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This presentation is an excerpt of the

Study on sound level limits of M- and N-category vehicles

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On behalf of the European Commission

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Content

1. Introduction,
2. Feedback gathering and literature review,
3. Testing of vehicles’ sound emission values,
4. Cost benefit analysis,
5. Proposal for phase 4 limit values,
6. Discussion about amendments of the measurement method and ASEP requirements.

Introduction

Subject and aim of the study

- With this study, the EC aims at obtaining the technical background so as to review and possibly update (improve) the sound level limits for M- and N-category vehicles, for the next phases of Regulation (EU) No 540/2014.
- Along with the technical feasibility, costs and benefits of possible new (improved) sound emission level limits need to be also estimated.
- In this context, it is important to assess the current and future state of play and the development of the relevant technology.
- In addition, a proper cost-benefit analysis must be carried out.
- A justified and documented proposal is therefore required, with an appropriate timeframe for the application of the possible new limits.
- The ultimate objective is to protect the environment and human health, by providing an improved sound level range for M- and N-category vehicles.

Content

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Feedback gathering, literature rev.

Description

- **Feedback gathering** procedure with questionnaire to stakeholders, organised as follows:

  Social partners, Countries (i.e. ministries of foreign affairs, national permanent representations to the EU), cities (i.e. local authorities, municipalities, European cities networks), citizens (i.e. European consumer and other organizations), Environmental organizations and institutes, Noise concerned associations

  Industrial stakeholders, Manufacturers (individual and associations)

  National (technical and non-technical) authorities, Technical services and type approval authorities, Departments of transport, market surveillance and enforcement authorities

- **Literature review** to explore the current state-of-the-art sound emissions control technology and analysis of TA databases (KBA and RDW).

Feedback gathering, literature rev.

Qualitative assessment of the feedback gathering procedure

- *In total, there were 67 replies to the request for answering the questionnaires, out of which 66 were positive replies (filled in questionnaires received).*
- *In particular, 20 answers came from social partners filling in the corresponding questionnaire and 46 from technical entities.*

The following slides are related to the feedback gathered from technical entities only.

Feedback gathering, literature rev.

Current status: Regulation (EU) No 540/2014 and Regulation (EU) No 117 sound emission limits

- *Sound limits of phases 1 and 2 are considered easily achievable for most vehicle categories.*
- ***In general, reaching limits of phase 3 is considered challenging as technological advancements are necessary.***
- *In general, a further reduction of the limits of phase 3 of the regulation is not considered feasible, as current limits are considered already difficult to achieve for some vehicle categories.*
- *Two main difficulties are expected in the case of a further limit values reduction: The first one is related to tyres. In cases where tyre road noise is the dominating source the reduction potential of measures only applied on parameters other than tyres will be very limited and not cost effective.*
- *A further reduction of the tyre road noise contribution would be required before other reduction measures.*

Feedback gathering, literature rev.

Possibly lower M- and N-category vehicle sound emission limits

- *The second one is related to reducing sound emissions from the engine and the exhaust. Reduction of engine noise may also increase fuel consumption because of weight increase (additional equipment).*
- *Some additional measures, not related to vehicle technology, include better maintenance of road infrastructure, quieter road surfaces and more efficient traffic management.*

Sound emissions from tyres

- *Most stakeholders mention that it is not possible to improve sound emission performance of tyres, without serious influence on their wet grip and rolling resistance, based on a study by ACEA (ACEA – Tyre Performance Study – Noise VS other performances).*
- *On the other hand, it is also mentioned that a reduction of 2 dB is possible, while keeping other parameters unchanged. This is also supported by a comment stating that there is no relation between tyre rolling sound and wet grip or rolling resistance.*

Feedback gathering, literature rev.

Additional sound emission provisions (ASEP)

- *Regarding ASEP, it is widely accepted that it targets cycle-beating and can help reduce annoyance from single events but does only have little impact on environmental noise on an L_{eq} basis. The goal of ASEP is to ensure that vehicles are performing as expected over a larger operation range than covered by the TA noise test. But this is not seen as an issue for categories other than M1 and N1 vehicles.*
- *Additionally, making ASEP a mandatory part of the type-approval procedure is expected to increase its credibility.*
- ***Suggestions for improvement include tests under a wider range of velocity, acceleration and engine speed and measurements during WOT and partial load, coast down and cruising.***
- *Also, the work by GRBP IWG ASEP is widely welcomed.*

Feedback gathering, literature rev.

Other aspects

- *Except from the already mentioned sound sources, **road surfaces** are considered quite important as tyre rolling sound is expected to have a major contribution in the total sound emissions.*
- *Other parameters influencing the sound emissions are the **driving behaviour, maintenance of road infrastructure, AVAS, horns, reversing alarm, after market silencers and replacement tyres**.*

Feedback gathering, literature rev.

Cost/benefit impact from the expected sound emissions reduction

- ***Almost half of the survey participants believe that lowering sound limits will have a low contribution in protecting the environment and human health, as the corresponding reduction in real life sound emissions would be minimal.***
- *On the other hand, the other half of the stakeholders suggest that lower sound limits along with additional measures (different test cycles and off-cycle requirements like RD-ASEP, road surface optimisation and absorptive materials on buildings' facades), would have a high or medium contribution in environmental and human health protection.*
- ***Half of the survey participants (48%) believe that lower sound level limits will not contribute significantly to the reduction of single noise events, while in-use testing along with ASEP are thought to be sufficient for controlling single noisy events.***

Feedback gathering, literature rev.

Cost/benefit impact from the expected sound emissions reduction

- *Regarding the cost that will be possibly incurred from the introduction of lower sound emission level limits, most stakeholders refer to a study by ACEA in 2011. There are only a few answers that provide a cost estimation (other than the ACEA study) and mention that 80-200 €/dB for every new vehicle is expected in order to conform with the current phase 3 limits.*
- ***Participants believe that the only way to reduce the sound emissions of the existing fleet is to enforce alternative measures like quieter tyres and silent road surfaces.***

Feedback gathering, literature rev.

Analysis of type approval databases

- *Two different and partly complementary databases could be used for the project:*
  - The KBA database containing type approval data for different vehicle types in the EU from different type approval years (2005 to 2019).
  - The RDW database containing type approval data for different vehicles in the Dutch vehicle stock with first registration years from 1983 to 2020.
- *Type approval frequency distributions of the KBA database are shown in Figure 1. The frequencies are related to the number of vehicle types, independent of their sales rates.*
- *Type approval frequency distributions of the RDW database are shown in Figure 2. The frequencies are related to the number of individual vehicles in the stock, independent of the vehicle type although different vehicle types can be identified in addition to a certain extend.*

KBA type approval database

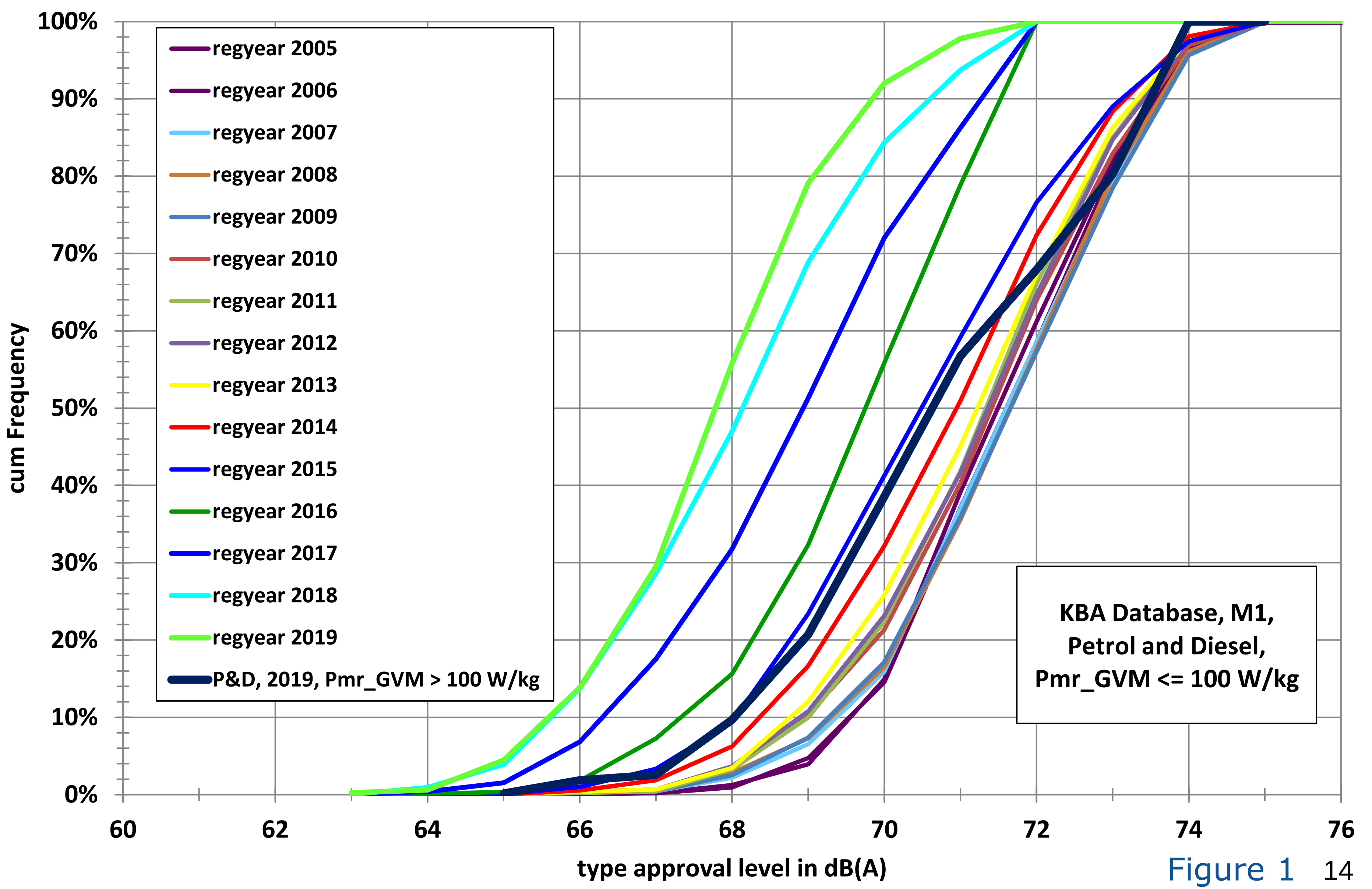

Figure 1

RDW type approval database

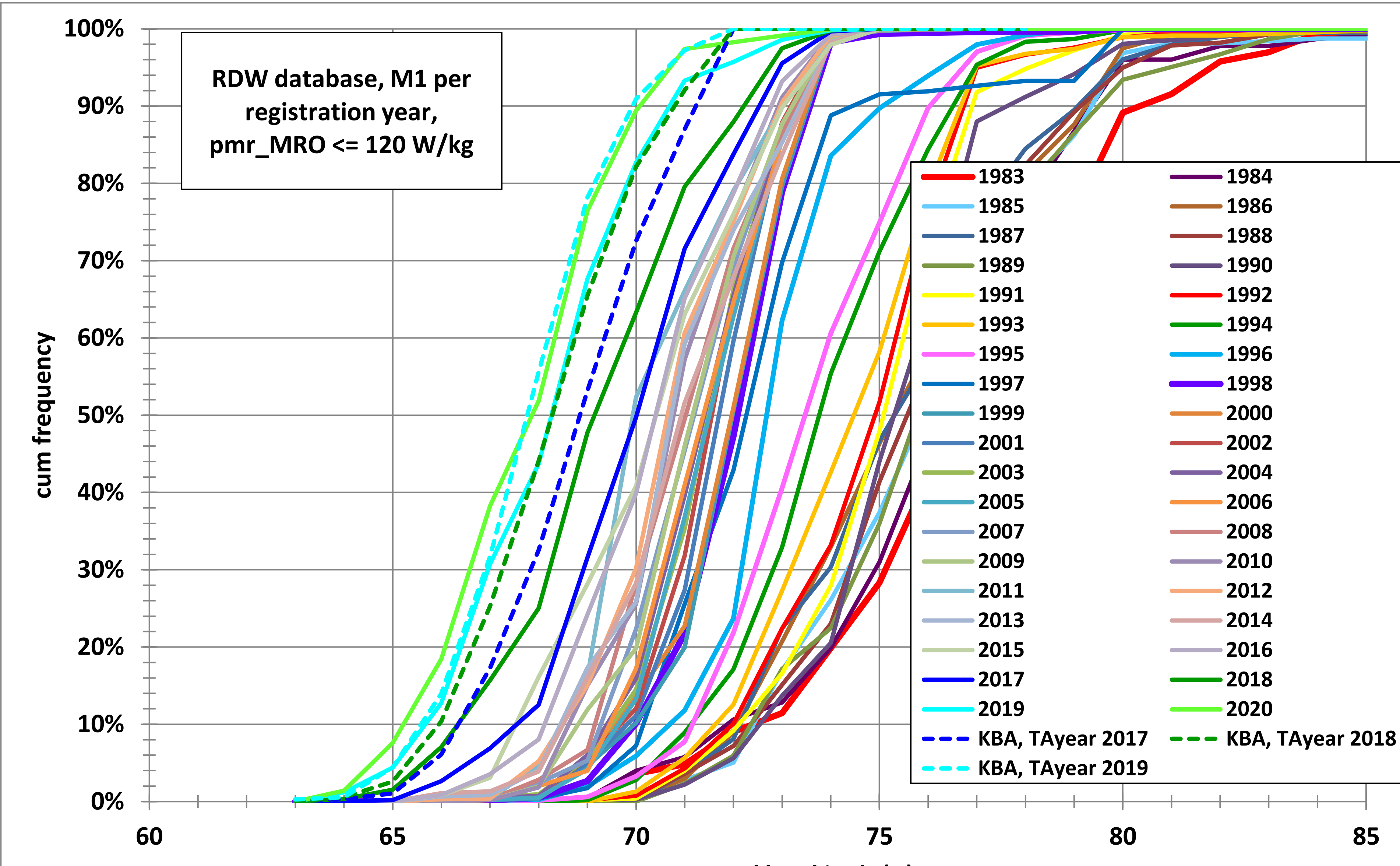

Figure 2

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Testing of vehicles' sound emission values

Vehicle selection and justification

*The objective of including vehicle testing with sound emission measurements in the study is to verify current sound levels of state-of-the-art vehicles and to investigate the current sound emissions control technology and the technical feasibility for improvement of sound level performance. Furthermore, to assess the contribution of various sources (vehicle components) to the sound level (**noise source ranking**).*

- *Due to budget restraints only 16 vehicles could be tested within this project. The 16 vehicles were distributed over the range of vehicle categories and subcategories according to Regulation EU 540/2014 as shown in Table 1.*
- ***As can be seen, not all vehicle subcategories could be considered by the vehicle selection. The selection criteria reflect a compromise between subcategory coverage, market share and differences in technical design like manual vs automatic transmission.***
- *The technical data are shown in Tables 2a and 2b. The distribution of P_{rated} vs m_{test} of the tested M1 vehicles are shown in Figure 3.*

Testing of vehicles' sound emission values

M category vehicles, used for the carriage of passengers		# tested vehicles
Category	Vehicle subcategory	
M1	power to mass ratio ≤ 120 kW/1 000 kg	3
	120 kW/1 000 kg < power to mass ratio ≤ 160 kW/1 000 kg	2
	160 kW/1 000 kg < power to mass ratio	1
	power to mass ratio > 200 kW/1 000 kg number of seats ≤ 4 R point of driver seat ≤ 450 mm from the ground	-
M2	TPMLM <= 2500 kg	
	2500 kg < TPMLM <= 3500 kg	-
	3500 kg < TPMLM <= 5000 kg, Pn <= 135 kW	1
	3500 kg < TPMLM <= 5000 kg, Pn > 135 kW	-
M3	Pn <= 150 kW	-
	150 kW < Pn <= 250 kW	-
	Pn > 250 kW	2
N category vehicles, used for the carriage of goods		**# tested vehicles**
Category	**Vehicle subcategory**	
N1	TPMLM <= 2500 kg	-
	2500 kg < TPMLM <= 3500 kg	2
N2	Pn <= 135 kW	2
	Pn > 135 kW	1
N3	Pn <= 150 kW	-
	150 kW < Pn <= 250 kW	1
	Pn > 250 kW	1

Table 1

Testing of vehicles' sound emission values

Vehicle category	Vehicle	Powertrain	Subcategory	Limit Phase 1 [dB(A)]	Limit Phase 3 [dB(A)]	Homologation Level [dB(A)]	Power [kW]	Rated speed [1/min]	gross weight [kg]	Test weight [kg]	Max. weight [kg]	PMR
M1	Roadster	IC engine with MT	120 < PMR ≤ 160	73	69	68	135	7000	1117	1073	1260	125,8
M1	Hot Hatchback	IC engine with AT	PMR > 160	75	71	73	294	5850	1590	1604	2060	183,3
M1	Subcompact	IC engine with CVT	PMR ≤ 120	72	68	69	53	6000	1055	1092	1450	48,5
M1	Subcompact SUV	IC engine with AT	PMR ≤ 120	72	68	70	92	6000	1349	1310	1770	70,2
M1	Compact Wagon Hybrid	Hybrid with AT	120 < PMR ≤ 160	73	68	68	288 65	6000	2031	2170	2500	132,7 30,0
M1	Compact SUV	IC engine with MT	PMR ≤ 120	72	68	72	110	3500	1660	1800	2300	61,1
N1	Light Commercial Van Low Power	IC engine with MT	M > 2.5 t	74	71	73	96	3500	2082	2222	3140	43,2
N1	Light Commercial Van High Power	IC engine with AT	M > 2.5 t	74	71	71	140	3800	2586	2557	3500	54,8

Table 2a

Testing of vehicles' sound emission values

Vehicle category	Vehicle	Powertrain	Subcategory	Limit Phase 1 [dB(A)]	Limit Phase 3 [dB(A)]	Homologation Level [dB(A)]	Power [kW]	Rated speed [1/min]	gross weight [kg]	Test weight [kg]	Max. weight [kg]	PMR
M2	Light Commercial People Mover	IC engine with MT	M>3,5t	75	72	75	120	3800	2370	3106	4100	38,6
N2	Commercial Van Manual Transmission	IC engine with MT	Pn ≤ 135 KW	77	74	78	132	3500	4081	5630	7200	23,4
N2	Commercial Van Automated Transmission	IC engine with automated MT	P_n ≤ 135 KW	77	74	76	132	3500	4152	5632	7200	23,4
N2	Light Commercial Truck	IC engine with AT	P_n > 135 KW	78	75	76	155	1800	5484	6140	7490	25,2
M3	Highway Coach	IC engine with AT	P_n>250KW	80	77	76	350	1600	16105	16540	24750	21,2
M3	City Coach	IC engine with AT	P_n>250KW	80	77	76	260	1800	11232	11340	19000	22,9
N3	Commercial Truck	IC engine with automated MT	150KW< P_n ≤ 250 KW	81	77	80	175	1800	6900	11210	15000	15,6
N3	Long Distance Truck	IC engine with AT	P_n > 250 KW	82	79	80	309	1800	9790	13821	26000	22,4

Table 2b

M1 test vehicles

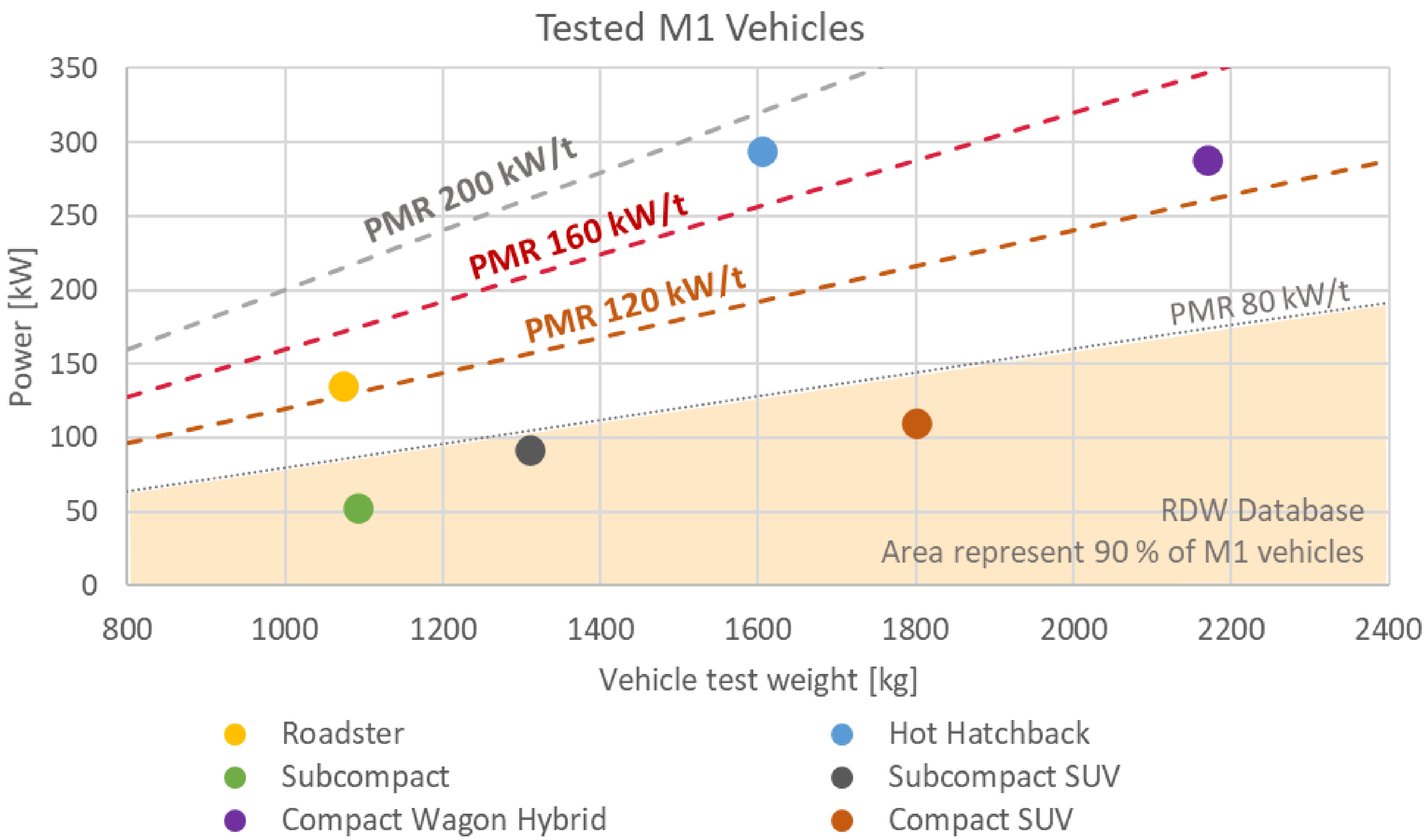


Figure 3

M1, N1 testing procedures

- *The vehicles were tested according to*
  - Annex 3, whose test result has to comply with the corresponding limit value,
  - Annex 7, ASEP (Additional Sound Emission Provision) tests for M1 and N1 with internal combustion engines.

