legal requirement until 20 km/h and ramped out until 40 km/h
- Increased tyre noise due to higher vehicle weight of BEV neglected
- Biggest improvements at lower driving speeds depending on individual AVAS configuration
- Potential deterioration for M1 around 30 km/h at cruise cond. due to min. sound requirement (AVAS)

→ Significant potential at low driving conditions until 30 km/h for busses & light commercials due to dominant PTR contribution
→ Electrification has the potential to reduce sound emissions at lower but not at higher speeds

Impact Analysis on Real Traffic – Sensitivity Analysis

- **Impact determination of various parameters on the calculation model, e.g.**

✓ Market penetration speed
✓ BEV and truck share rate
✓ Traffic density and flow
✓ Tyre/road interaction

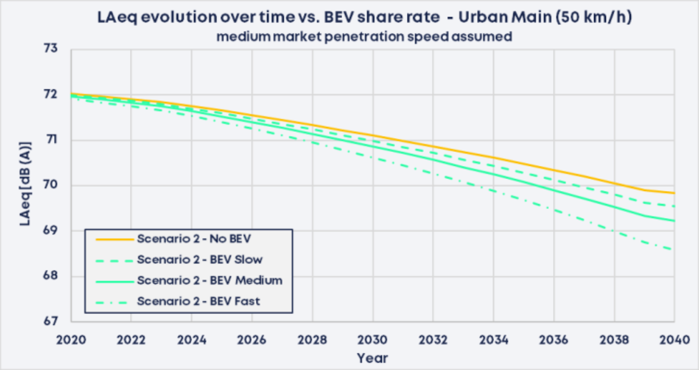
- **E.g. M1 BEV share rate:**

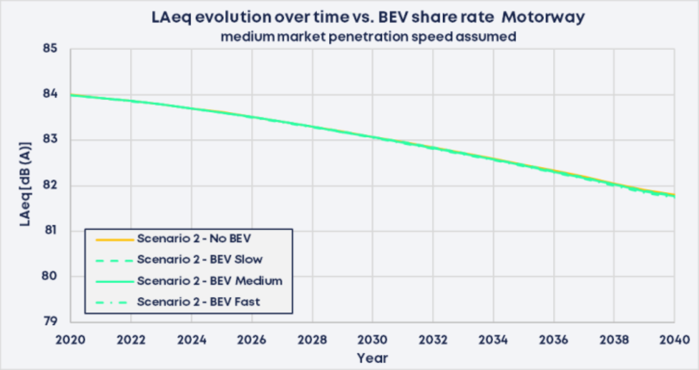
✓ Medium: Realistic BEV share of 34% in 2040 (Bloomberg study)

✓ Slow: (BEV share rate of 17% in 2040) vs. Medium:
Urban Main (50 km/h): +0.3 dB(A)

✓ Fast: (BEV share of 68% in 2040) vs. Medium:
Urban Main (50 km/h): -0.6 dB(A)

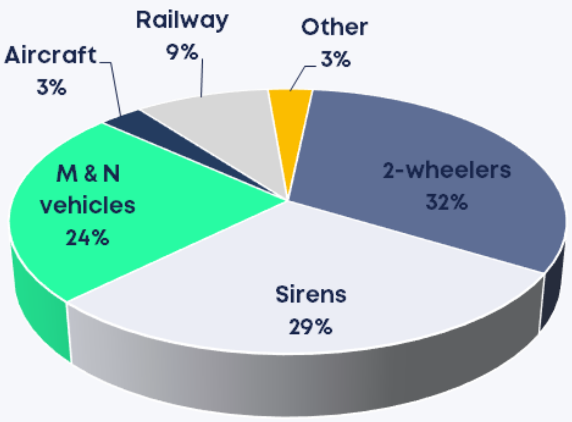
✓ Motorway (120 km/h) for all share rates: 0.0 dB(A)

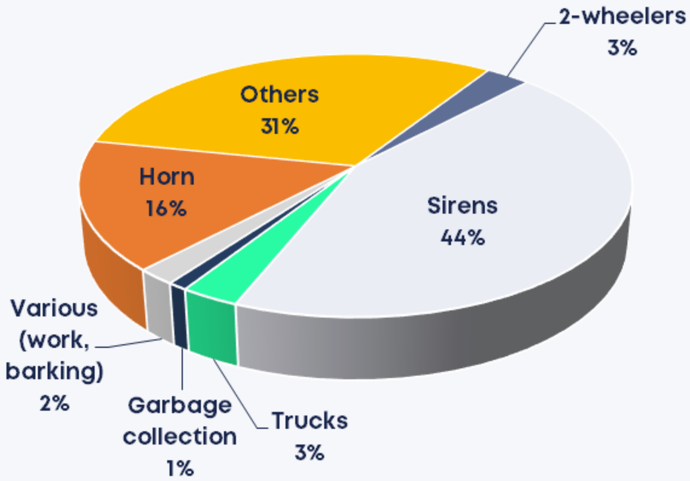




→ Under urban conditions the increased share rate of electric vehicles has a significant impact on LAeq: Δ=0.9 dB(A) Slow vs. Fast
→ At higher driving speeds the effect of the share rate of electric vehicles on LAeq is low: Δ≈0.0 dB(A) Slow vs. Fast