Extended test results and Lroll

- *For detailed knowledge of the rolling vs propulsion sound share, additional tests in different gears at different vehicle speeds were carried out for three M1, one N1, one M2, three N2, two M3 and the two N3 vehicles.*
- *The gears measured include the gear used for UNECE R51.03 tests and lower gears. Each dot in the figures is related to the vehicle speed at point PP' (v_{pp}') and by the maximum sound pressure level during the pass by (L_{max}).*
- *The results for M1 are shown in Figure 4 to Figure 7.*

M1 extended test results

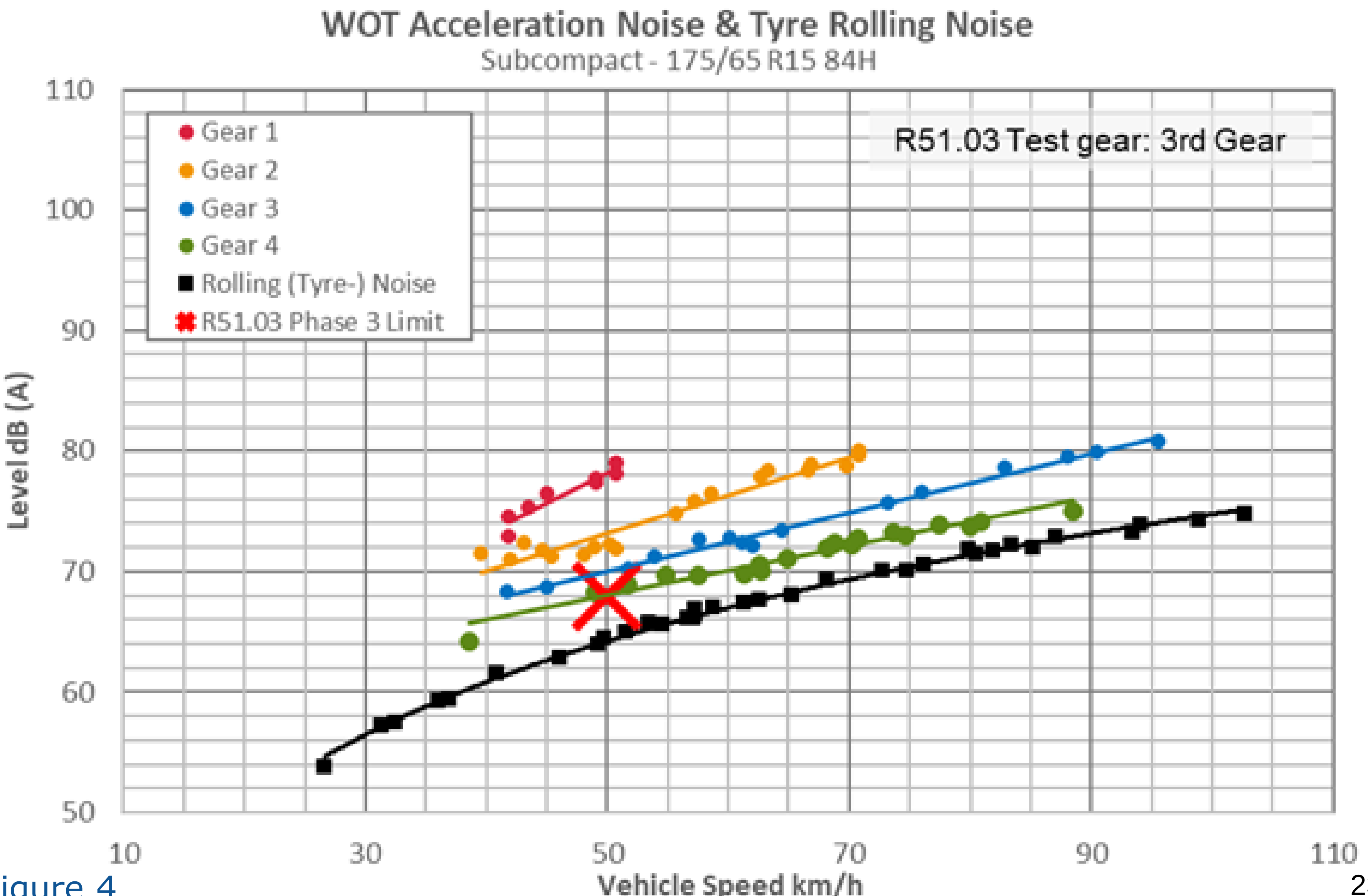


Figure 4

M1 extended test results

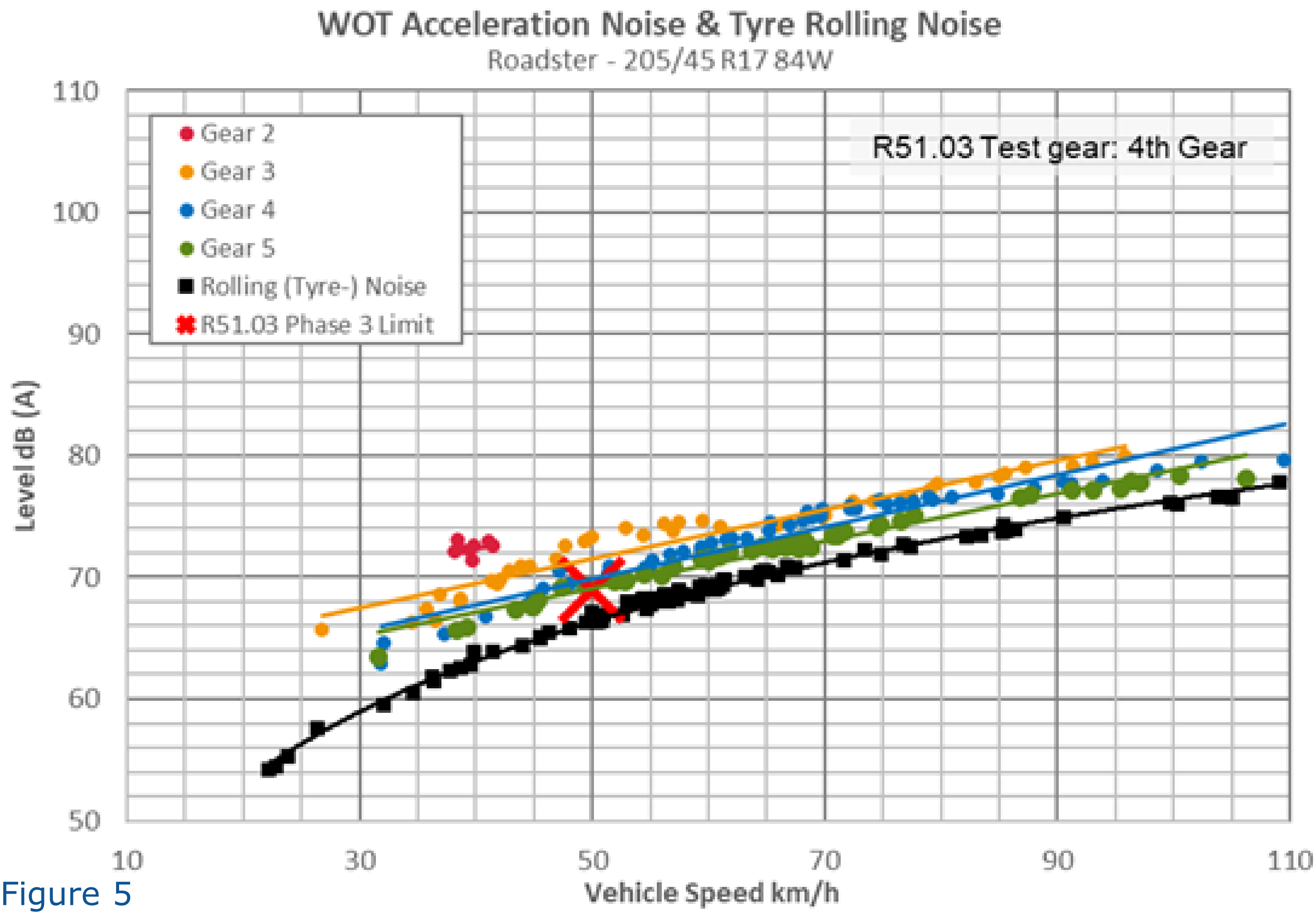


Figure 5

M1 extended test results

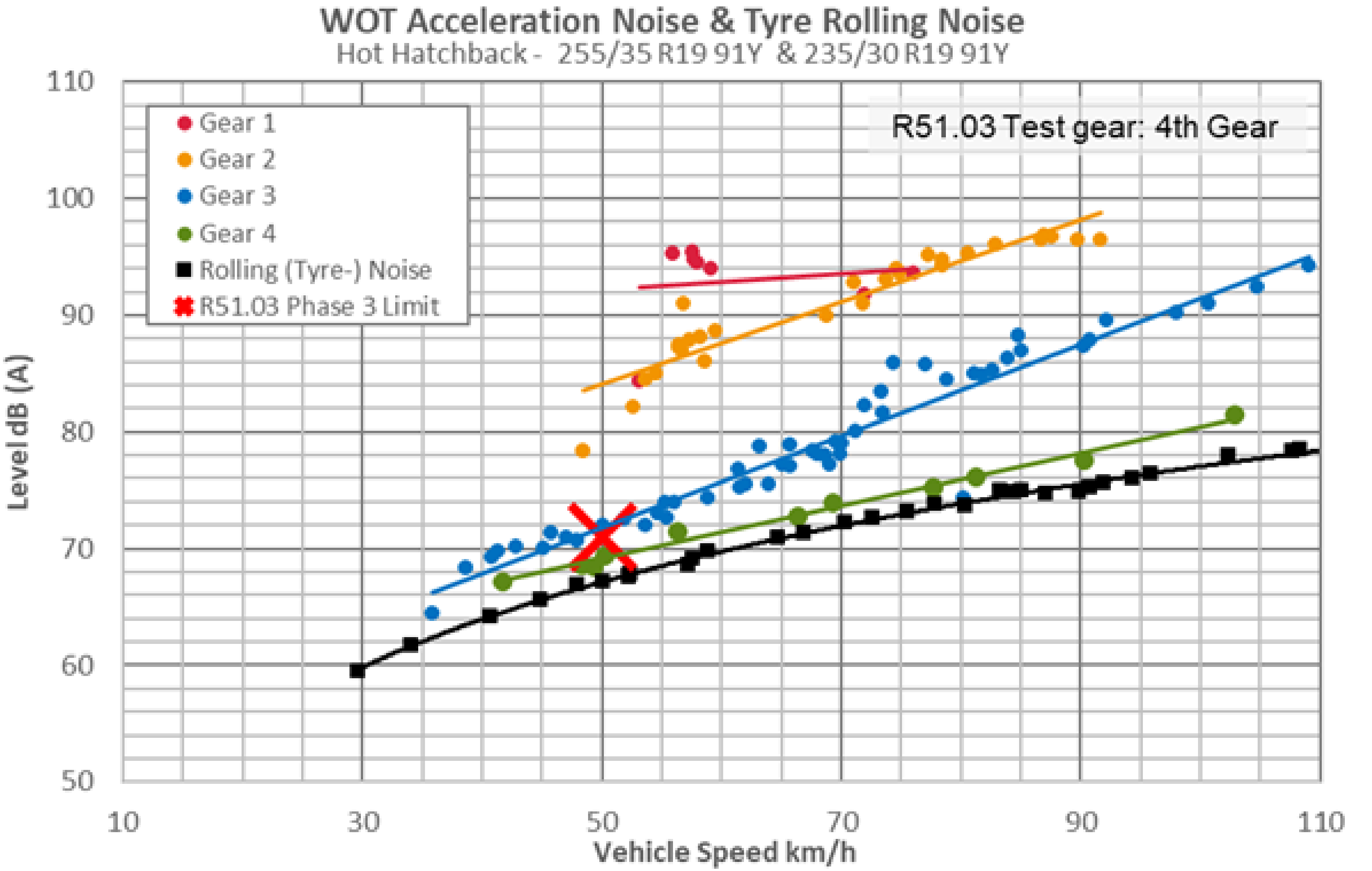
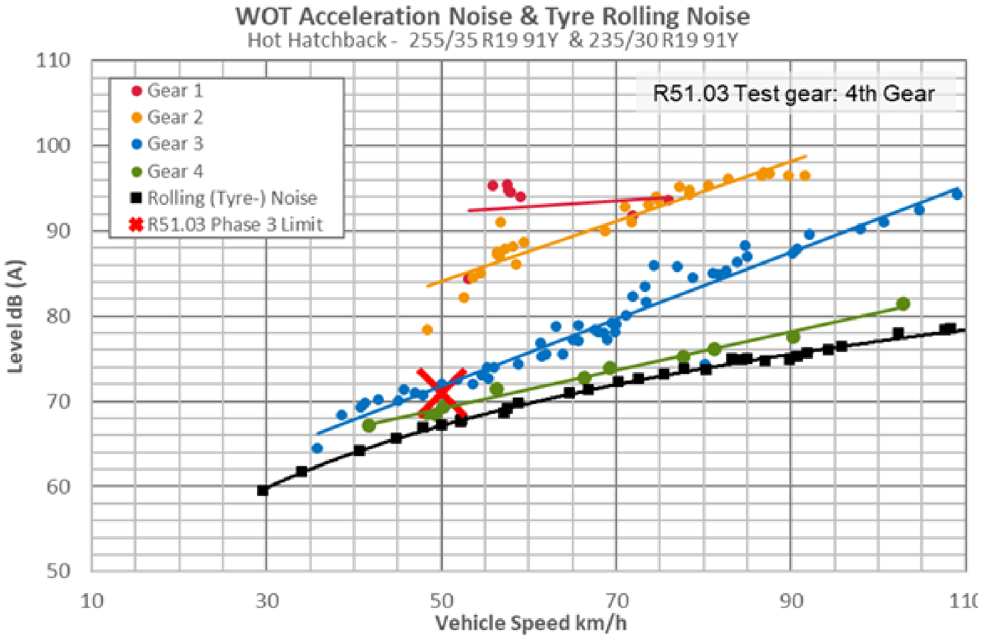


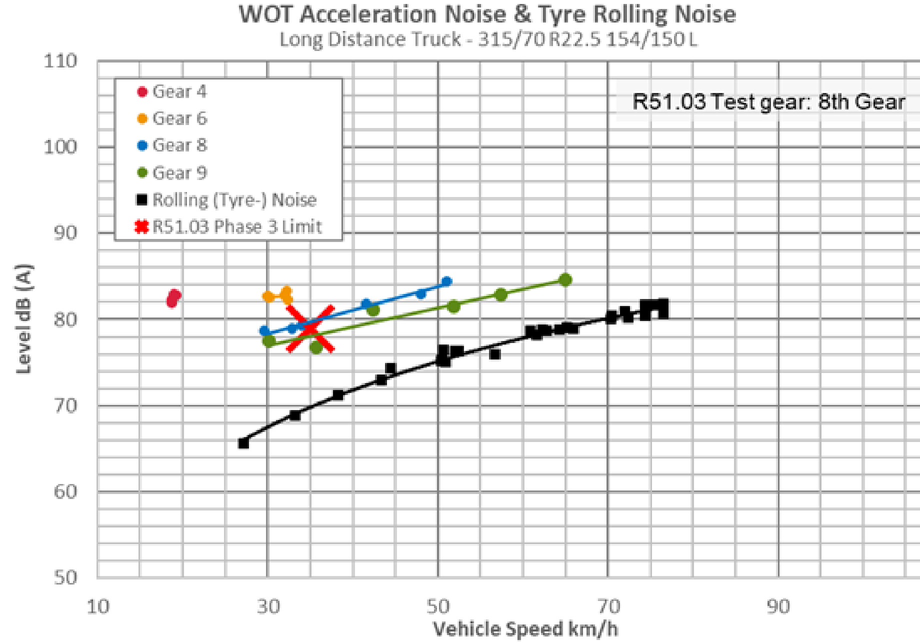
Figure 6

M1 extended test results

M1, pmr > 160



N3, Pn = 309 kW



M1, subcompact

Figure 7

Results M2, M3, N1, N2 and N3

- *The results of the extended tests for the other vehicle categories are shown in Figure 8 to Figure 15.*

N1 extended test results

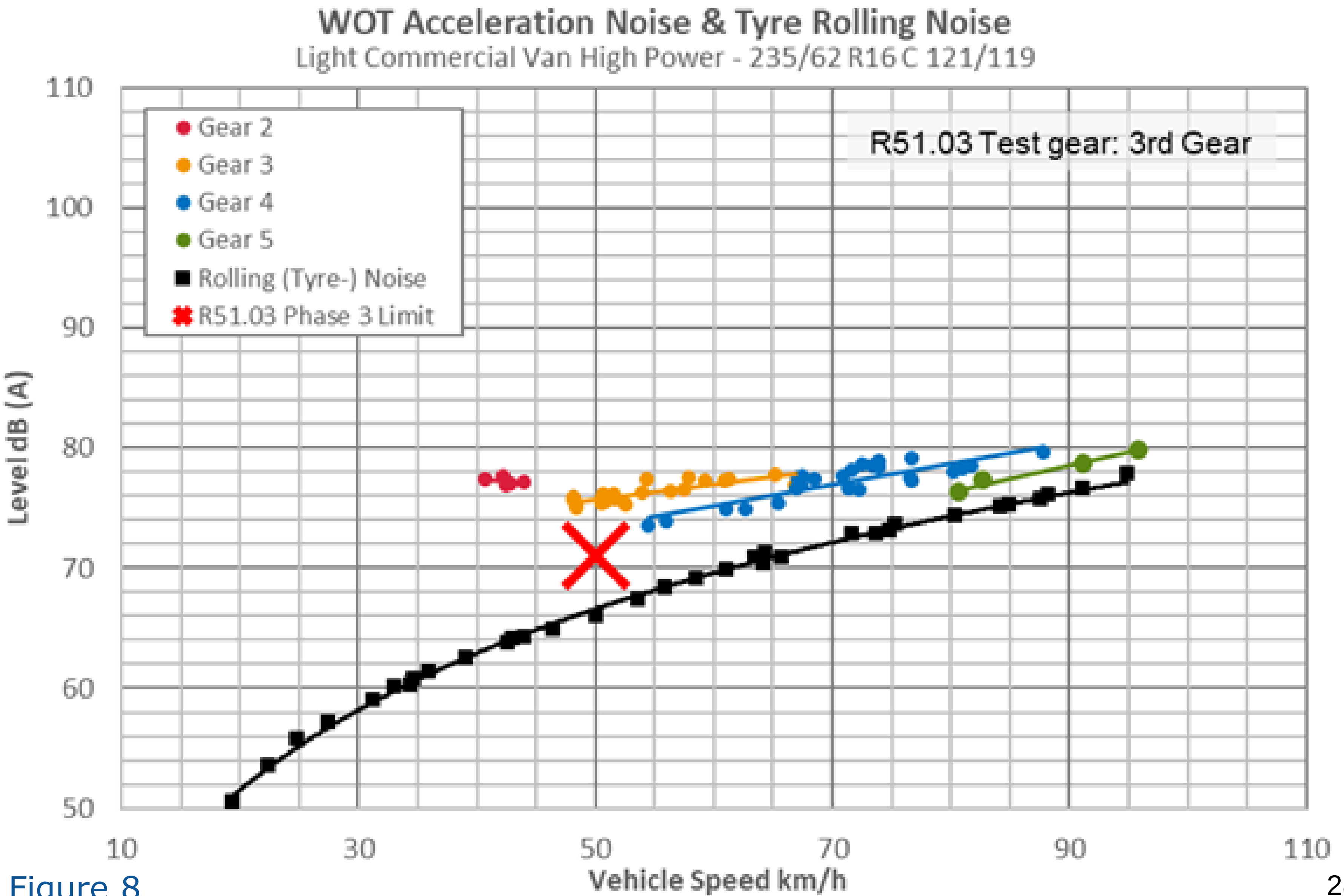


Figure 8

M2 extended test results

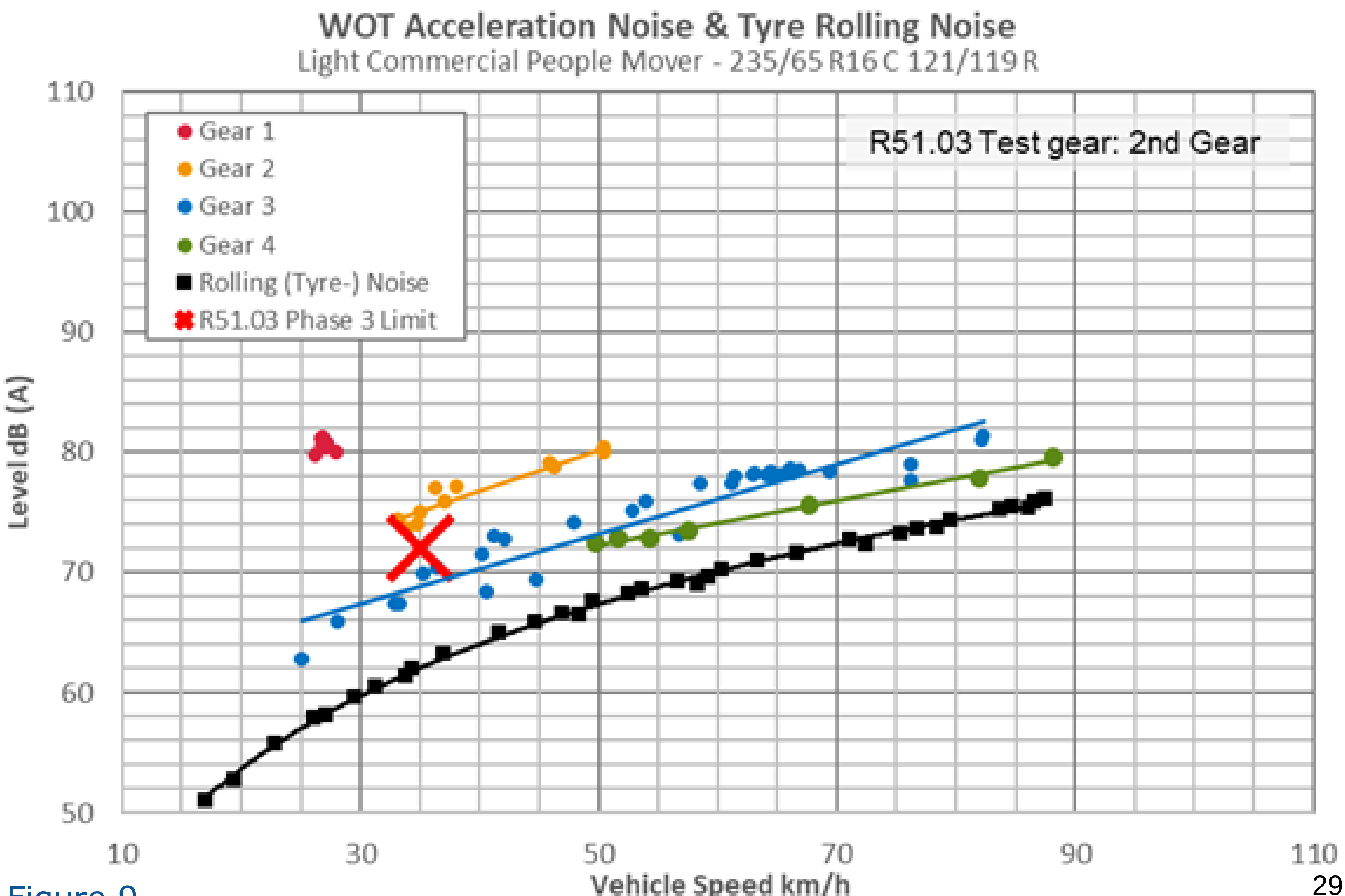


Figure 9

N2 extended test results

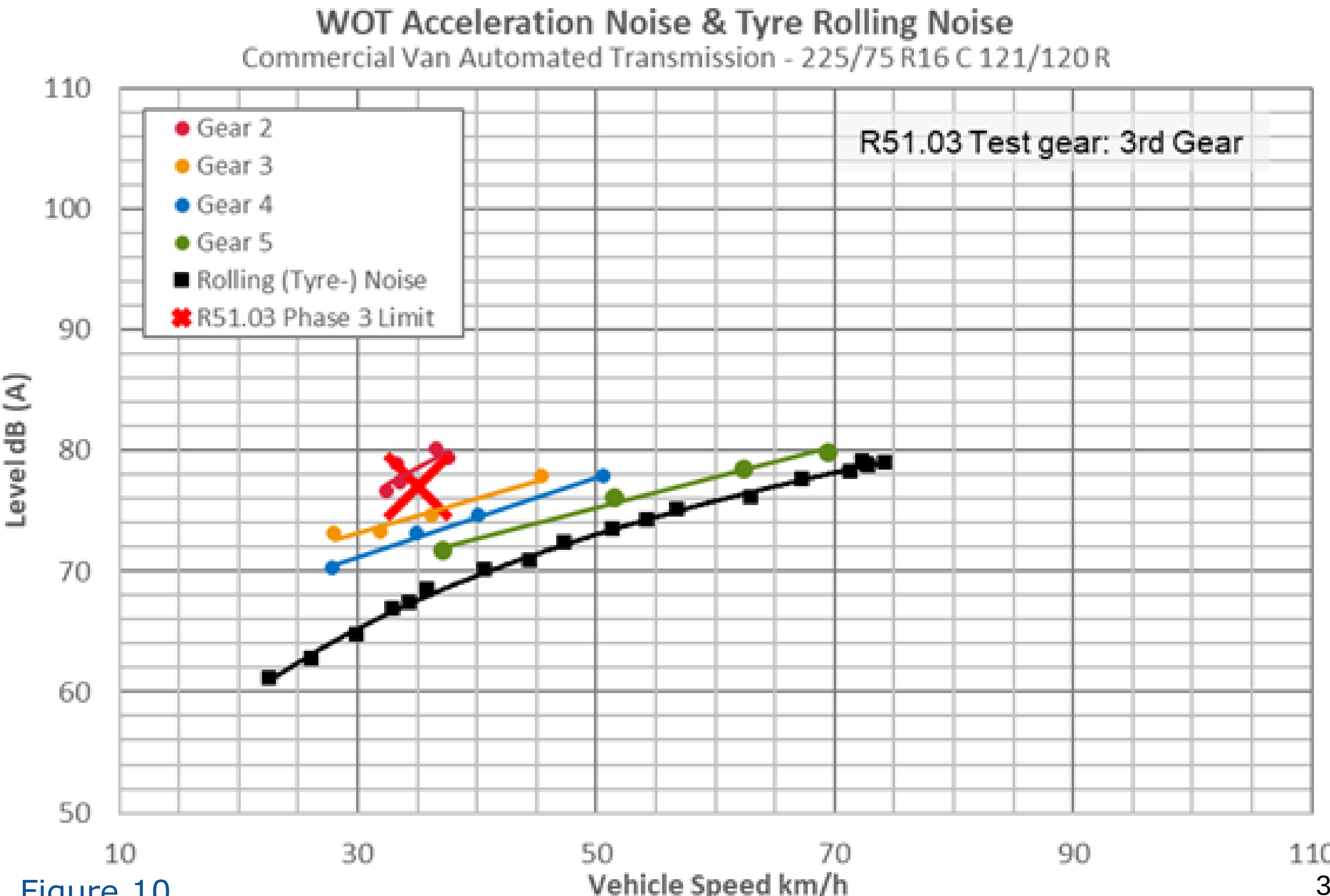


Figure 10

N2 extended test results

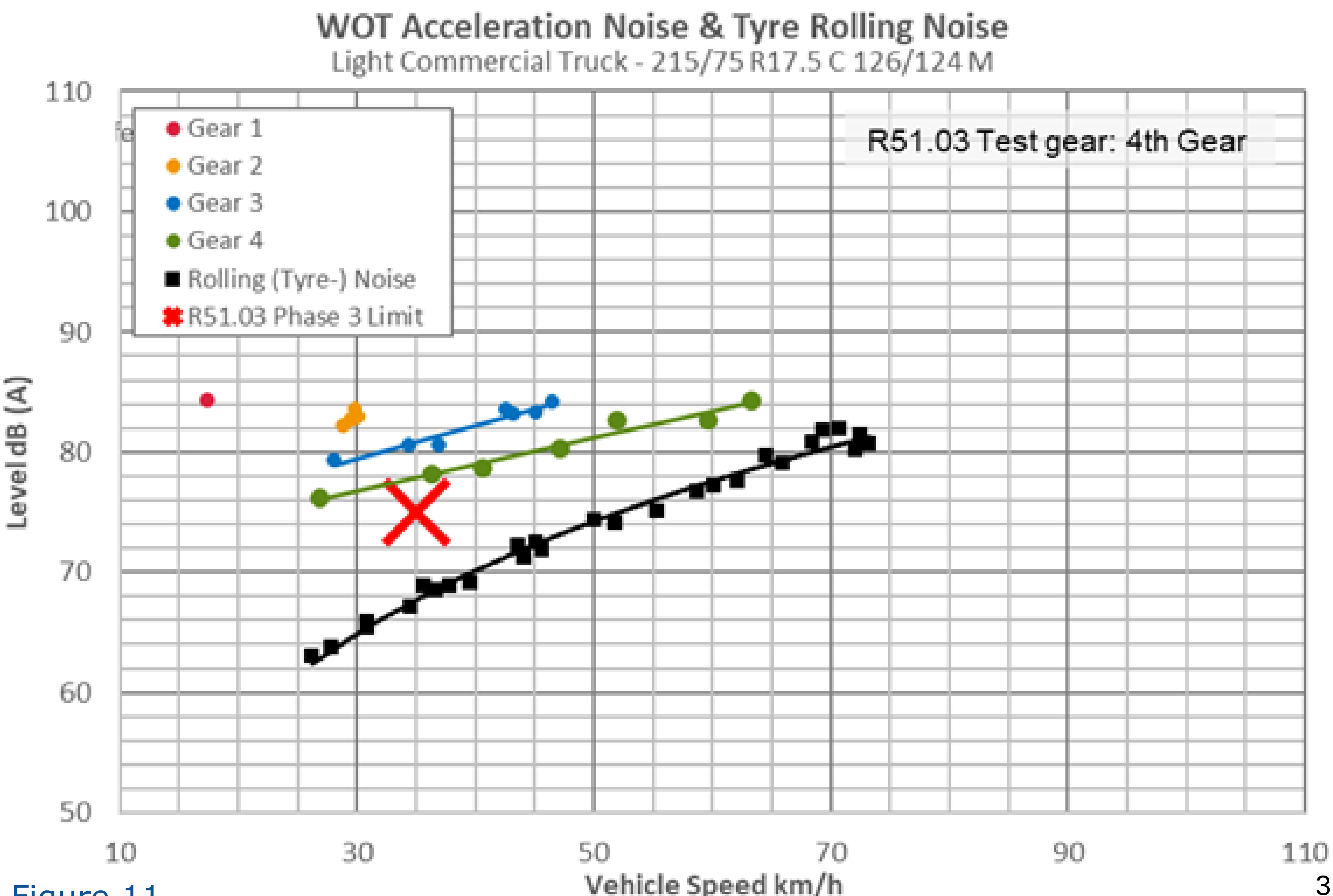


Figure 11

M3 extended test results

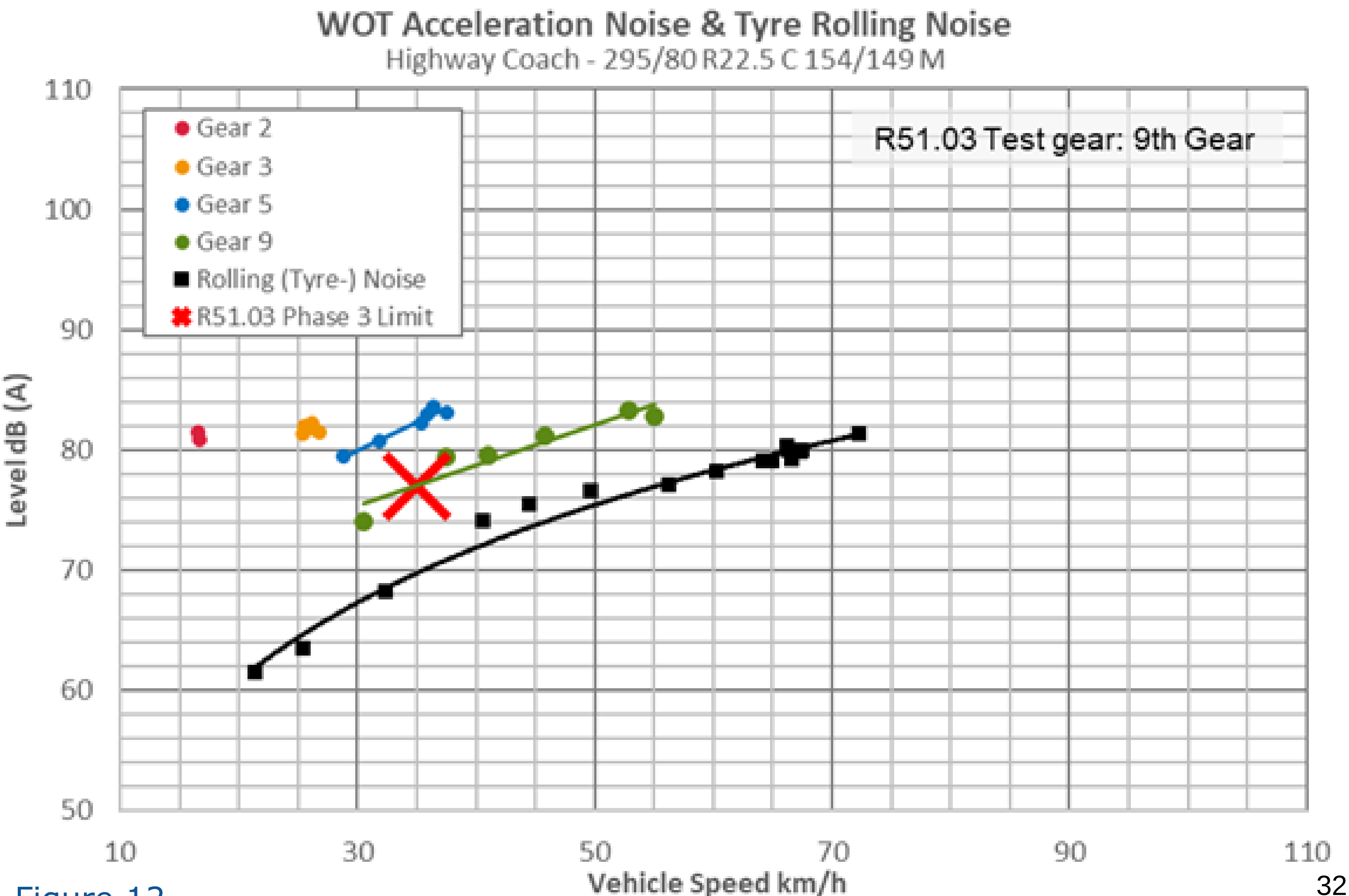


Figure 12

M3 extended test results

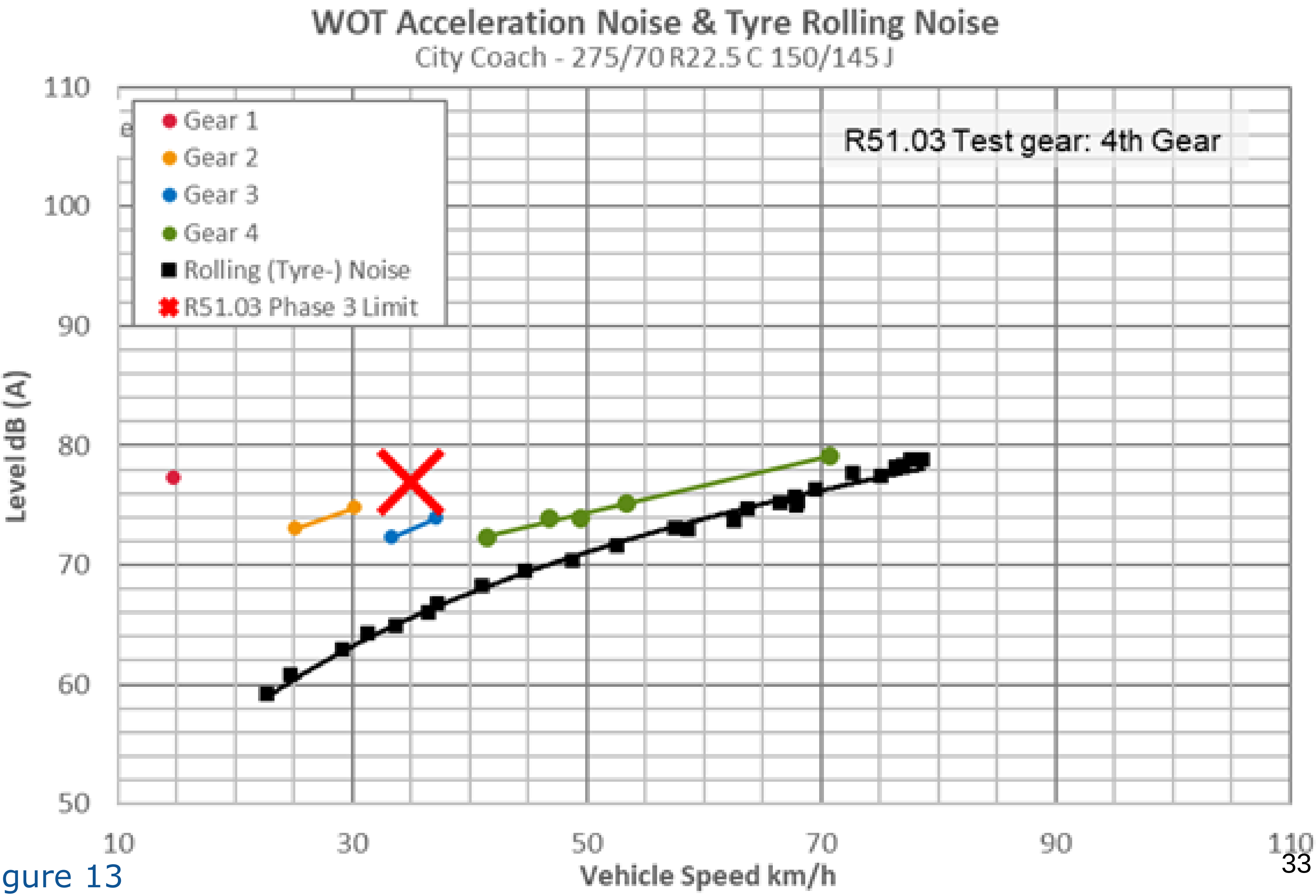


Figure 13

N3 extended test results

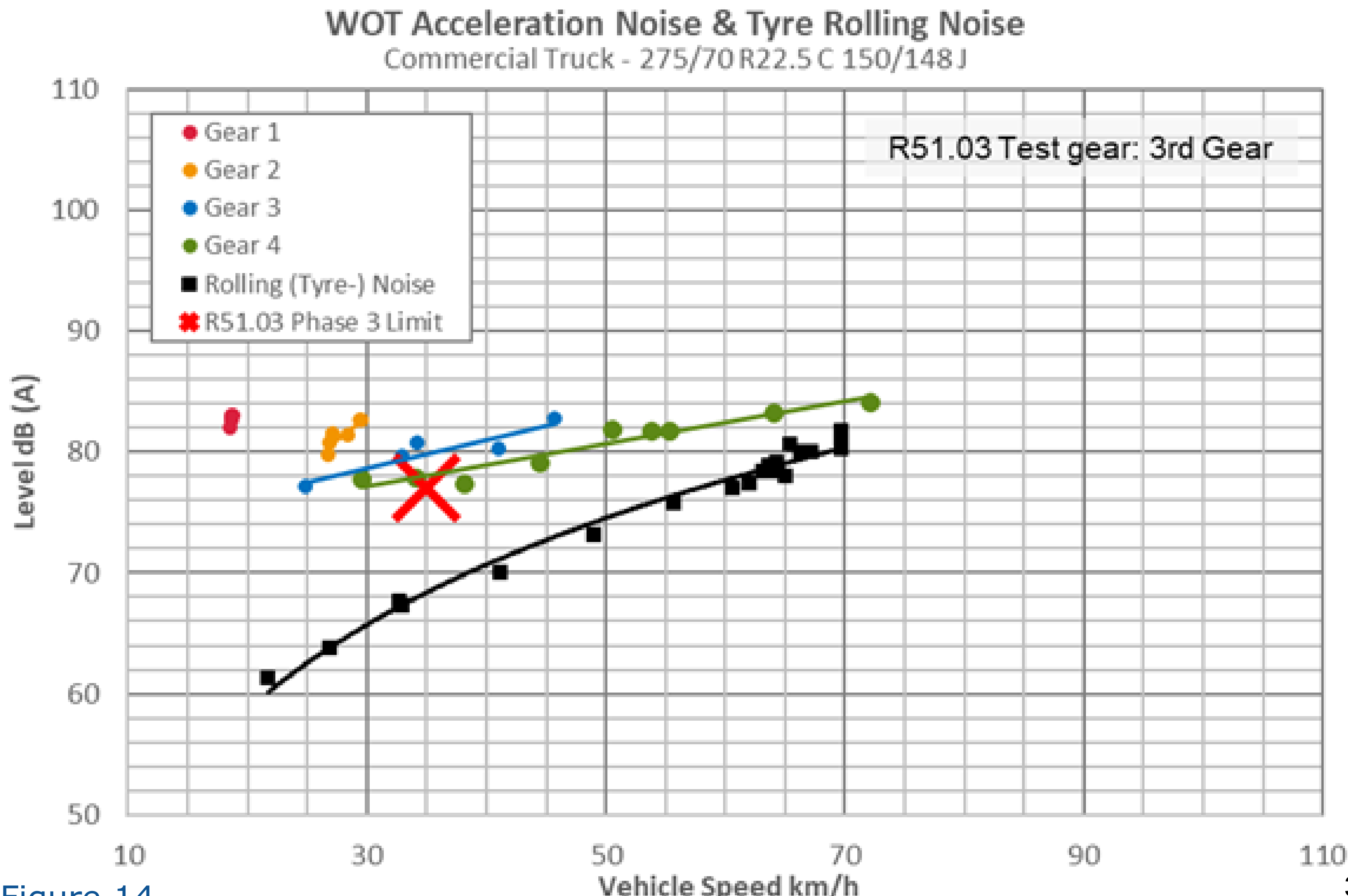


Figure 14

N3 extended test results

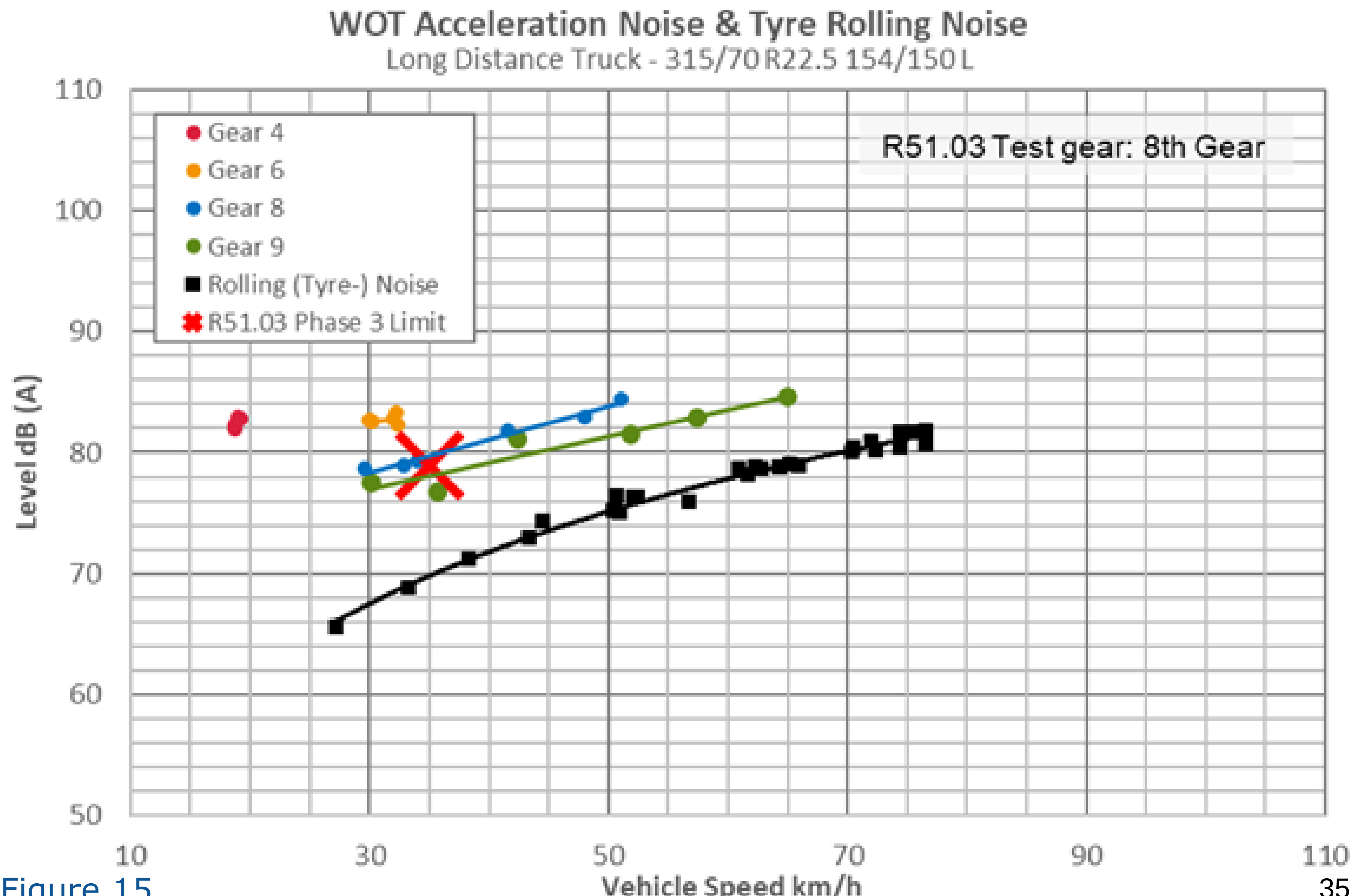


Figure 15

Results for use of different tyres

- *In an additional task some of the test vehicles were measured with different tyres equipped.*
- ***The biggest differences in L_{roll} were found for the N3 vehicle (long distance truck, 4 dB(A)).***
- *For the other vehicles the differences vary between 0.2 and 1.4 dB(A).*