Impact Analysis on Real Traffic – Single Events, Noise Psychology





- This study is limited to road traffic noise of categories M & N vehicles
- The perception of "annoyance" is often context dependent and therefore cannot be generalised
- Not considered in our calculations and this study:
  - ✓ Other transport noise sources, e.g. 2-wheelers, railway, etc.
  - ✓ Single events that can influence Laeq, e.g. Siren, Horn
  - ✓ Driving style and reckless behaviour in road traffic

→ The potential benefits shown on the previous slides have to be seen in context to other transport noise sources and single events since the contribution of M & N vehicles is rather low to the total "transport noise" and even lower to the overall noise

Source: Bruitparif - SIA Conference Automotive in Soundscapes (4th November 2020)

Conclusions & Outlook

Conclusions 1 / 2

Small Benefit by Limit Value Reduction

- Minimal effect seen at higher speeds where tyre/road contact is the dominant sound source
- At lower speeds the sound reduction potential is limited by minimum sound level requirements (AVAS)
- Benefits of PTR sound reduction in TA are only effective at tyre/road sound levels similar to ISO or better and at low speeds

Counteracting Effects in Real Traffic Scenarios

- Aftermarket tyres or exhausts and differing road surfaces typically lead to higher sound emissions compared to TA values
- Sound emissions can be highly increased through an inappropriate driving style or reckless driving behaviour (single events)

Conclusions 2 / 2

Limited Technical Feasibility

- Low potential to reduce tyre rolling noise: max. -1 dB(A) without unacceptable impact on safety
- Minor potential to further reduce powertrain noise due to trade off with exhaust emission regulations and package constraints etc.
- Despite lower PTR sound levels even certain EV concepts could struggle to comply with limits beyond Phase 3 due to the negative impact of their increased weight on the tyre rolling sound
- Development has to cover all measurement uncertainties (track, temperature, …) and therefore manufacturers are forced to develop 1-2 dB(A) below the actual limit

Time Delayed Effect

- Effect of limit reduction is directly related to market penetration rate; due to the increasing average fleet age, the full impact of a limit value reduction will only be seen in the far future
- The time delayed effect is most significant for reductions made on PTR sound. Measures taken on tyres show faster benefits due to faster market penetration. Only improvements on the road surface show an immediate impact on the entire vehicle fleet

→ Other measures have to be considered and investigated in conjunction with future regulation development

Outlook

Further Analysis for Final Report

- Further scenarios beyond actual Phase 3 limits will be considered in final report
- More details to explain key findings and conclusions
- Table to demonstrate the effectiveness of measures on vehicle part sources relative to real world driving conditions different from type approval (Proposal GRBP)
- Review PHENOMENA study / technical development of UN regulations
- Review the impact of the introduction of RD-ASEP

Recommended Further Investigations

- Further investigation of the current AVAS system in real traffic
- Additional and more recent data would allow for even more precise and realistic output from the calculation tool, e.g. PTR vs vehicle speed for BEVs and cat. N3
- Standard scenarios to be used for calculations, e.g. share of veh. categories for certain street types
- Comparison on available modelling tools
- More recommendations for further studies to follow during report writing

In case of questions or comments, please do not hesitate to contact us

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Annex 1: List of Abbreviations 1 / 3

Abbreviation	Explanation
ACEA	Association des Constructeurs Européens d'Automobiles
AVAS	Acoustic Vehicle Alerting System
BEV	Electric vehicle using only batteries as energy storage
CNOSSOS	Common Noise Assessment Methods in Europe
C1	Tyres for passenger cars
C2	Tyres for light commercial vehicle
C3	Tyres for heavy vehicles
DB	Data base
END	Environmental Noise Directive 2002/49/EC specifying noise indicators
ETRTO	European Tyre and Rim Technical Organisation
EU 7	Stage 7 of exhaust emission restriction for M1 and N1 vehicles in the EU (in discussion)
EV	Electric vehicle – vehicle that uses only electric motor(s) for propulsion
GRPB	UN ECE Working Party on Noise and Tyres (Groupe Rapporteur Bruit et Pneumatiques)
GSR	General safety regulation (EU) 2019/2144

Abbreviation	Explanation
ICE	Internal combustion engine
ISO	International Standardisation Organisation
LAeq	Level A-weighted equivalent of sound pressure levels (weighted average max. pressure of different vehicle categories processed to one representative sound source) [dB(A)]
Lurban	Vehicle sound pressure level representing urban condition [dB(A)]
OE	Original Equipment
OEM	Original Equipment Manufacturer
OICA	Organisation Internationale des Constructeurs d'Automobiles
Phenomena	Project assessing the potential health benefits of noise abatement measures in the EU
PMR	Power to Mass Ratio index (PMR) [as numerical quantity with no dimension]
Pn	Nominal engine power [kW]
PTR	Powertrain, including engine, transmission, differential and axles
RD-ASEP	Real Driving additional sound emission provisions
TA	Type approval