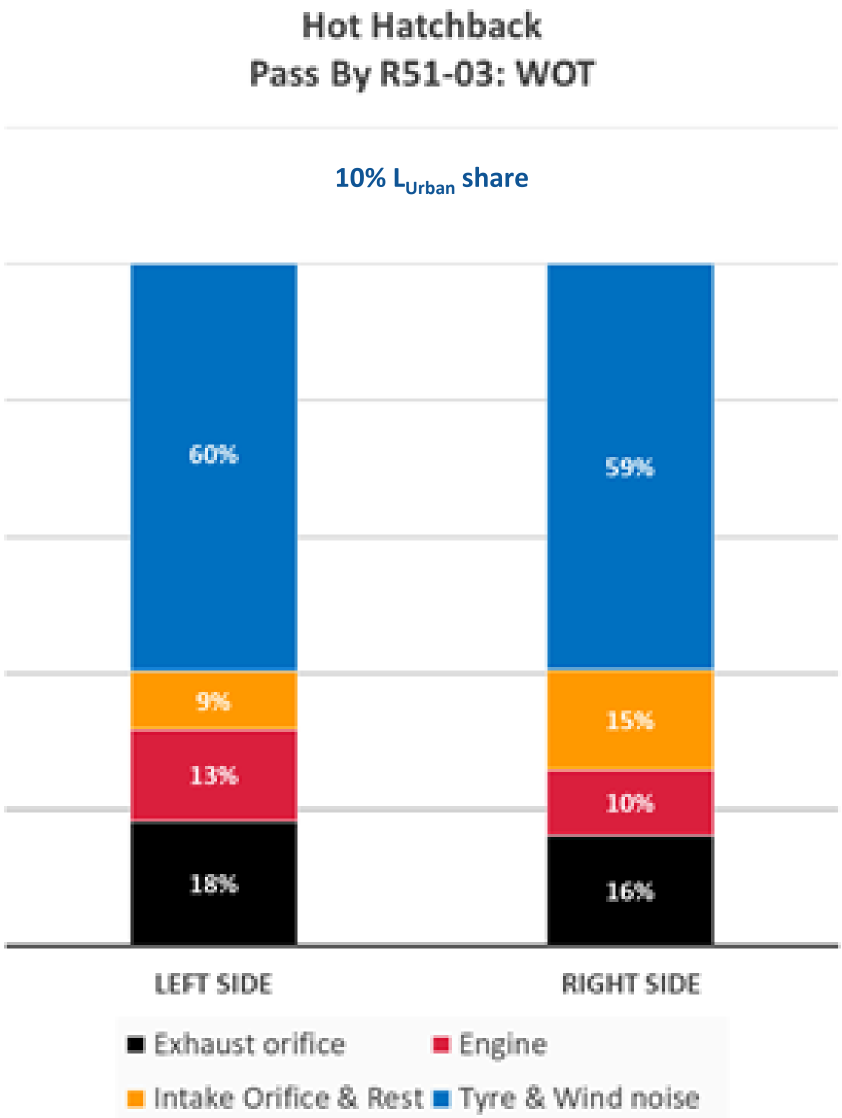
Noise source ranking

- *To analyse the different contributions to the pass by noise, a detailed step by step cancelling of main noise sources was performed for some test vehicles and the pass-by sound results were used to calculate the contributions of different sources.*
- *The following vehicles were chosen:*
  - M1 – Hot Hatchback | PMR > 160 W/kg
  - M1 – Compact Wagon Hybrid | 120 W/kg < PMR > 160 W/kg
  - M1 – Compact SUV | PMR < 120 W/kg
  - N1 – Light Commercial Van High Power
  - N2 – Commercial Van Automated Transmission
  - N3 – Long Distance Truck

Noise source ranking

- *The main noise sources that were separated by the calculations are:*
  - Exhaust – Treated with total muffler and if applicable muffler encapsulation
  - Engine – Treated with engine encapsulation
  - If Applicable Transmission / Differential – Treated with sound deadening lead mats
- *The remaining noise share is mainly generated by the tyre rolling noise, the wind noise and the remaining parts from the treated vehicle systems.*
- *The results are shown in Figure 16 to Figure 21.*

Noise source ranking



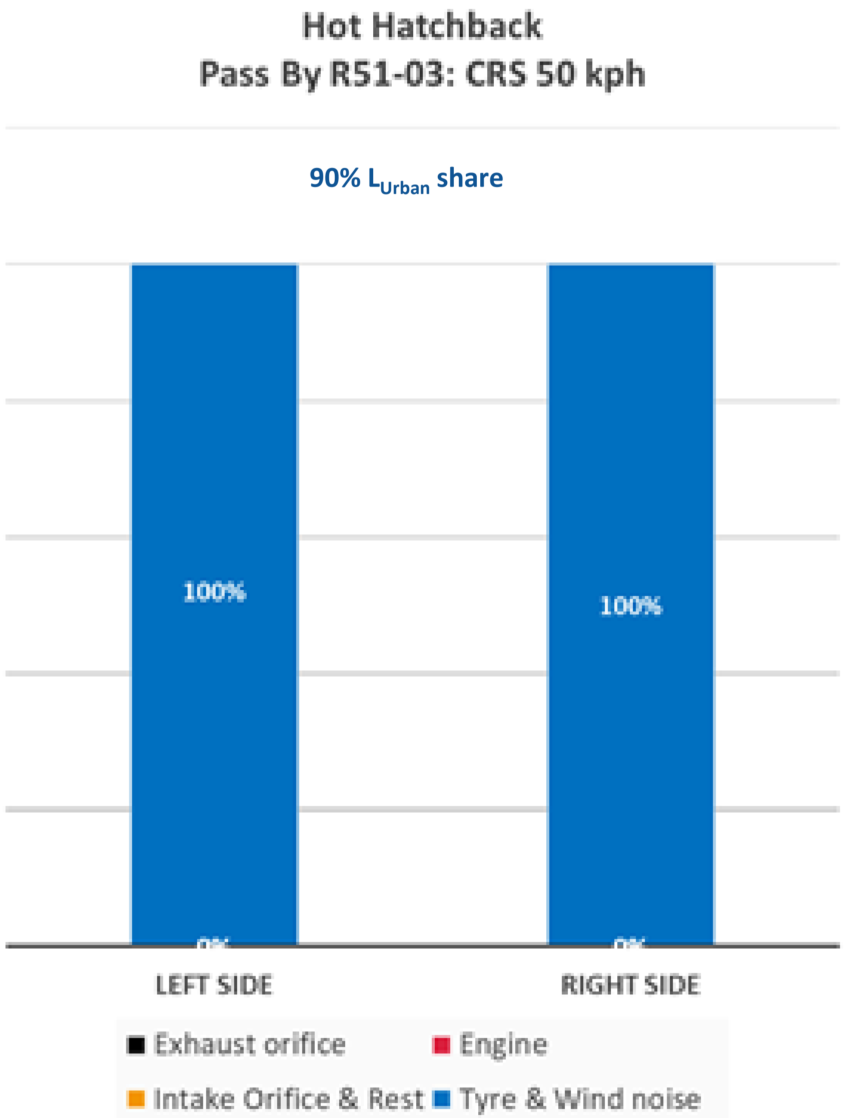


Figure 16 Conclusion: L_{urban} is 95% L_{roll}, not in line with practical use.

Noise source ranking

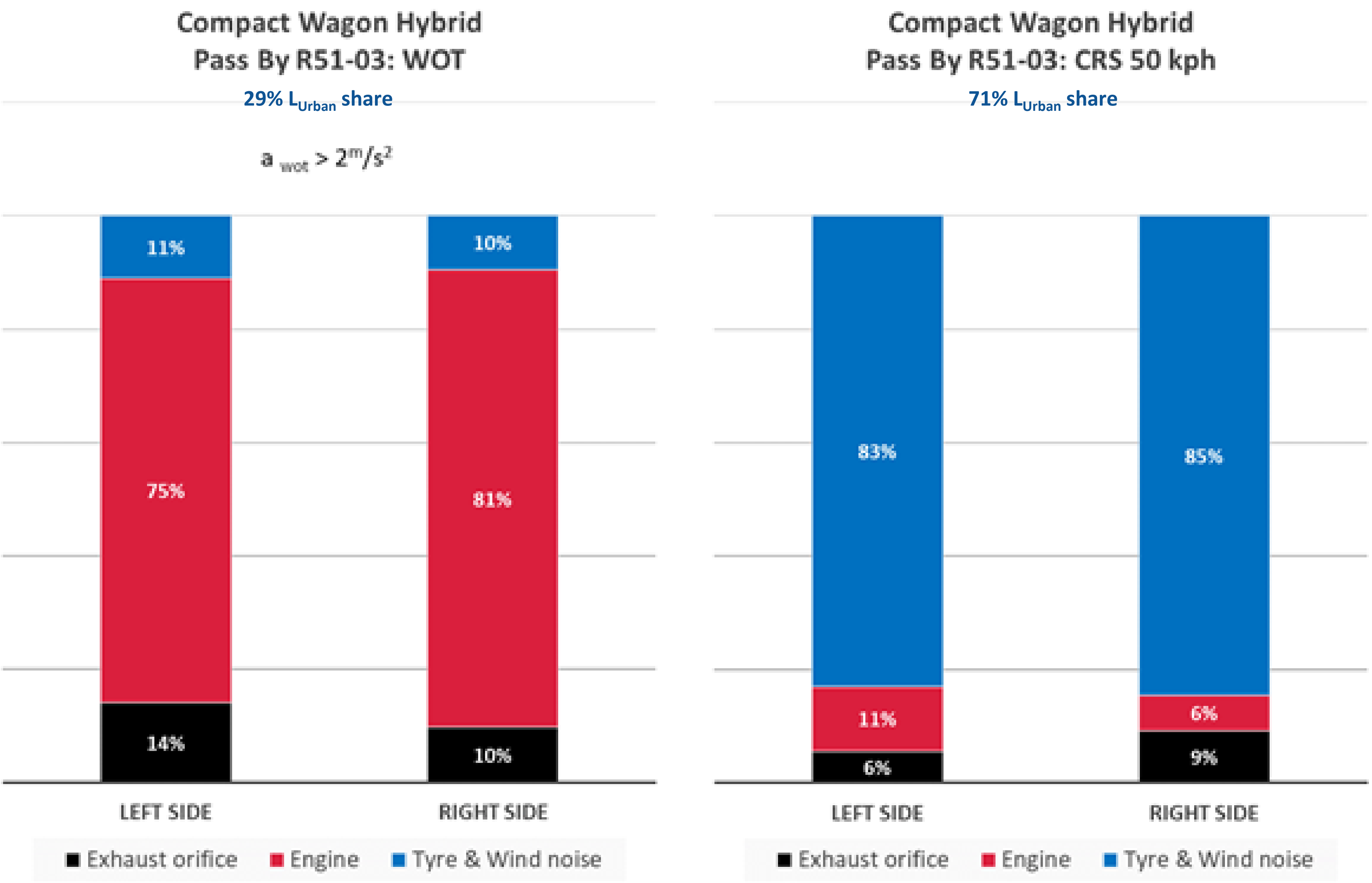


Figure 17

Noise source ranking

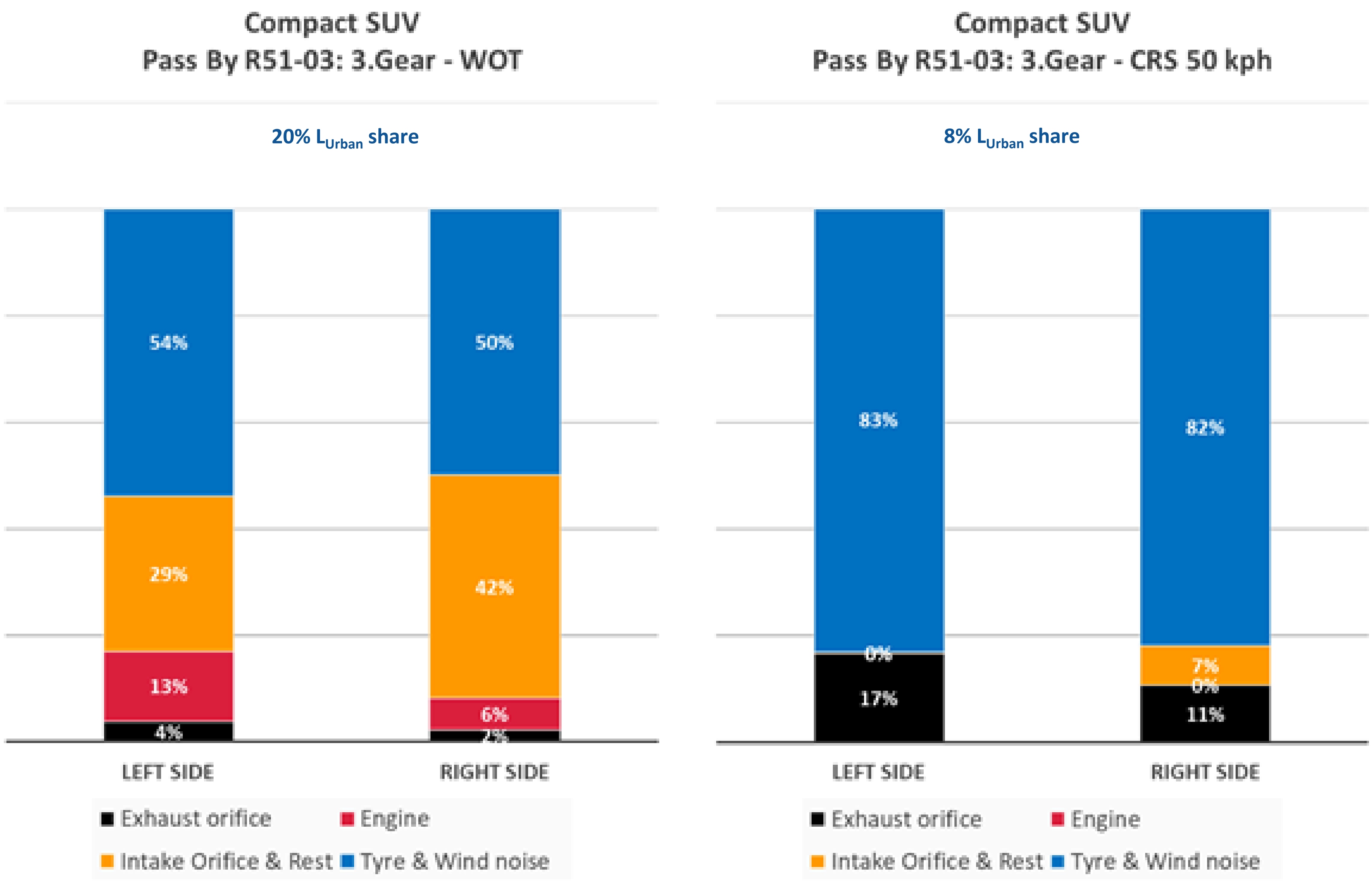
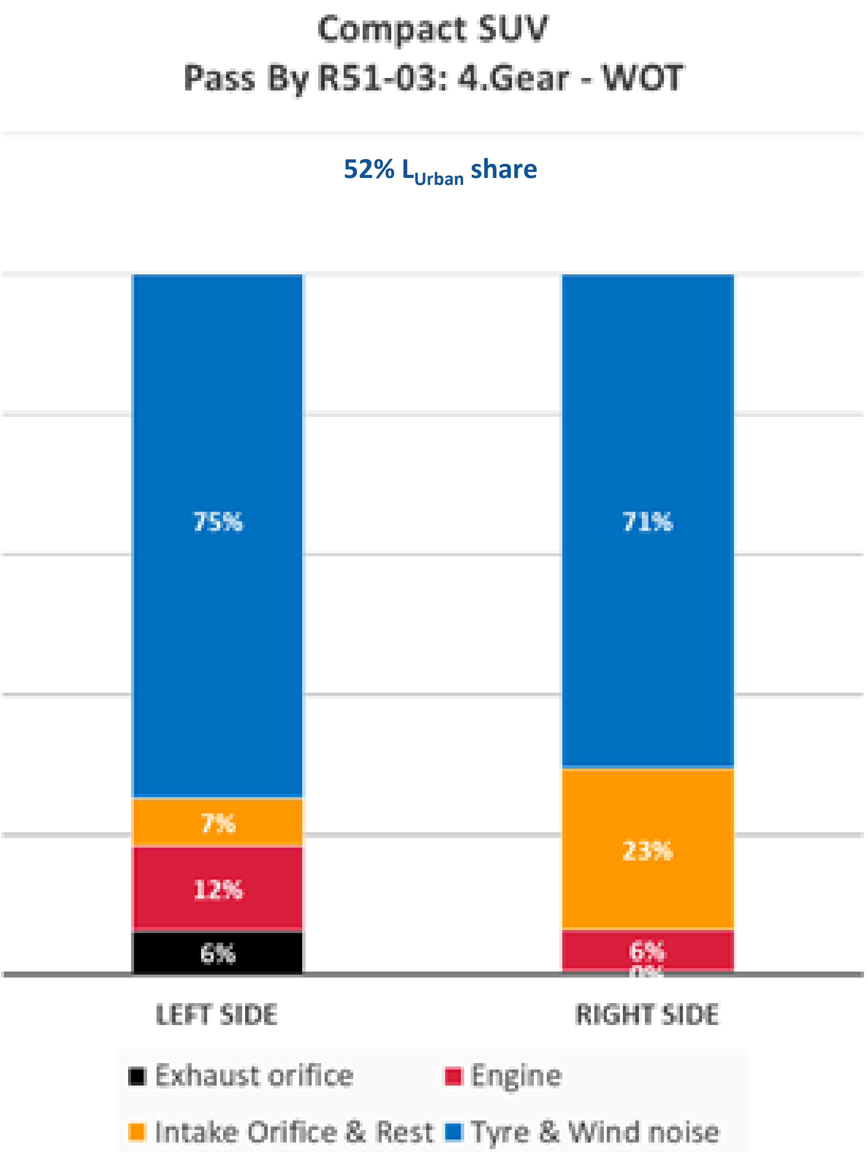


Figure 18a

Noise source ranking



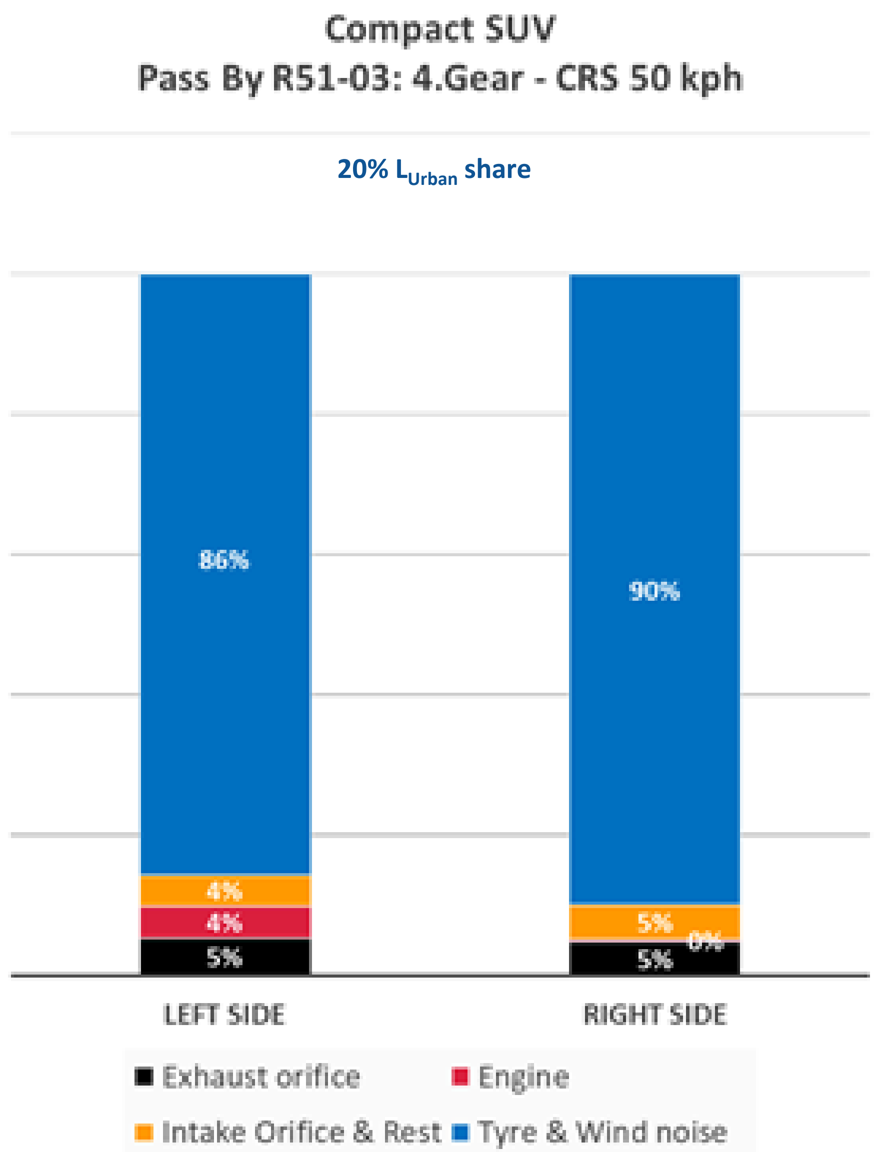


Figure 18b

Conclusion: L_{urban} is dominated by L_{roll}.

Noise source ranking

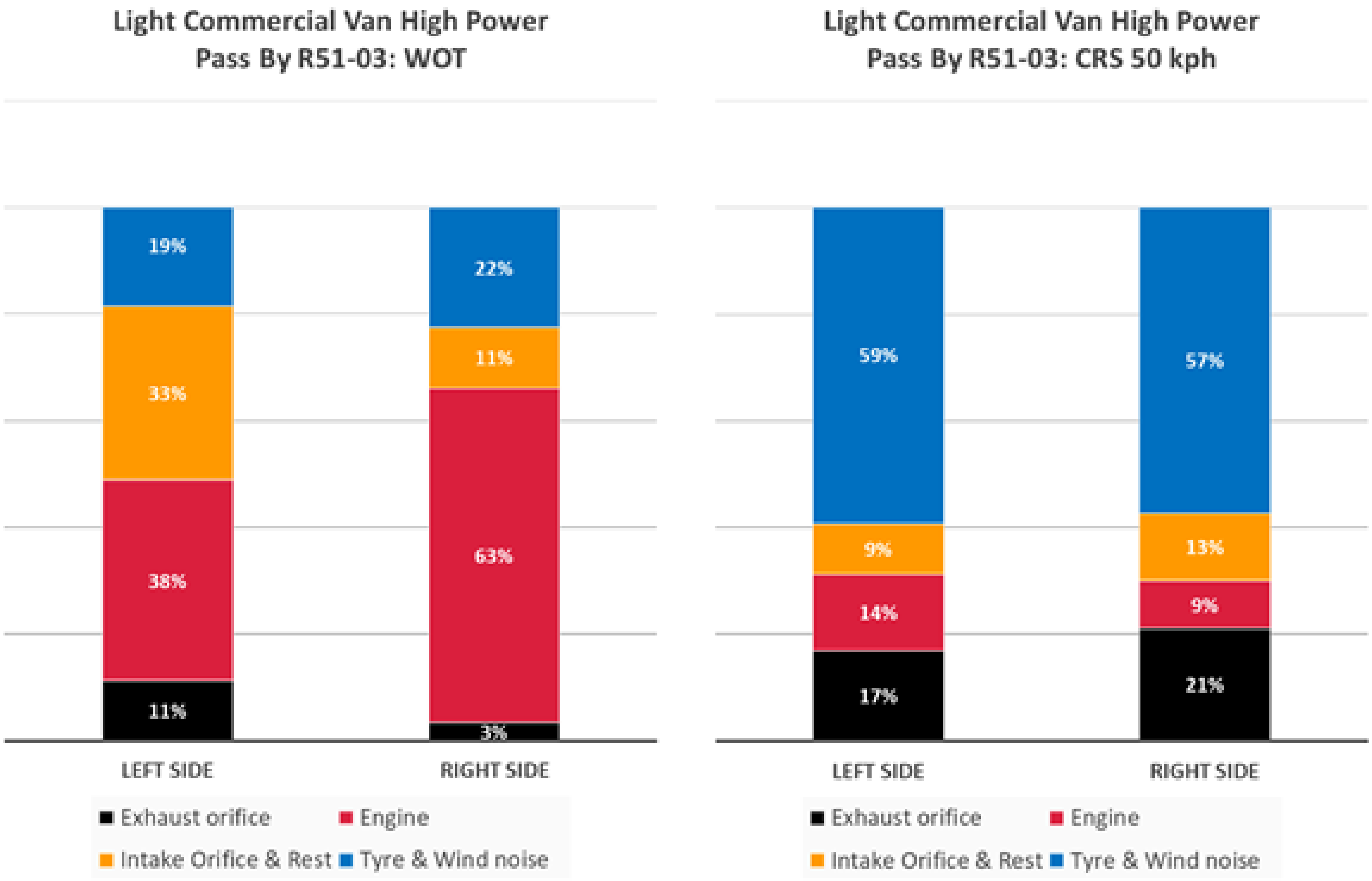


Figure 19

Noise source ranking

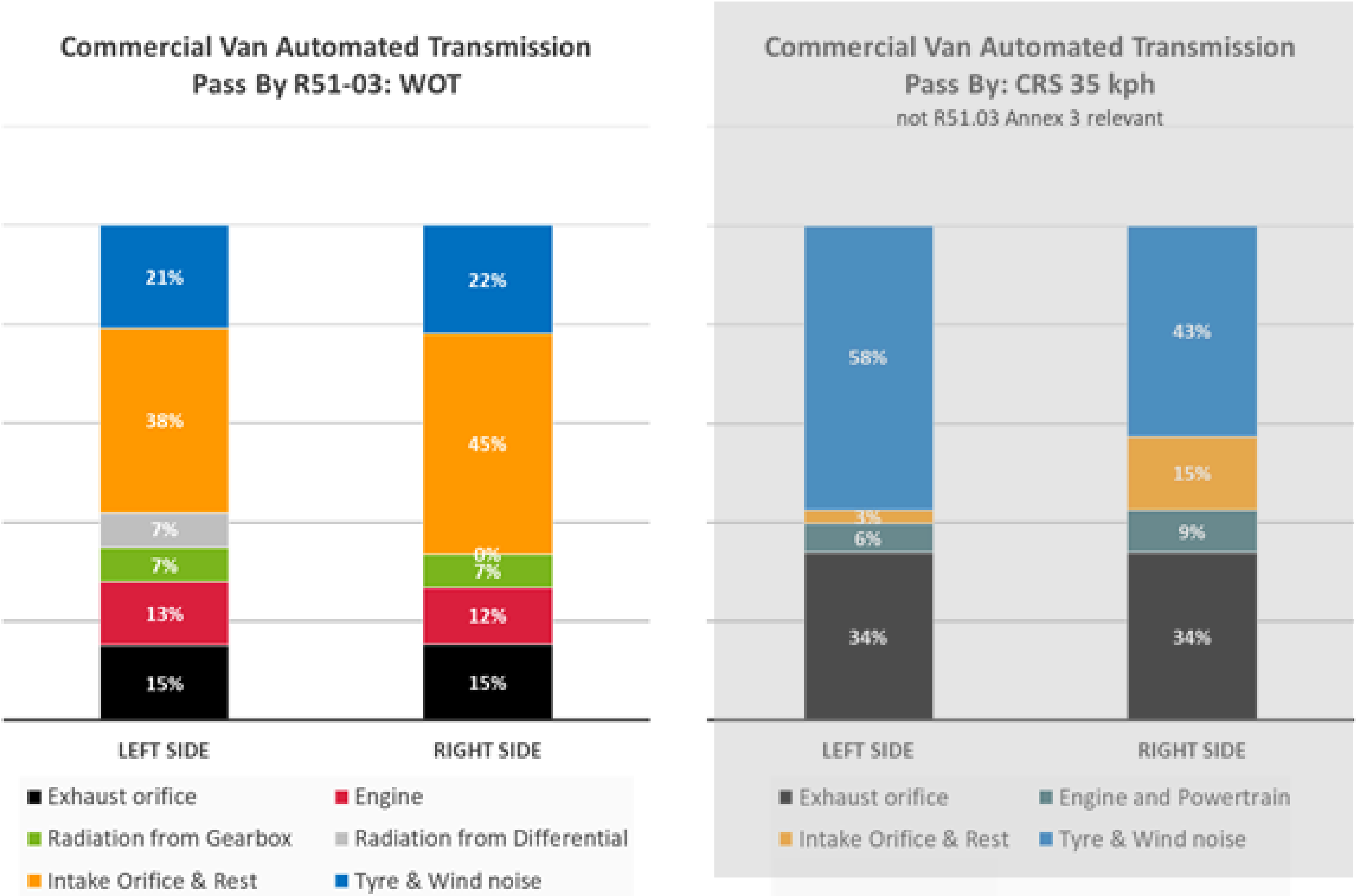
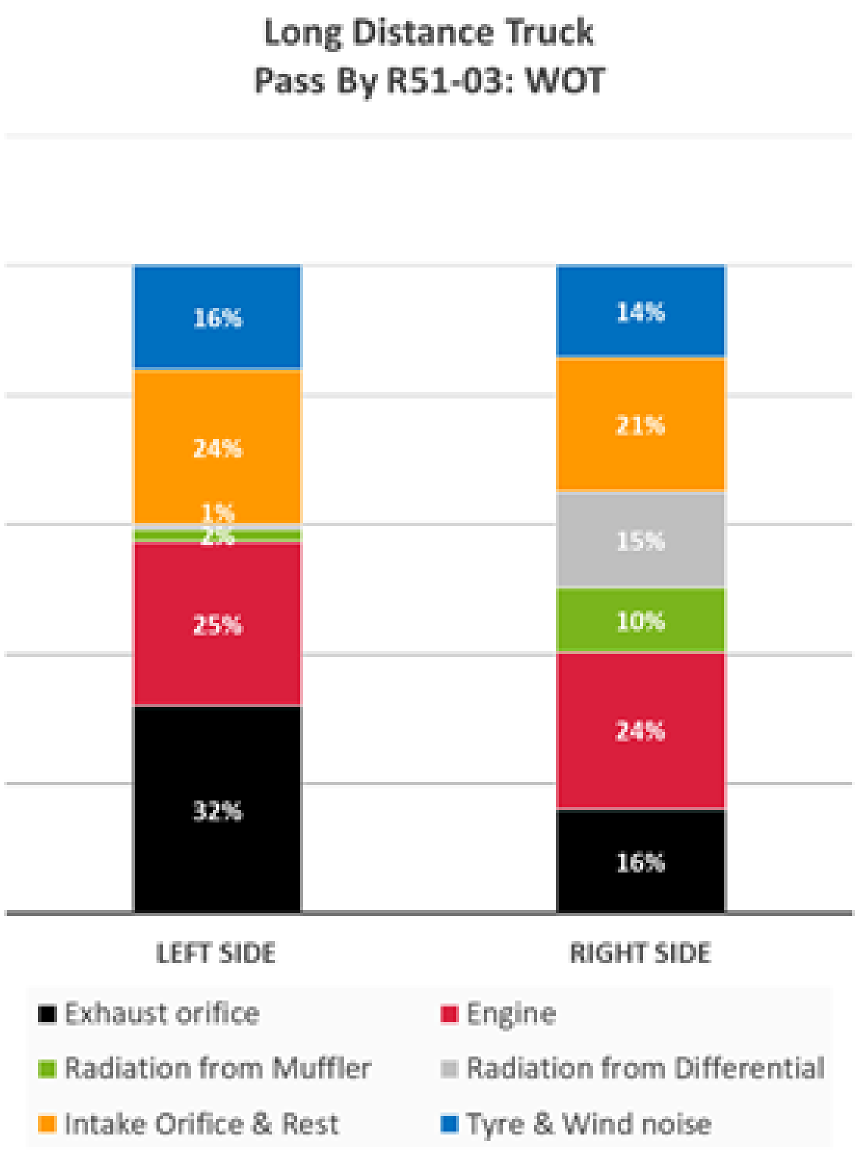


Figure 20

Noise source ranking



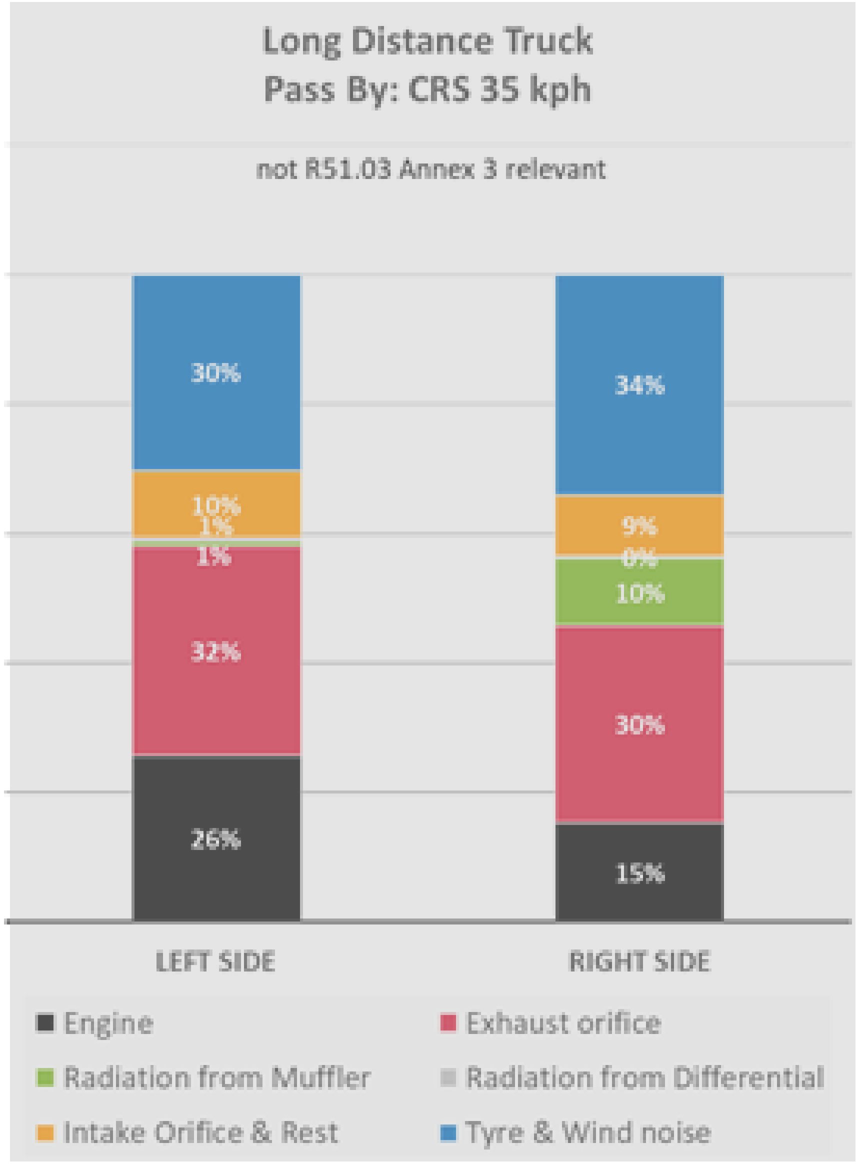


Figure 21

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Cost benefit analysis

Context

- *This study was conducted in parallel with the Phenomena study (2021) for the EU DG Environment, in which vehicle sound limits were also covered from a broader perspective. This was done together with other infrastructural, traffic management and urban planning measures.*
- *Also, two methods for assessment of health benefits were applied, in a different approach to previous studies such as Venoliva (2011) and others, following recent EU Guidelines (2019).*
- *In this study the same approach is taken, but with more detailed scenarios for vehicle sound limits.*
- ***The appraisal period in this study is 2020-2045**, whereas in the Phenomena study a shorter period up to 2035 was evaluated, so as to identify best options for the shorter term.*

Cost benefit analysis

Methodology – health benefits

- *The methodology for health impacts is based on the DPSEEA approach for environmental health impact assessment, recommended by WHO.*
- *DPSEEA stands for Driving forces – Pressures – State – Exposure – Effects – Actions*
- *The DPSEEA causal chain for road traffic noise is illustrated further in Figure 22.*
- ***Traffic parameters are the starting point, followed by the sound emission of the vehicles on the roads. The environmental noise levels are then calculated, which are used in noise mapping, followed by the distribution of numbers of people exposed to different bands of noise levels.***

The DPSEEA approach

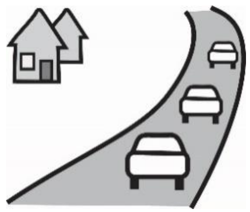
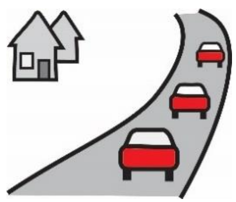
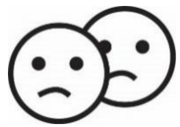
Traffic		- road network - traffic volumes - driving speeds - vehicle types
emission		sound emission of vehicles - propulsion noise (engine) - rolling noise (tyres and road)
Levels		sound propagation (noise map calculation) - buildings - noise barriers
exposure		numbers of people exposed to noise levels
effects		annoyance, sleep disturbance, myocardial infarctic healthy life years lost monetised health effects in euros

Figure 22

Cost benefit analysis

Methodology – health benefits

- *Finally, the health effects are calculated from the exposure distribution, expressed in three ways:*
  - Numbers of people with the following negative health effects:
    - annoyance
    - sleep disturbance
    - myocardial infarction
  - Healthy life years lost (DALYs, Disability-Adjusted Life Years)
  - Monetised health effects in euros
- *A single calculation model for the noise levels (façade levels) in the whole EU does not exist.* ***However, noise maps and noise exposure distributions of EU Member States can be used, collected by the EEA in the framework of END noise mapping.***

Cost benefit analysis

Methodology – END exposure distributions from 2017

- *The END exposure distributions represent the year 2017. These are used as a starting point for extrapolation to the appraisal period 2020-2045 for this study.*
- *Noise level changes are calculated for the period 2017-2045 and are applied to the 2017 exposure distributions. This is illustrated by the following examples for road traffic:*
  - For the baseline scenario, the noise levels gradually change due to various effects:
    - Autonomous traffic growth (typically 1% per year for road traffic),
    - Gradual change of vehicle fleet with increasing numbers of hybrid and electric vehicles.
  - For an alternative scenario, additional noise level reductions may be achieved by measures such as:
    - quieter powertrains, including electric vehicles,
    - quieter tyres.

Cost benefit analysis

Methodology – baseline vs alternative scenario

- *The health effects are calculated for the two scenarios from the exposure distributions. Finally, the difference between the effects for the two scenarios is equal to the health benefit for the noise solution.*

Methodology – health benefits, exposure distributions

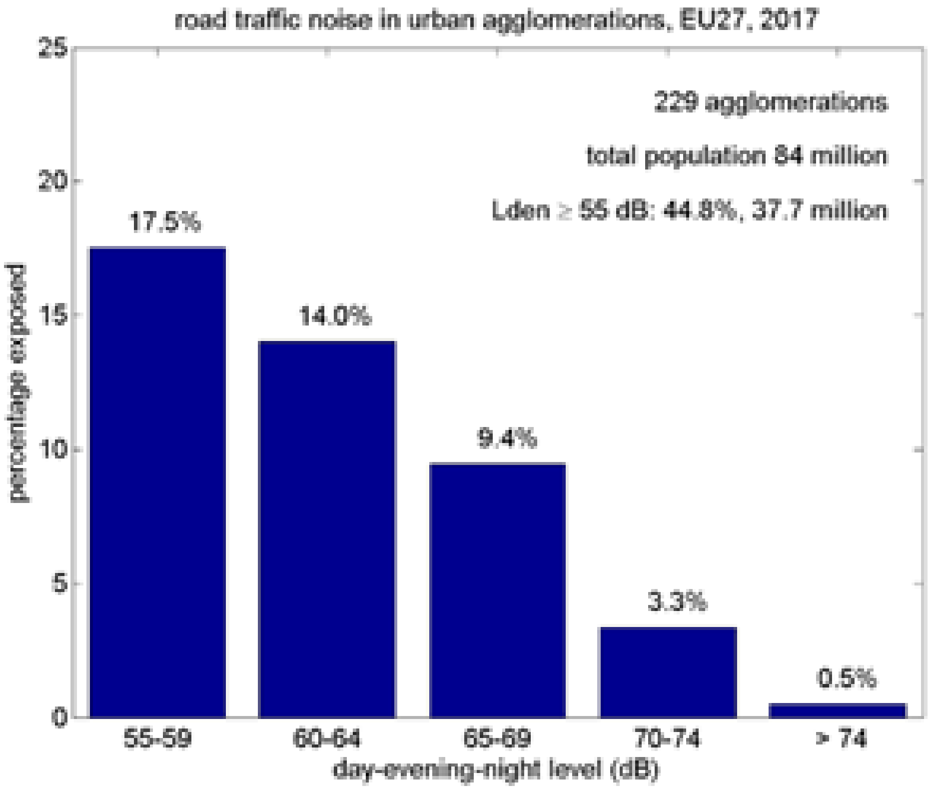
- *The façade level is also used in exposure-response relations:*
  - The day-evening-night level L_{den} for annoyance,
  - the night level L_{night} for sleep disturbance.
- *Therefore, the END prescribes that exposure distributions must be calculated both for L_{den} and for L_{night}.*
- *The values of L_{den} and L_{night} are given in 5 dB intervals.*

Methodology – aver. exposure distributions for agglomerations

- *Figure 23a shows EU average exposure distributions for road traffic noise in urban agglomerations, derived from the END data for 2017. The END data is not complete, as data from many agglomerations was not reported.*

EU average exposure distributions for road traffic noise in agglomerations, based on the END data for 2017.

Note: 3 agglomerations did not provide night data.



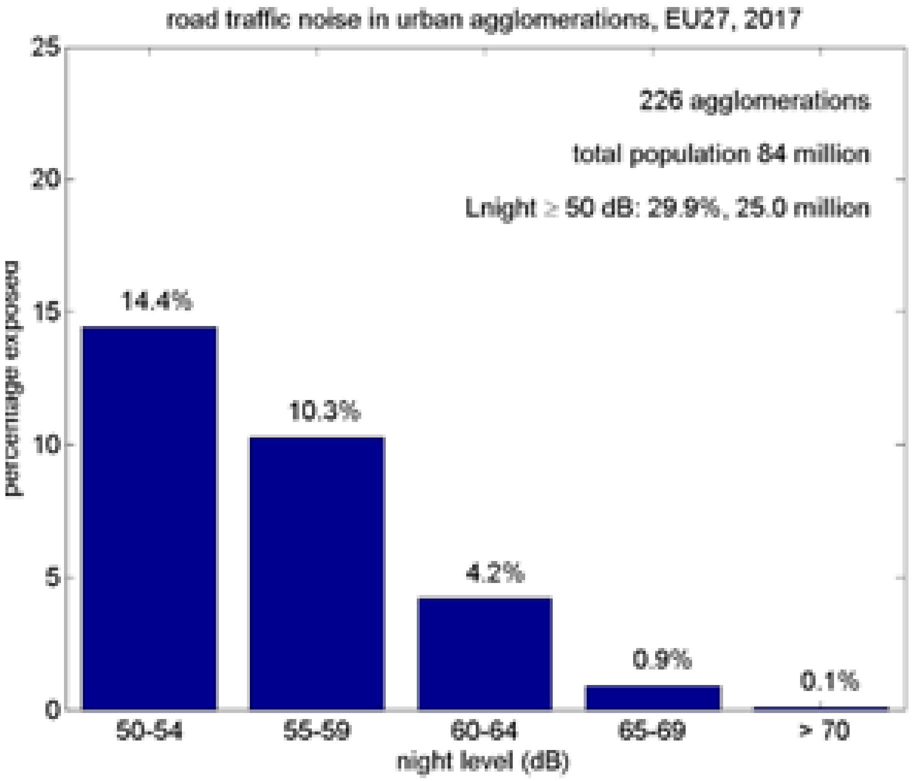


Figure 23a

Cost benefit analysis

Methodology – average exposure distributions for major roads

- *Figure 23b shows EU summed exposure distributions for major roads outside agglomerations, derived from the END data for 2017.*
- *In this case the exposure is expressed not as percentages, but as the absolute number of persons exposed in millions. The data for major roads is assumed to be more complete than the data for agglomerations, based on the data submitted to the EEA.*
- *The total road length represented by the data is about 350,000 km, as follows from the data on the EEA website.*

EU summed exposure distributions for noise from major roads outside agglomerations, based on the END data for 2017

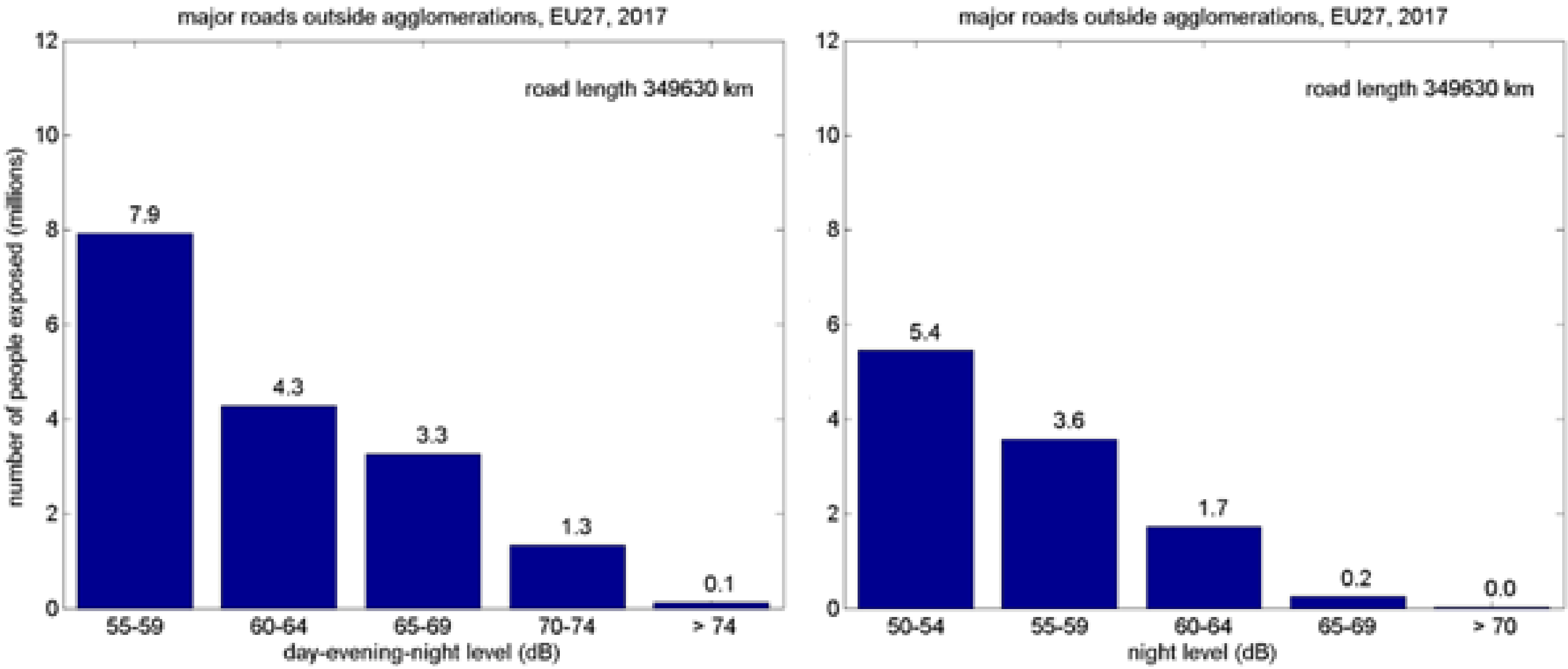


Figure 23b

Cost benefit analysis

Methodology – Extrapolation below the END exposure limits

- *For the application of the health impact assessment methods described in previously, the exposure distributions were extrapolated to include two 5dB intervals below the END exposure limits of 55 dB L_{den} and 50 dB L_{night}.*

Methodology - Effect of noise abatement on the exposure distr.