Annex 1: List of Abbreviations 3 / 3

Abbreviation	Explanation
UN ECE	United Nations Economic Commission for Europe World Forum for the harmonization of vehicle regulations
UN R51	UN ECE Regulation No. 51 Uniform provisions concerning the approval of motor vehicles having at least four wheels with regard to their sound emissions
Phase 1	Phase 1 of limits valid in UN R51
Phase 2	Phase 2 of limits valid in UN R51
Phase 3	Phase 3 of limits valid in UN R51
UN R117	UN ECE Regulation No. 117 Uniform provisions concerning the approval of tyres with regard to rolling sound emissions and/or to adhesion on wet surfaces and/or to rolling resistance
UN R138	UN ECE Regulation No. 138 Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility (defining AVAS)
WOT	Wide open throttle = full load acceleration

Annex 2: Scope of Study

Review Current Status

- Literature research: Analytical approach, state of the art, previous/recent studies, etc.
- Analysis of TA data 2010 vs. 2020 in terms of sound emissions
- Comparison and alignment with EU registration data

Limit Value Scenarios & Industry Consultation

- Interviews with several vehicle or tyre manufacturers
- Analysis of sound level vs. limit value evolution, technical feasibility and part source contributions
- Analysis of interactions with other regulations: UN R138, UN R118, UN R117, EU7 Emission, GSR

Impact of Limit Value Reductions & Alternative Measures

- Development of an expedient calculation tool to estimate the impacts of suitable measures
- Impact of AVAS and replacement/aftermarket equipment
- Estimation of reduced number of noise affected people based on END parameters

Review PHENOMENA Study & Technical Development of UN Regulations

- Analysis of assessment systematic and discussion about the handling of economic parameters
- Better implementation of alternative propulsion types, minimisation of measurement uncertainties as well as harmonisation among other type approval regulations

Annex 3: Definition of Vehicle Categories M and N

Vehicle category		Subcategory	
M1	Vehicles used for carriage of passengers, comprising not more than eight seats in addition to the driver's (= max. 9 seats)	M1-a M1-b M1-c M1-d	PMR ≤ 120 kW/t 120 kW/t < PMR ≤ 160 kW/t PMR > 160 kW/t PMR > 200 kW/t
M2	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tons. (Bus)	M2-a M2-b M2-c M2-d	M ≤ 2.5 t 2.5 t < M ≤ 3.5 t M > 3.5 t	Pn ≤ 135 kW M > 3.5 t	Pn > 135 kW
M3	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tons. (Bus)	M3-a M3-b M3-c	Pn ≤ 150 kW 150 kW < Pn ≤ 250 kW Pn > 250 kW
N1	Vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tons. (Pick-up Truck, Van)	N1-a N1-b	M ≤ 2.5 t M > 2.5 t
N2	Vehicles used for the carriage of goods and having a maximum mass exceeding 3.5 tons but not exceeding 12 tons. (Commercial Truck)	N2-a N2-b	Pn ≤ 135 kW Pn > 135 kW
N3	Vehicles used for the carriage of goods and having a maximum mass exceeding 12 tons. (Commercial Truck)	N3-a N3-b N3-c	Pn ≤ 150 kW 150 kW < Pn ≤ 250 kW Pn > 250 kW

Annex 4: Number of valid Data Sets for Vehicle Categories M and N

Vehicle category			Valid Data Sets in ACEA database 2010	Valid Data Sets in OICA TA database 2020
M1	M1-a	PMR ≤ 120 kW/t	522	1306
	M1-b	120 kW/t < PMR ≤ 160 kW/t	54	181
	M1-c	PMR > 160 kW/t	23	109
	M1-d	PMR > 200 kW/t	12	59
			Including 54 offroad vehicles	Including 109 offroad vehicles
M2	M2-a	M ≤ 2.5 t	37	0
	M2-b	2.5 t < M ≤ 3.5 t	10	14
	M2-c	M > 3.5 t | Pn ≤ 135 kW	0	8
	M2-d	M > 3.5 t | Pn > 135 kW	0	1
M3	M3-a	Pn ≤ 150 kW	14	0
	M3-b	150 kW < Pn ≤ 250 kW	13	25
	M3-c	Pn > 250 kW	18	13
N1	N1-a	M ≤ 2.5 t	115	95
	N1-b	M > 2.5 t	10	64
			Including 11 offroad vehicles	Including 13 offroad vehicles
N2	N2-a	Pn ≤ 135 kW	32	14
	N2-b	Pn > 135 kW	31	62
N3	N3-a	Pn ≤ 150 kW	4	2
	N3-b	150 kW < Pn ≤ 250 kW	56	14
	N3-c	Pn > 250 kW	90	61

Thankyou!