- *In practice, there are many different sources, such as motorways and urban streets, with different emission reductions.*
- ***Therefore, the approach is to first calculate a weighted average emission reduction over all sources, and next apply this reduction to the reference exposure distribution (from 2017 END data).***
- ***Use is made of a model for calculating the noise level change that takes into account different road types, based on a model previously developed for the Netherlands.***

Cost benefit analysis

Method for calculating the health burden and the costs of noise

- *Two different calculation methods are used for the calculation of health effects:*
  - Method 1, described in a recent handbook on the external costs of transport,
  - Method 2, developed in the framework of EU project Heimtsa.
- *For both methods, the EU exposure distributions with 5 dB intervals extrapolated below the lower limits of 55 dB L_{den} and 50 dB L_{night} are used as input.*
- ***Method 1** yields the total external costs of health effects caused by noise .*
- ***Method 2** also yields the total costs, but in addition, numbers of affected people are calculated, as well as numbers of healthy life years lost (**DALYs**). By using both methods, a broader picture of the health burden is provided than with a single method.*

Cost benefit analysis

Method for calculating the health burden and the costs of noise

- *The costs estimated with method 1 are considerably higher than the costs estimated with method 2, up to a factor of 4.* ***This difference reflects the fact that noise impact assessments are subject to a large uncertainty.***
- *The exposure-response functions used in this project are shown in Figure 24. The Miedema ERFs for road were used in this project.*

Effects of noise, exposure-response functions

Since there are no ERFs of WHO for Annoyed and Sleep disturbed (only for high annoyance and high sleep disturbance), the previously used Miedema ERFs for road were used in this project.

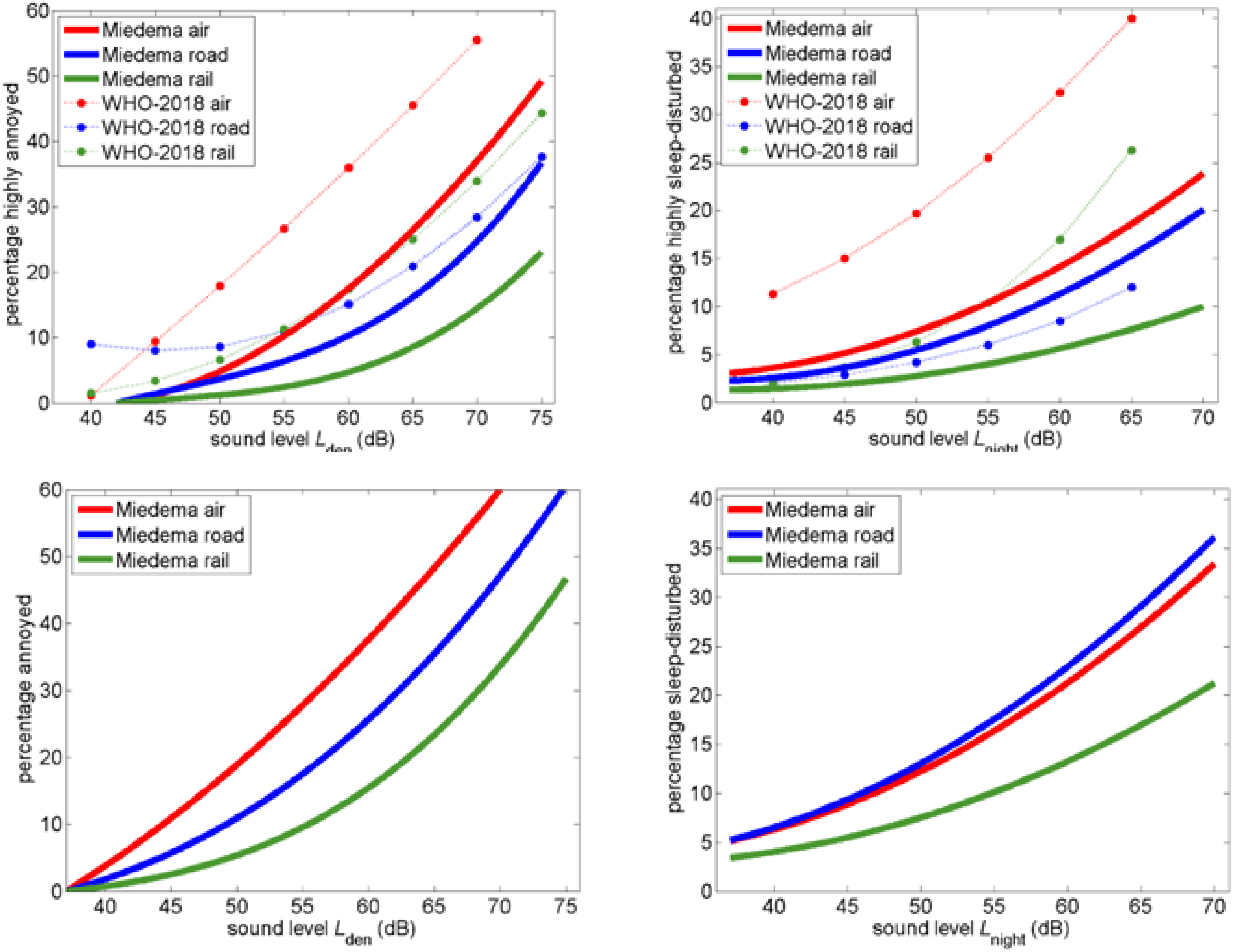


Figure 24

Cost benefit analysis

Monetary valuation with method 1

- ***Method 1*** *is based on a table of values for the costs of environmental noise, reflecting the welfare loss per decibel increase.* ***The values are based on studies reported in the literature and are reproduced here in Table 3****. For a given L_{den} level the costs over the lower dB bands are integrated.* ***Below 50 dB L_{den} the costs are zero****.*

Values of the costs of traffic noise for the EU28, in units of Euro/dB/person/year

Lden (dB)	Road		
	annoyance	health	total
50-54	14	3	17
55-59	28	3	31
60-64	28	6	34
65-69	54	9	63
70-74	54	13	67
>74	54	18	72

The total integrated costs for the EU are calculated by combining the table with the EU exposure distributions (method 1).

Table 3

Cost benefit analysis

Monetary valuation with method 2

- *Method 2 for monetary valuation of the effects of noise is based on an extensive literature survey. As described before, a distinction is made between three health endpoints:* ***annoyance, sleep disturbance, and myocardial infarction.***
  - For annoyance, a fixed cost of 85 Euro per annoyed person per year, based on HEATCO, is used.
  - For sleep disturbance, the costs are calculated in terms of productivity loss caused by high sleep disturbance, with a value of 2% of EU average GDP per employee.
  - The total costs for myocardial infarction are calculated from the morbidity costs (7300 Euro per case) and the costs of life years lost with 40 000 Euro per life year.

Cost benefit analysis

Costs

- *The industry cost estimates for the scenarios are based on methodology applied in the Venoliva study and a subsequent study.*
- *The costs for implementing tighter noise limits consist of additional R&D and additional production costs. These are only incurred when real noise reductions must be implemented but not for vehicle models that already fulfil tighter limits.*

Additional development costs

- *Additional development costs are estimated over a 7-year period during which new models are developed to comply with the new limits. The noise reduction must be achieved on powertrains if tyres remain unchanged.*
- *An example is given in Table 4.*

Estimated annual additional development costs

for a 2 dB limit reduction for all vehicle types, as function of number of new models n_j per vehicle type j per annum, base annual development cost Cd_j for first dB reduction, reduction margin NR_{0j} and required reductions NR_j for vehicle type j. A multiplier of 1.16 is applied for cost of investment.

Vehicle group j	n_j	Base annual devt. cost for first dB C_{dj} (€)	$NR_{0,j}$ dB	NR_j dB	Additional annual devt. cost $C_{dev,j}$ (M€)
Cars	225	165.700	1	2	37.3
Vans	8	165.700	1	2	1.3
Buses	10	165.700	1	2	1.7
Lorries	10	165.700	1	2	1.7
HGVs	15	165.700	1	2	2.5
Total/year (M€)					44.4
Incl. investment multiplier 1.16					51.5

Table 4

Cost benefit analysis

Additional production costs (see Table 5)

- *The additional production costs C_{prod} can be calculated from an estimate for additional materials and manufacturing, assumed proportional to the noise reduction, and slowly decreasing over the lifetime of the production cycle to take into account gradual efficiency improvements in production.*
- *The additional production costs are assumed for short term noise reduction solutions, but reducing to zero after 7 years due to gradual integration and introduction of longer term and more effective design solutions.*

Annual additional production costs in first year of production

as a function of required noise reduction, number of vehicles produced per annum m_j and average additional production cost per dB of noise reduction C_{pj}.

Vehicle group j	Number of vehicles of type j produced annually m_j	Additional annual production cost per vehicle / dB C_{pj} (€)	Noise reduction (dB)	Additional, annual production cost $C_{prod,j}$ (M€)
Cars	15800000	15	1	237
Vans	2200000	15	1	33
Buses	36000	250	1	9
Lorries	107000	250	1	27
HGVs	388000	250	1	97
Total(M€)				403

Table 5

Cost benefit analysis

Road traffic noise emission model

- *For road traffic noise, the methodology described in the foregoing is based on the EU exposure distributions (Figures 23a and 23b) for the year 2017 for urban agglomerations and major roads specified for L_{den} and L_{night}.*
- *Effects of noise abatement solutions (and autonomous developments) in the period 2017-2045 are taken into account by estimating a change of the 2017 exposure distributions. This is illustrated schematically in Figure 25.*
- *The road traffic noise emission model takes into account:*
  - the emission of individual road vehicles,
  - Traffic load and speeds of the vehicles on the different types of roads.
- ***The model has been developed for situations in the Netherlands and was adapted for this study by using parameters appropriate for the EU. The most important elements of the model are described in the following slides.***

Illustration of the effects of different types of noise abatement solutions on the END exposure distributions used to calculate the (reduced) health burden

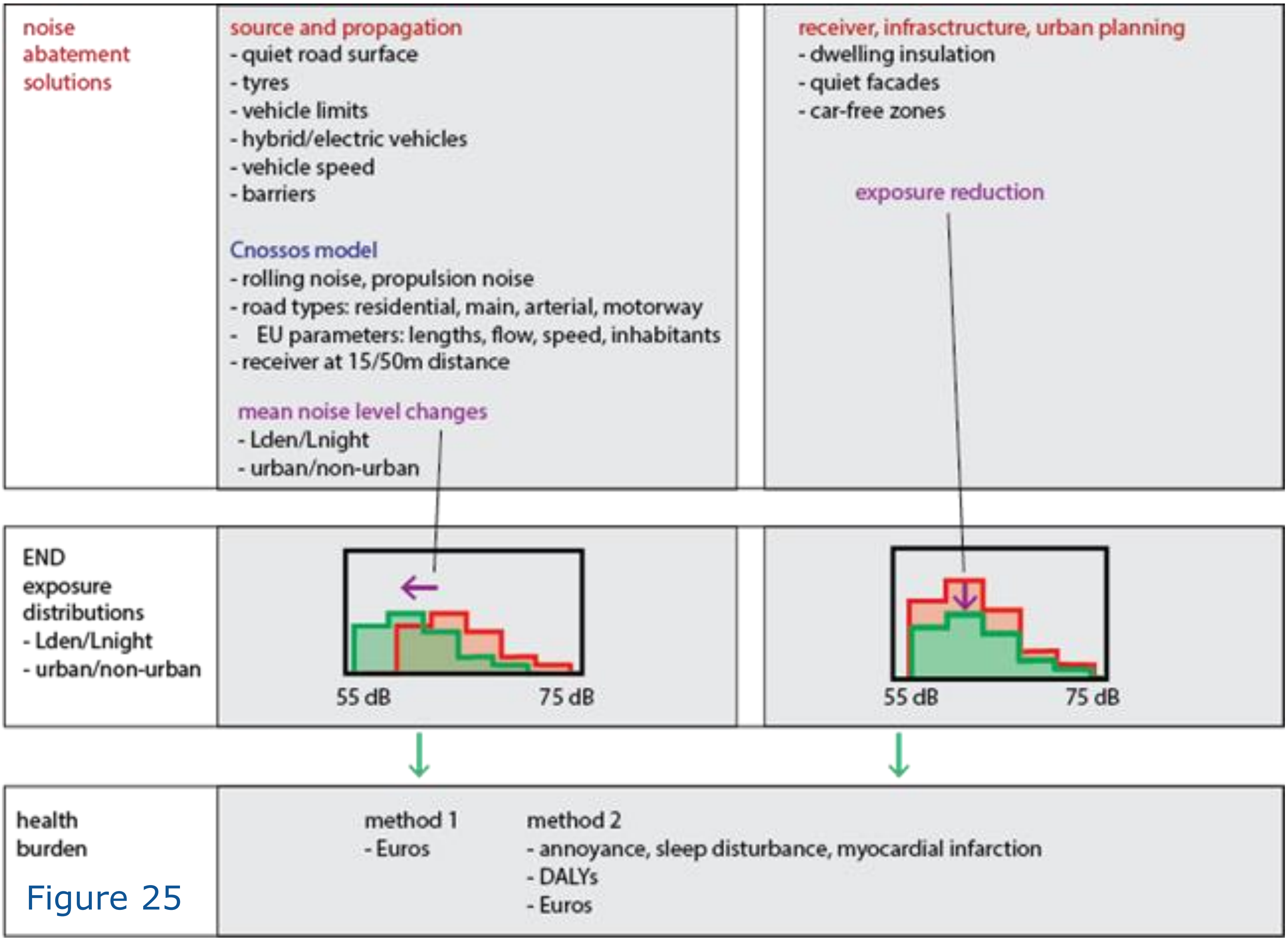


Figure 25

Cost benefit analysis

Road traffic noise emission model

- *Eight road types are distinguished in the model, also previously defined in Venoliva and subsequent studies:*

1. urban	*residential streets with intermittent flowing traffic,*
2. urban	*residential streets, free flowing traffic,*
3. urban	*main roads, intermittent flowing traffic,*
4. urban	*main roads, free flowing traffic,*
5. urban	*arterial roads,*
6. urban	*motorways,*
7. non-urban	*motorways,*
8. nonurban	*main roads.*

Cost benefit analysis

Road traffic noise emission model

- *For residential streets and main roads, 1/3 of the overall road length is assumed to have intermittent traffic flow with acceleration and deceleration, whereas 2/3 of overall road length has free traffic flow.*
- *Intermittent traffic is mainly around crossings, junctions and accelerating & decelerating traffic applies to residential and main roads.*
- ***Dense traffic, saturated traffic and congestions are more temporary and not relevant for L_{den}, due to shorter time and lower noise levels.***
- *They might be more relevant for exhaust emissions, depending on the behaviour.*
- *Inhabited road lengths of the 8 types were estimated for the EU, and also numbers of inhabitants per km (see Table 6). Traffic loads and speeds were also estimated for the different road types (Table 7). The fleet composition varies with road type.*
- *For example, the percentage heavy vehicles (trucks) is generally higher on non-urban motorways than on residential streets.*

Lengths of eight road types (inhabited) and numbers of people along the roads

	Type		Inhabited length (km)	Number of people per km
1	Residential street, intermittent	Urban	1/3 * 965652	250
2	Residential street, free	Urban	2/3 * 965652	250
3	Main road, intermittent	Urban	1/3 * 199796	500
4	Main road, free	Urban	2/3 * 199796	500
5	Arterial road	Urban	94118	500
6	Motorway	Urban	3824	1000
7	Motorway	Non-urban	34141	50
8	Main road	Non-urban	1517922	20

Table 6

Parameters of the vehicle flow on the eight road types

	Type		Vehicle flow (vehicles per 24h)	Speed C1/C2/C3 (km/h)
1	Residential street, intermittent	Urban	500	30 / 30 / 30
2	Residential street, free	Urban	500	50 / 40 / 40
3	Main road, intermittent	Urban	20000	50 / 40 / 40
4	Main road, free	Urban	20000	50 / 50 / 50
5	Arterial road	Urban	33700	80 / 70 / 70
6	Motorway	Urban	48500	100 / 85 / 85
7	Motorway	Non-urban	48500	115 / 85 / 85
8	Main road	Non-urban	16000	80 / 80 / 80

Table 7

Cost benefit analysis

Road traffic noise emission model

- ***For each road type four subtypes are considered:***
    1. roads with a standard road surface,
    2. roads with a standard road surface and noise barriers (10 dB attenuation),
    3. roads with a quiet road surface,
    4. roads with a quiet road surface and noise barriers.
- *From the traffic loads and speeds noise levels L_{den} and L_{night} are calculated at a distance of 15 m (non-motorway) or 50 m (motorway) from the road.*
- *For sound propagation, only geometrical spreading of sound waves is taken into account. Ground attenuation and air absorption are neglected.*

Cost benefit analysis

Cnossos vehicle emission model with corrections

- *In order to calculate the emission of individual vehicles, the Cnossos model for vehicle noise emission is used with some modifications.*
- *The final mean noise levels ($L_{den,urban}$, $L_{den,non-urban}$, $L_{night,urban}$, $L_{night,non-urban}$) are used for modification of the END exposure distributions, as illustrated in Figure 25.*
- *The Cnossos model has separate contributions from propulsion noise and rolling noise. Three vehicle categories are considered:*
    - light vehicles (C1),
    - medium-heavy vehicles (C2),
    - heavy vehicles (C3).
- ***Other vehicle types such as motorcycles are not included here**. The reason for this is that the other vehicle types have a very limited contribution to the year-averaged L_{den} and L_{night} levels at EU level, and they are normally not included in END noise-mapping calculations.*

Cost benefit analysis

Cnossos vehicle emission model with corrections

- ***A correction term is applied to make the Cnossos noise emission model match the Dutch model. The correction term is 4 dB for light vehicles and 5 dB for medium heavy and heavy vehicles.***
- *The underestimation of road vehicle emission levels by Cnossos has been found also in other studies performed in the Netherlands and is partly due to a mismatch between the emission model and the propagation model in Cnossos.*
- *The Cnossos model contains the following emission corrections:*
    - correction for quiet road surfaces,
    - correction for vehicle acceleration at crossings or other obstacles,
    - correction for studded tyres.

Cost benefit analysis

Cnossos vehicle emission model with corrections

- *The correction for quiet road surfaces depends on frequency and driving speed. The same correction is used in the Dutch calculation method.*
- *To keep the methodology practical for the purpose of this study, **the non-spectral version of the Dutch method was implemented**. **In line with this, the Dutch model was also used for the correction for vehicle acceleration, which is applied for roads with intermittent traffic flow.***
- *The correction for studded tyres in the CNOSSOS model is replaced by a more general correction for quiet tyres.*
- *This formulation of the vehicle emission model makes it possible to calculate the effects of the following noise reduction measures, for the three vehicle types:*
  a. vehicle emission reductions (propulsion noise correction)
  b. reduction by quiet tyres (rolling noise correction)
  c. reduction by a quiet road surface (rolling noise and propulsion noise correction).

Cost benefit analysis

Calculation of noise reduction measures

- *For the vehicle emission reductions **(a)**, six types are considered*

  1. 2015: no reduction, fleet as in 2015,
  2. 2016: reduction according to 2016 emission limits (540/2014 phase 1),
  3. 2020/22: reduction according to 2020/22 emission limits (540/2014 phase 2),
  4. 2024/26: reduction according to 2024/26 emission limits (540/2014 phase 3),
  5. **hybrid vehicles: reduction of propulsion noise by 5 dB (mainly for plug-in hybrids),**
  6. **electric vehicles: reduction of propulsion noise by 10 dB.**

- *The values of the vehicle emission corrections ΔLW,veh are given in Table 8, for 5 vehicle categories.*

Vehicle emission corrections (propulsion noise) for six emission limits / vehicle types and five vehicle categories

Vehicle category	2015 dB	2016 dB	2020/22 dB	2024/26 dB	Hybrid dB	Electric dB
car, C1	0	-0.186	-2.1	-4.1	-5	-10
van, C1	0	-0.186	-2.1	-4.1	-5	-10
bus, C2	0	0	-1.8	-2.8	-5	-10
truck, C2	0	0	-1.8	-2.8	-5	-10
heavy truck C3	0	0	-1.5	-3.5	-5	-10

- The 5 vehicle categories are aggregated to 3 vehicle categories by weighted energetic averages of cars and vans for the Cnossos C1 category and trucks and buses for the C2 category with 90% weighting for cars and trucks and 10% for vans and buses.

Table 8

Cost benefit analysis

Calculation of noise reduction measures

- *The reduction of tyre noise **(b)** is also a type of vehicle emission reduction but is included here as a separate reduction.*
- *It is quantified by the tyre label.*
- *For the reductions by a quiet road surface **(c)**, the following five road surface types are considered. These surfaces are also applied in other countries:*
    1. standard surface, dense asphalt concrete,
    2. thin top layers,
    3. porous asphalt,
    4. double-layer porous asphalt,
    5. double-layer porous asphalt fine.
- *The emission correction is zero for road surface type 1. The correction for quiet road surfaces is calculated based on the Dutch calculation method.*

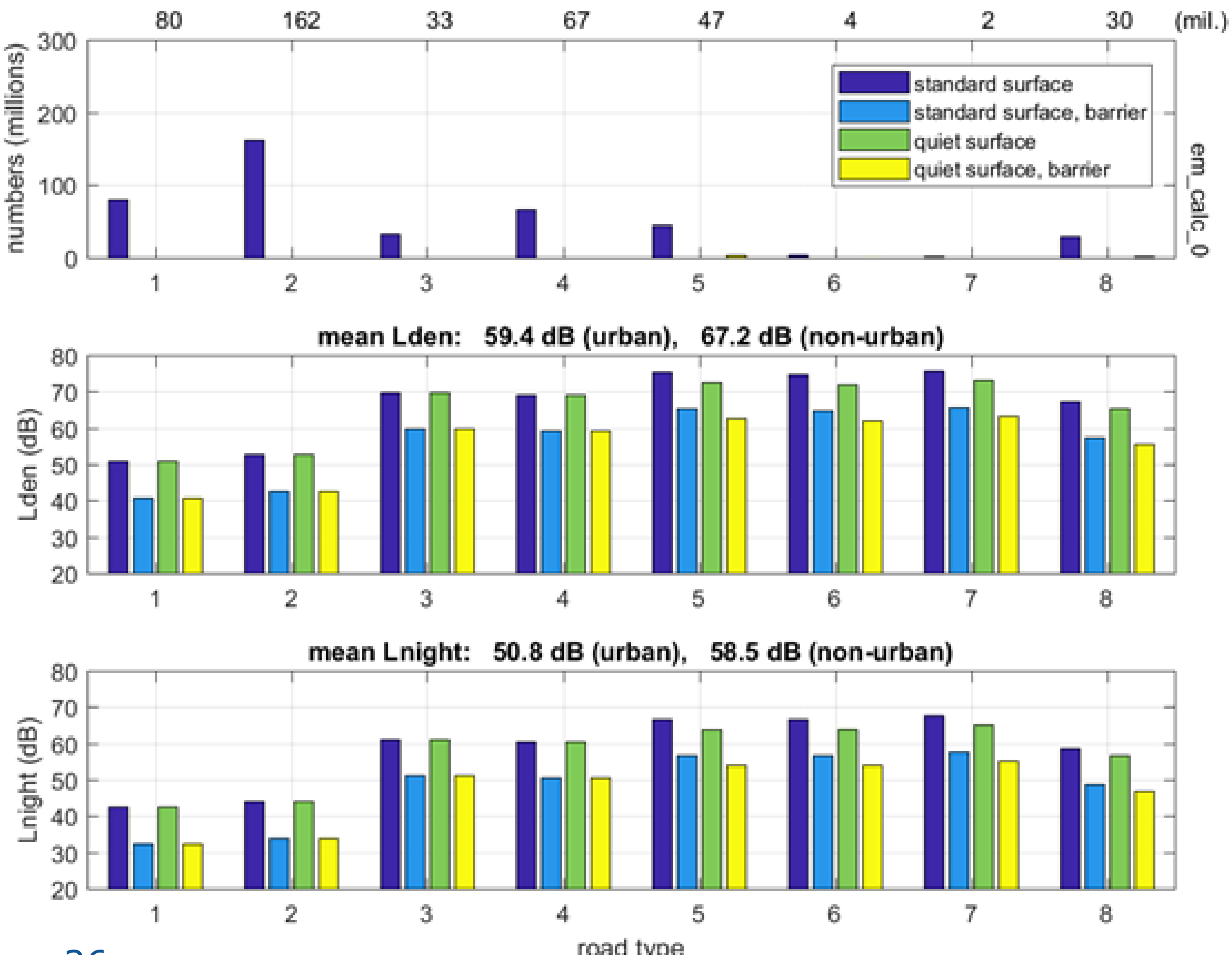
Cost benefit analysis

Scenarios – Baseline scenario

- *The baseline scenario (Business as usual, BAU) is defined by the situation for road traffic noise in 2017-2020, and its autonomous development in the period until 2045.*
- *The developments in the baseline scenario reflect existing noise reduction solutions based on existing legislation. The annual traffic growth of 1% is based on EU growth figures for passenger and freight road traffic.*

Exposure data for the baseline scenario

Top: millions exposed along road types 1 to 8 (most are near standard surface roads without barriers); middle and bottom: average L_{den} and L_{night} exposure levels per road type and averages for urban/non-urban



	Type	
1	Residential street, intermittent	Urban
2	Residential street, free	Urban
3	Main road, intermittent	Urban
4	Main road, free	Urban
5	Arterial road	Urban
6	Motorway	Urban
7	Motorway	Non-urban
8	Main road	Non-urban

gure 26

Cost benefit analysis

Scenarios – Baseline scenario

- *The 2016 EU reference scenario forecasts the following percentages for hybrid and electric vehicles in 2030: 25% hybrid and 2% electric. From a more recent EC document and communication with the EC , the following values were derived:*
- - *cars*
    - Hybrid 6% in 2030,   Electric 14% in 2030
- - *vans*
    - Hybrid 6% in 2030,   Electric 8% in 2030.
- - *buses*
    - Hybrid 7% in 2030,   Electric 18% in 2030.
- - *trucks (heavy goods)*
    - Hybrid 16% in 2030, Electric 1% in 2030.

Cost benefit analysis

Scenarios – Baseline scenario

- *These new values were used here and were linearly extrapolated to 2045, assuming zero values in 2020 as an approximation (in 2018 there were 0.8% hybrid and 0.2% electric in the EU).*
- ***For the baseline scenario no reductions for tyre noise are foreseen in this period up to 2045.***

Cost benefit analysis

Scenarios – Specification of alternative scenarios

- *In choosing potential scenarios, the results of the survey, literature review and stakeholder feedback and findings from the tests were considered.*
- *Based on this, the scenarios as listed in Table 9 were specified for CBA calculations. Table 9a contains 6 different reduction measures (scenarios A to F).*
- *Scenarios A to B are related to type approval limit value reductions leading to lower limit values than currently specified in phase 3 of Regulation (EU) No. 540/2014.*
- *Scenario C (75 dB cap for all vehicles) affects mainly M3 and N3 vehicles.*
- *Scenario D specifies limit values for L_{wot} in addition to the L_{urban} limit values.*
- *Scenario E is related to an improved, wide range pass-by test better representing the acceleration levels and driving conditions and resulting effectively in a 2 dB reduction of powertrain noise in real traffic conditions.*

Baseline and alternative scenarios for TA limit changes including the effects of test method quantities and tyre noise

	Scenario	Explanation
0	Baseline	Vehicle limits as foreseen in Regulation (EU) No. 540/2014 and tyre limits as in Regulation (EU) No. 2016/1350 stage 2.
A	Available limit space	Adjust limits to space found in the type test databases, after Phase 3 • Passenger cars: -1 dB(A) • Vans: -1 dB(A) • Busses & Lorries: -1 dB(A) • Heavy trucks: -1 dB(A)
B	Targeted limit tightening	Same as scenario A but with tighter limits for lorries/trucks/buses after phase 3 • Passenger cars: -1 dB(A) • Vans: -1 dB(A) • Busses & Lorries: -2 dB(A) • Heavy trucks: -2 dB(A)
C	75 dB(A) cap	A cap at 75 dB(A) affecting L_{WOT} limits for M3 / N3 vehicles by 3 dB.
D	L_{WOT} restrictions	Stricter limits on L_{WOT} for all vehicles by 2030, and reducing engine noise and thus reduced noise in intermittent traffic.
E	Improved pass-by test	An improved, wide range pass-by test should better represent the acceleration levels and driving conditions producing powertrain noise, resulting effectively in a 2 dB reduction of powertrain noise in real traffic conditions (without changing the Lurban limits).
F	Quieter tyres	Tighter tyre noise limits by 3 dB

Table 9a

Cost benefit analysis

Scenarios –Specification of alternative scenarios

- *Assessment of most common and popular tyres on the market, shows that currently about 10 – 20% already have an A-label (M1), meaning that they are already 3 dB or more below the Stage 2 limit value.*
- *A recent Swiss study also considers 3.5 dB reduction as a realistic scenario. The number of tyres with a noise level of 4 dB (or more) below this limit is very limited.*
- *Therefore, 3 dB tighter tyre noise limits for all three tyre label categories are used as a possible scenario to identify the possibilities and effects of such a noise reduction measure,* ***starting in 2022****.*
- *With the average lifetime of a tyre between 3 – 4 years, this reduction should be fully implemented in 2026.*
- ***These facts/assumptions are reflected in Scenario F (tyre noise limit reduction by 3 dB.***
- *Table 9b contains the combinations of scenarios AF, BF, AE, BE, DE and EF.*

Baseline and alternative scenarios for TA limit changes including the effects of test method quantities and tyre noise

	Scenario	Explanation
0	Baseline	Vehicle limits as foreseen in Regulation (EU) No. 540/2014 and tyre limits as in Regulation (EU) No. 2016/1350 stage 2.
AF	**Available limit space and new tyre limits**	**Scenario A and F combined**
BF	Targeted limits and new tyre limits	Scenario B and F combined
AE	Available limit space and improved test	Scenario A and E combined
BE	Targeted limits and improved test	Scenario B and E combined
DE	LWOT restrictions and improved test	Scenario D and E combined
EF	ASEP extension and quieter tyres	Scenario E and F combined

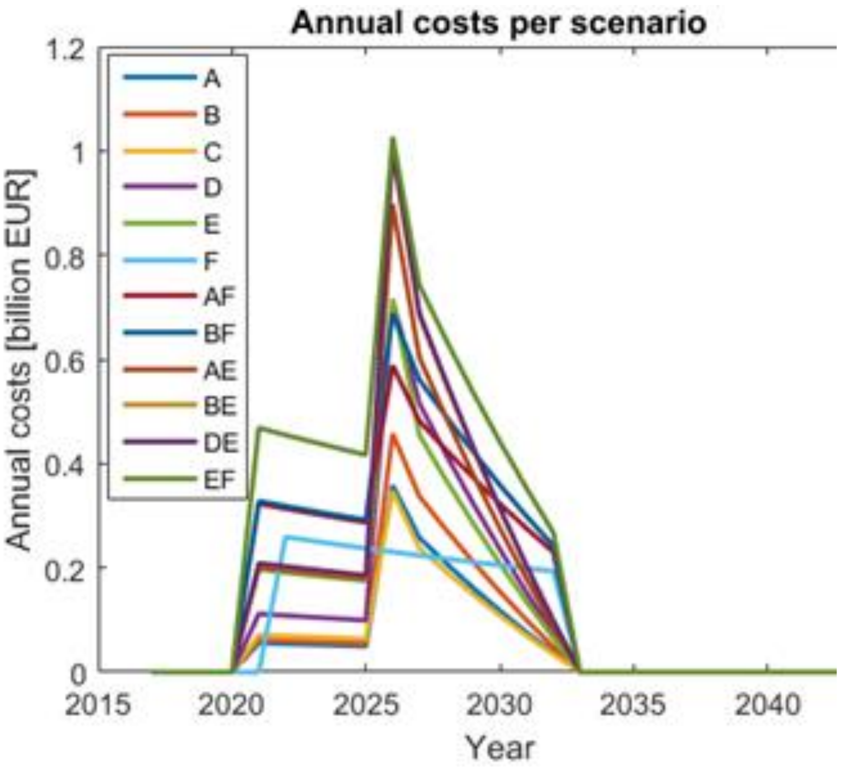
Table 9b

Cost benefit analysis

Scenarios – Costs and benefits for the different scenarios

- *Figure 27 shows the costs for the different scenarios on an annual base and cumulative.*
- *Figure 28 shows the benefits for the different scenarios on an annual base and cumulative and for the two methods as described before.*
- *The noise levels L_{den} and L_{night} averaged over the different road types and their reductions for each scenario are set out in Table 10 for urban and non-urban roads.*
- *Figure 29 shows the health burden reduction in 2045 and benefit-to-cost ratio (BCR) for the period 2017 – 2045 for each vehicle noise reduction scenario.*

R&D and production costs per scenario, including the costs for quieter tyres



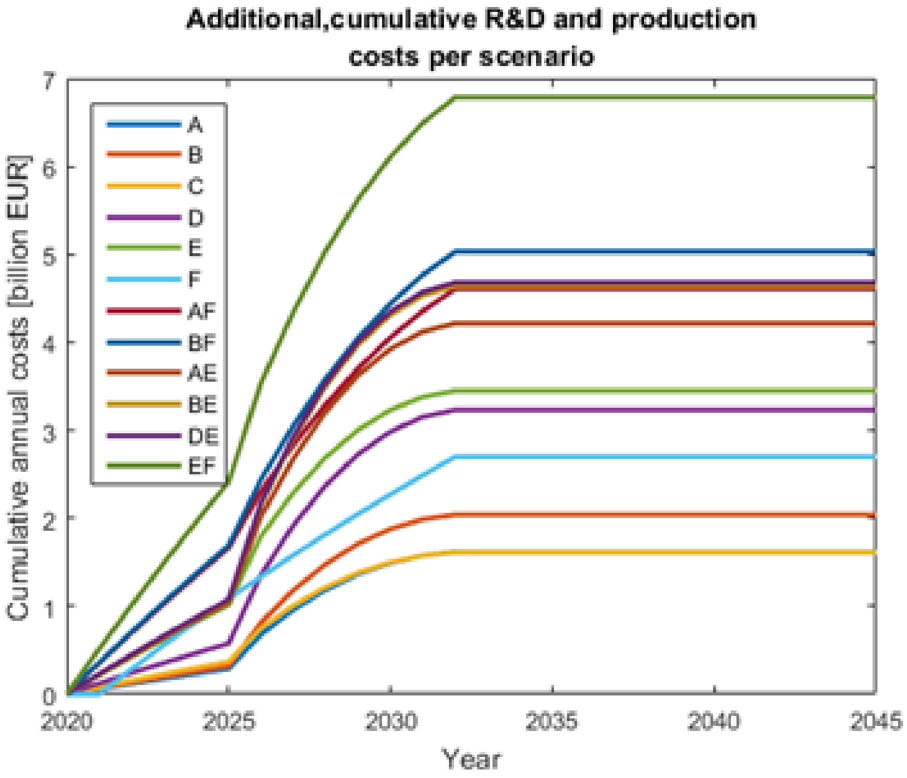
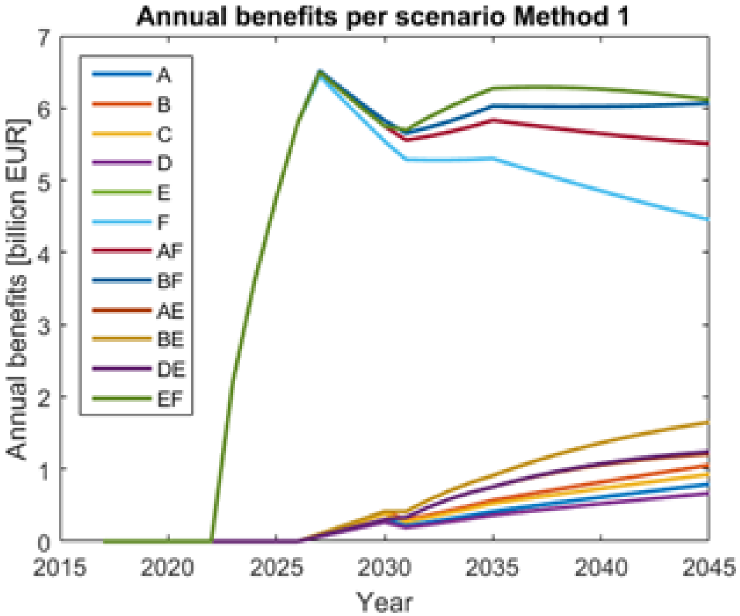
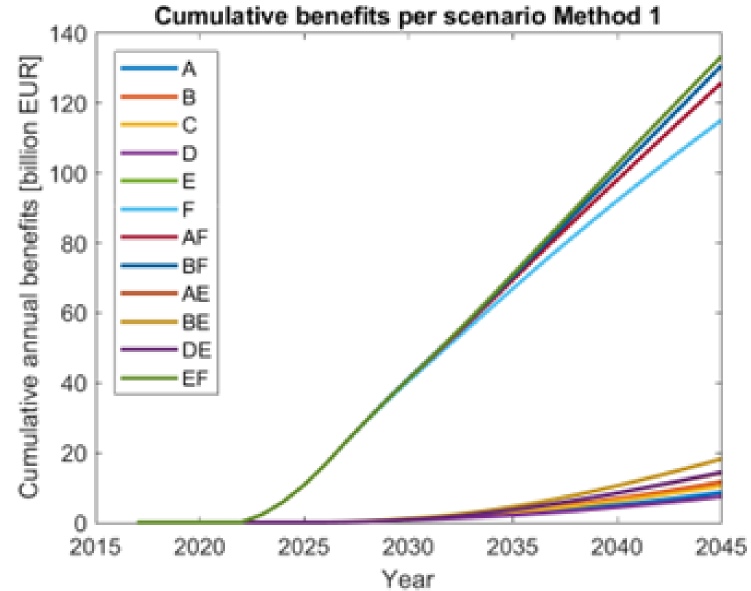


Figure 27

Benefit per scenario, including the costs for quieter tyres





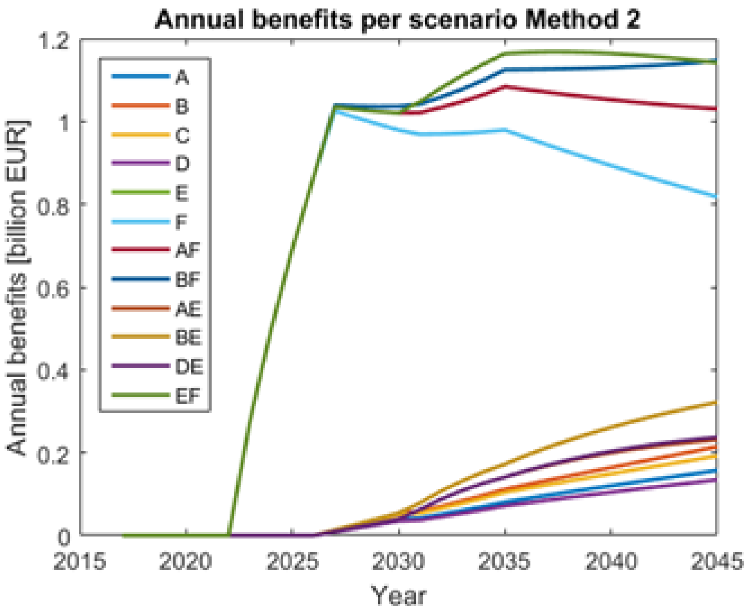
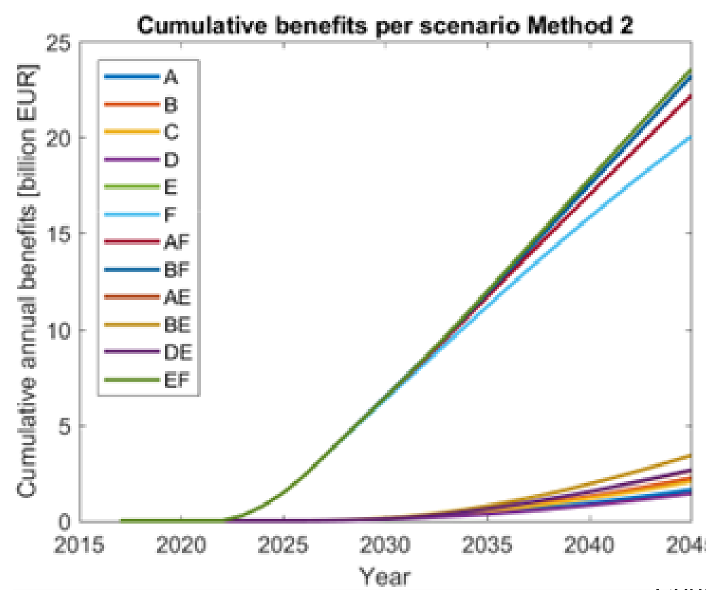


Figure 28



L_{den} and L_{night} values in dB(A) and reductions for the baseline and alternative scenarios (in dB)

Scenario	Lden		Lnight		ΔLden		ΔLnight	
	Urban	Non-urban	Urban	Non-urban	Urban	Non-urban	Urban	Non-urban
0. Baseline	59.4	67.2	50.8	58.5	-	-	-	-
A. Available limit space	59.1	67.1	50.5	58.4	-0.3	-0.1	-0.3	-0.1
B. Targeted tightening	59.0	67.0	50.4	58.4	-0.4	-0.1	-0.5	-0.2
C. 75 dB(A) cap	59.1	67.0	50.4	58.4	-0.3	-0.1	-0.4	-0.1
D. L_{WOT} limit	59.2	67.1	50.5	58.4	-0.2	-0.1	-0.3	-0.1
E. Improved test	59.0	67.0	50.3	58.4	-0.5	-0.1	-0.5	-0.2
F. Quieter tyres - 3dB	57.9	65.2	49.4	56.6	-1.5	-1.9	-1.5	-1.9
Scenario A & F	57.5	65.1	48.9	56.4	-1.9	-2.1	-1.9	-2.1
Scenario B & F	57.3	65.0	48.7	56.3	-2.1	-2.2	-2.2	-2.2
Scenario A & E	59.0	67.0	50.3	58.4	-0.5	-0.1	-0.5	-0.2
Scenario B & E	58.8	67.0	50.2	58.3	-0.6	-0.2	-0.7	-0.2
Scenario D & E	59.0	67.0	50.3	58.4	-0.5	-0.1	-0.5	-0.2
Scenario E & F	57.3	65.0	48.7	56.4	-2.2	-2.2	-2.1	-2.2

Table 10

Health burden reduction in 2045 and benefit-to-cost ratio (BCR) for the period 2017 – 2045 for each vehicle noise reduction scenario

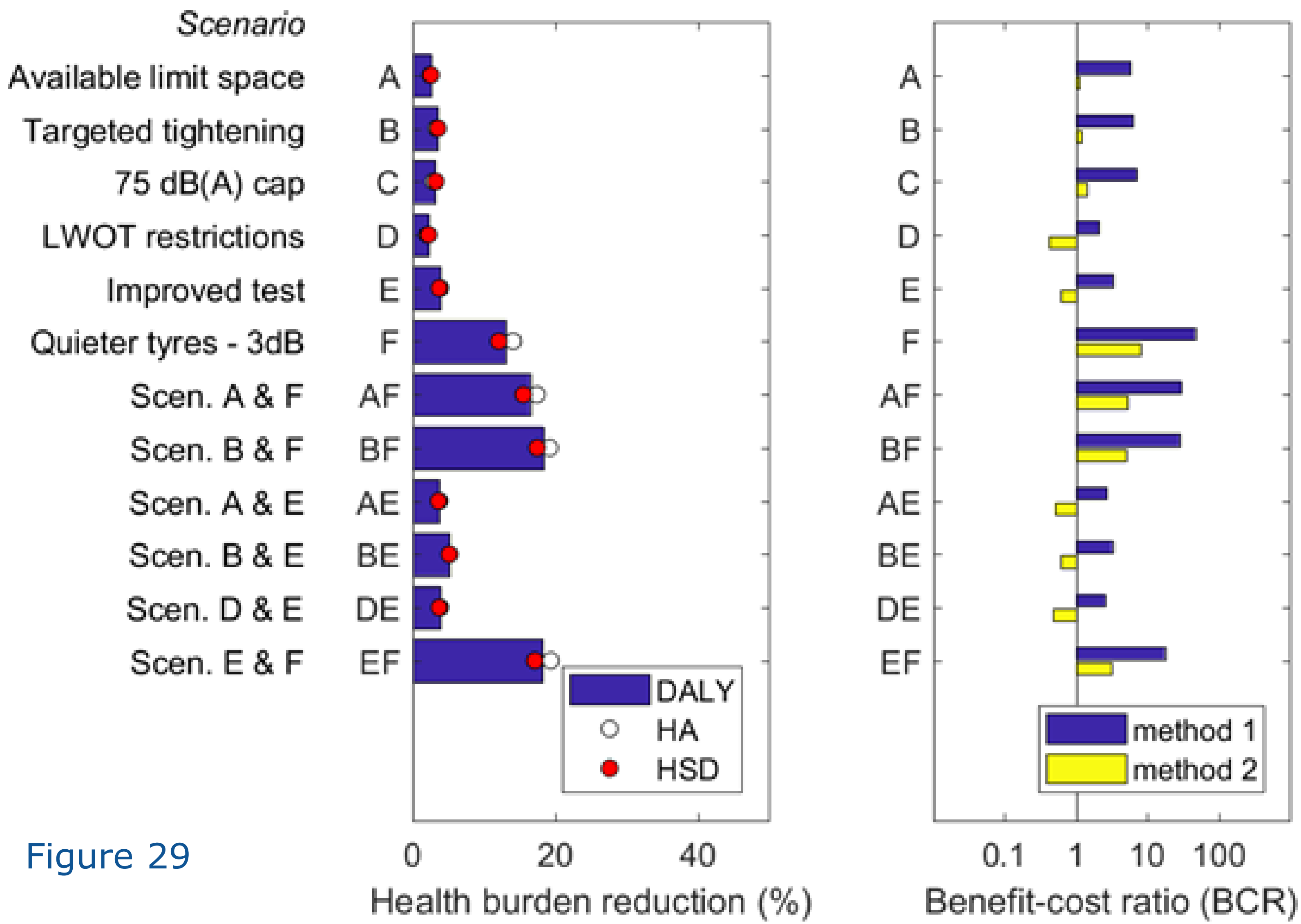


Figure 29

Cost benefit analysis

Scenarios – Costs and benefits for the different scenarios

- *From Figure 29 it can be seen that quieter tyres are very effective to reduce the health burden by 12-19%, which is the main quantity considered here. This single scenario also has a high benefit-to-cost ratio, as the costs of quieter tyres are limited compared to powertrain noise reduction.*
- ***Besides this, reduction of tyre noise in terms of tighter limits and thus type approval values will directly influence the real traffic noise exposure over the whole period considered, whereas powertrain noise reduction following the current test method is only partially reflected in real traffic noise. Consequently, also the combinations of tyre noise reduction with other scenarios are very effective.***

Content

1. Introduction,
2. Feedback gathering and literature review,
3. Testing of vehicles' sound emission values,
4. Cost benefit analysis,
5. Proposal for phase 4 limit values,
6. Discussion about amendments of the measurement method and ASEP requirements.

Proposal for phase 4 limit values

Introduction

- *Since the phase 2 limit values of Regulation (EU) No. 540/2014 are already in force since 1 July 2020 for new vehicle types and will come into force 1 July 2022 for first vehicle registrations and since the phase 3 limit values will come into force four years after the dates mentioned before* ***it is proposed to keep the phase 3 limit values unchanged because this time period will be too short for a further tightening of the phase 3 limits.***
- *Consequently, possible further limit value reductions should be discussed in the frame of a 4th phase to be added to the Regulation.*

Proposal for phase 4 limit values

Introduction

- *In particular, the analysis of the KBA and RDW databases for M- and N-category vehicles, which contain type approval values of recently type-approved vehicles, reveal that there are already vehicles type approved with lower sound emission values than the regulatory sound emission level limits and in some cases lower than the future phase 3 limits of Regulation (EU) No. 540/2014.*
- *The most important result from the CBA is that a further reduction of tyre limits (scenario F) is much more beneficial than further reductions of vehicle noise limits (Figure 29).*
- ***The percentage health burden reduction in 2045 is about 5 times higher for scenario F compared to the average of scenarios A to D. But scenario F is out of the scope of this study and thus cannot be considered here.***

Proposal for phase 4 limit values

Introduction

- *Scenario E (improvements of the ASEP requirements) is a bit more effective than scenarios A to D, but its implementation would also require an extension of the scope of this study and more effort than limit value reductions according to scenarios A to D. Therefore, this scenario is also not considered here.*
- ***And since the differences between the scenarios A to D are not so big, the potential for limit changes is assessed in the following slides, based on the KBA and RDW database analyses, which are in line with the CBA scenarios A and B.***
- *But this discussion needs to be conducted vehicle subcategory specific.*

Proposal for phase 4 limit values

M1 vehicles

- *M1 vehicles are divided into the following subcategories according to Regulation (EU) No. 540/2014:*
  1. power to mass ratio ≤ 120 W/kg,
  2. 120 W/kg < power to mass ratio ≤ 160 W/kg,
  3. 160 W/kg < power to mass ratio,
  4. power to mass ratio > 200 W/kg number of seats ≤ 4 , R point of driver seat ≤ 450 mm from the ground
- *Figure 30 shows the power to mass ratio distribution of M1 vehicles with ICE in the Dutch vehicle stock. The situation in other EU member states is similar.*
- *The biggest part of the vehicles (98.6%) belongs to subcategory 1. Subcategory 2 contains 0.9% of the vehicles, the remaining 0.5% account for subcategory 3 (0.3%) and subcategory 4 (0.2%).*

Power to mass ratio distribution of M1 vehicles with ICE in the Dutch vehicle stock

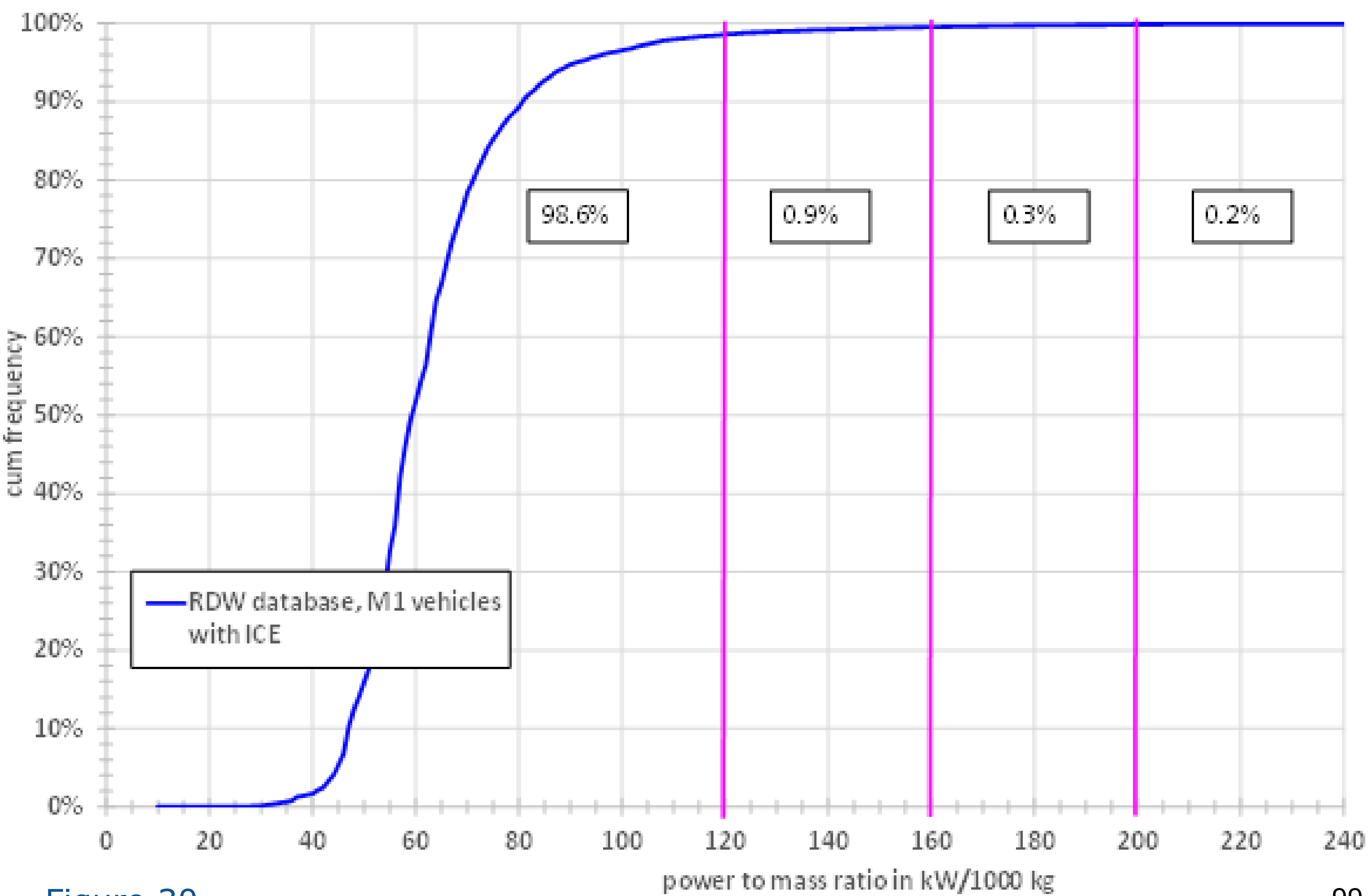


Figure 30

Proposal for phase 4 limit values

M1 vehicles, power to mass ratio ≤ 120 W/kg

- *Figure 31 shows the L_{urban} frequency distributions for M1 vehicles with pmr values up to 120 W/kg for different registration years from 2016 to > 2018 in the RDW database.*
- *Since the database is not complete with regard to the registration year 2020, 2019 and 2020 were put together in the class >2018.*
- *Earlier years than 2016 were not considered in order to make sure that the tyres for the vehicles had to comply with the stage 2 limit values of UNECE Regulation No. 117.*
- *The trend to lower L_{urban} values with increasing vehicle registration year can clearly be seen. The 50% percentile for 2016 is a bit more than 70 dB(A), for >2018 it is 68.4 dB(A).*
- *This is at least partly caused by the fact that the phase 2 limit values of Regulation (EU) No. 540/2014 for new vehicle types came into force 1st of July 2020.*

L_{urban} frequency distributions for M1 vehicles with pmr values up to 120 W/kg for different registration years

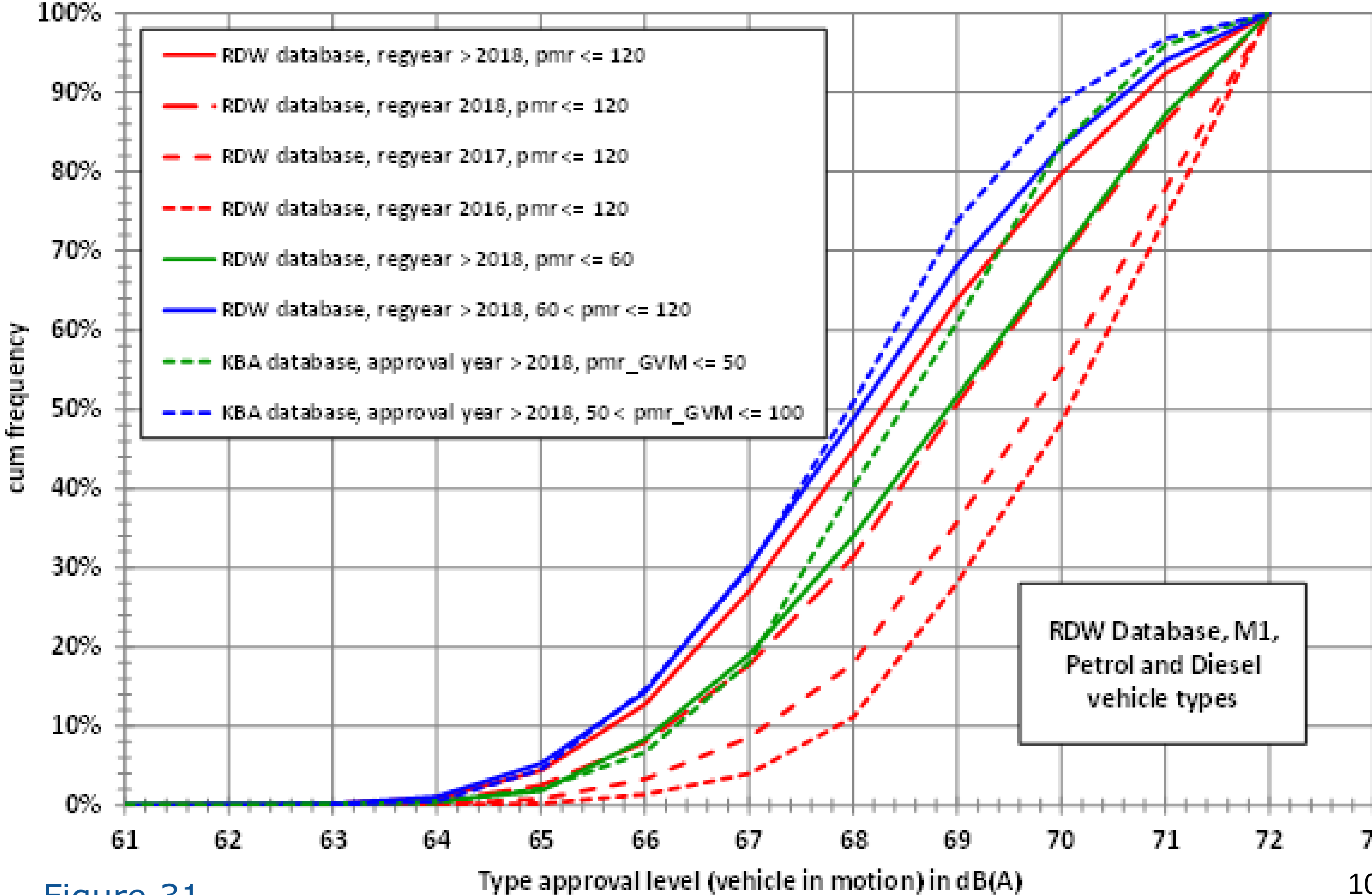


Figure 31

Proposal for phase 4 limit values

M1 vehicles, power to mass ratio ≤ 120 W/kg

- *For the registration year class >2018 additional distribution curves are shown for pmr <= 60 W/kg and 60 W/kg < pmr <= 120 W/kg.*
- *Interestingly enough, the L_{urban} values for the lower pmr class are higher than for the higher pmr class (50% percentiles 68.9 dB versus 68.1 dB). And this fact is confirmed by a corresponding comparison of data in the KBA database for the approval years >2018.*
- ***With this result the subcategorisation based on pmr boundaries could be questioned.***
- *Already 45% of the vehicle types in the Dutch stock are compliant with the phase 3 limit values of Regulation (EU) No. 540/2014 according to Figure 31. And 12.7% of the vehicle types would comply to a limit value of 66 dB(A) as candidate for a 4th phase to be added to Regulation (EU) No. 540/2014 beyond 2030.*
- *Furthermore, the database contains two vehicle types with L_{urban} = 63 dB(A), and one vehicle type each for L_{urban} = 62 and 61 dB(A).*

Proposal for phase 4 limit values

M1 vehicles, power to mass ratio ≤ 120 W/kg

- *But one should be careful with the interpretation of such extreme values. In the RDW database a series of manufacturers have vehicle types with L_{urban} <= 66 dB(A) with registration years >2018.*
- *But one has to take into account that these low values are dedicated to special versions of a vehicle type family. In most cases other versions of these vehicle types with L_{urban} <= 66 dB(A) have higher type approval values.*
- *An extreme example is shown in Table 11 in which type approval values from the RDW database for different types of the BMW 320i model are listed, all with the same engine and registered after 2018.*
- *The differences in mass in running order and pmr cannot explain the high L_{urban} range from 63 to 70 dB(A). Also differences in the transmission that are not included in the database could not be responsible.*

Type approval values in the RDW database for different types of the BMW 320i model registered after 2018

manufacturer	brandname	fuel type	no of cylinders	eng capacity in cm³	GVM in kg	MRO in kg	pmr in kW/t	rated power in kW	Lurban in dB(A)	Lstat in dB(A)
BMW	320I	petrol	4	1998	2170	1675	80.6	135	63	82
BMW	320I	petrol	4	1998	2071	1562	86.5	135	64	86
BMW	320I	petrol	4	1998	2055	1548	87.2	135	66	81
BMW	320I	petrol	4	1998	2050	1525	88.5	135	68	92
BMW	320I	petrol	4	1998	2123	1608	84.0	135	70	84

Table 11

Proposal for phase 4 limit values

M1 vehicles, power to mass ratio ≤ 120 W/kg

- *This situation is unsatisfactory but further clarification would have required measures and resources beyond the scope and the financial frame of this study.*
- *These results show that proposals for lower limit values could not only be based on the L_{urban} frequency distributions if other versions of a vehicle model would be far above the proposed limit. This situation is similar for other manufacturers and vehicle models.*
- *From the test results performed in this study on a selection of vehicles as described in chapter 3 it can be concluded that a further reduction of the limit values for the vehicle in motion within the vehicle type approval procedure will require more silent tyres, because the L_{urban} values are significantly influenced by the constant speed test whose results are close to the rolling sound levels of the vehicles.*

Proposal for phase 4 limit values

M1 vehicles, power to mass ratio ≤ 120 W/kg

- ***Therefore, two options are proposed for the future update of the limit values of this subcategory with preference for opt. a:***
  a. **No further limit value reduction prior to a limit value reduction for tyres,**
  b. **A further limit value reduction of 1 dB(A) to 67 dB(A) for a 4th phase starting 4 years after phase 3.**
- *In addition to that, the footnote [1] in the M1 limit value table in Regulation (EU) No. 540/2014 - "M1 vehicles derived from N1 vehicles: M1 vehicles with an R point > 850 mm from the ground and a total permissible laden mass more than 2 500 kg have to fulfil the limit values of N1 (2 500 kg < mass ≤ 3 500 kg)" - should be kept.*

Proposal for phase 4 limit values

M1 vehicles with 120 W/kg < power to mass ratio ≤ 160 W/kg

- *M1 vehicles with 120 W/kg < power to mass ratio ≤ 160 W/kg account for just under 1% of all M1 vehicles. The L_{urban} frequency distributions for these vehicle types for different registration years from the RDW database are shown in Figure 32.*
- *The registration year trend is the same as for M1 vehicle types in the previous subcategory, but the 50% percentile values are 1.2 dB(A) higher.*
- *Two vehicles of this subcategory could be included in the vehicle test task whose results are described in chapter 3: A roadster with manual transmission and a compact hybrid car with automatic transmission. Their test results are quite similar to the test results of the three vehicles belonging to the pmr <= 120 W/kg subcategory.*
- *The roadster almost fulfils the phase 3 limit value, the L_{urban} value of the compact hybrid vehicle is already below the phase 3 limit value. The 1 dB(A) higher limits of this subcategory compared to the pmr <= 120 W/kg subcategory are historical and can hardly be supported by technical reasons.*

L_{urban} frequency distributions for M1 vehicles with 120 W/kg < pmr <= 160 W/kg for different registration years

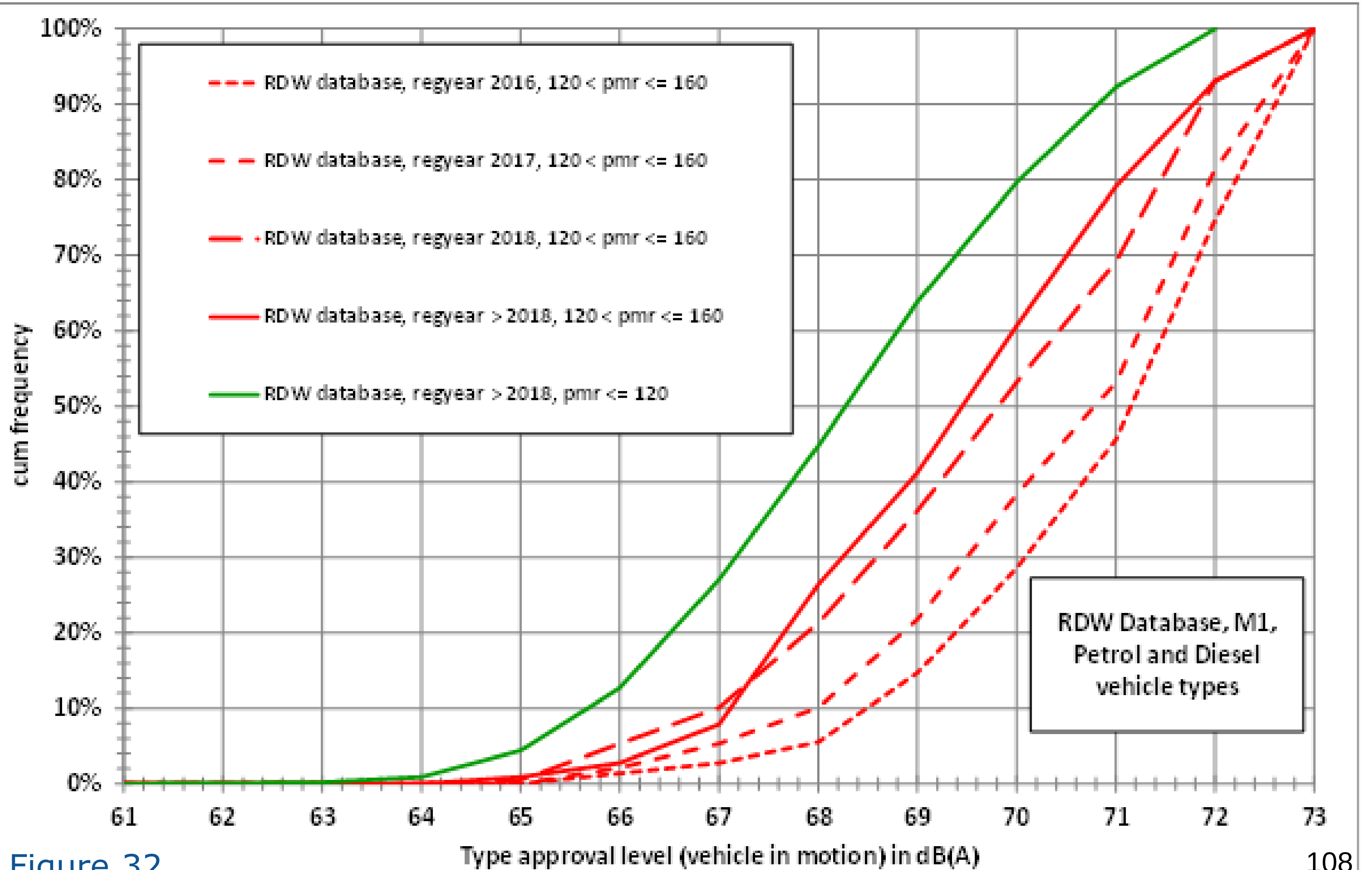


Figure 32

Proposal for phase 4 limit values

M1 vehicles with 120 W/kg < power to mass ratio ≤ 160 W/kg

- ***Therefore, the following options are proposed in accordance with the previous subcategory with preference for option a):***
  a. **Merge both subcategories to a new subcategory with pmr <= 160 W/kg on the basis of the current pmr <= 120 W/kg subcategory phase 3 limit but apply this merge 4 years after the start of phase 3,**
  b. **A further limit value reduction of 1 dB(A) to 68 dB(A) for a 4th phase starting 4 years after phase 3 in case the limit value for the previous subcategory is reduced to 67 dB(A).**

Proposal for phase 4 limit values

M1 vehicles with power to mass ratio above 160 W/kg

- *Regulation (EU) No. 540/2014 differentiates two M1 subcategories with pmr > 160 W/kg:*
    1. vehicles with pmr > 160 W/kg except those vehicles belonging to subcategory 2 below,
    2. pmr > 200 W/kg, number of seats ≤ 4 and R point of driver seat ≤ 450 mm from the ground.
- *The last requirement of the second subcategory cannot be extracted from the KBA and RDW databases, but it can be assumed that the majority of vehicle types with pmr > 200 W/kg belongs to the second subcategory.*
- *Therefore, the L_{urban} distributions for vehicle types with 160 W/kg < pmr <= 200 W/kg and vehicle types with pmr > 200 W/kg were separated for registration years > 2018 and 2017-2018 in order to get reasonable sample sizes.*

Proposal for phase 4 limit values

M1 vehicles with 160 W/kg < power to mass ratio

- *The L_{urban} frequency distributions for M1 vehicles with 160 W/kg < pmr <= 200 W/kg and pmr > 200 W/kg for registration years >2018 and 2017-2018 are shown in Figure 33.*
- *The phase 2 and phase 3 limit values are inserted as lines parallel to the y-axis. The phase 2 limit value of 73 dB(A) for the first subcategory is already fulfilled by 88% of the vehicle types in this subcategory and 87% of the vehicle types in the second subcategory so that there is no reason for different limits.*
- *The situation for the phase 3 limit is different: Almost 61% of the vehicle types from the first subcategory fulfil already the limit of 71 dB(A), but only 35% of the vehicle types in the second subcategory.*
- ***Therefore, it is proposed to merge both subcategories to a new subcategory pmr > 160 W/kg on the basis of the current 160 W/kg < pmr <= 200 W/kg subcategory phase 3 limit values but apply this merge 4 years after the start of phase 3.***

L_{urban} frequency distributions for M1 vehicles with 160 W/kg < pmr <= 200 W/ kg and pmr > 200 W/kg for registration years >2018 and 2017-2018

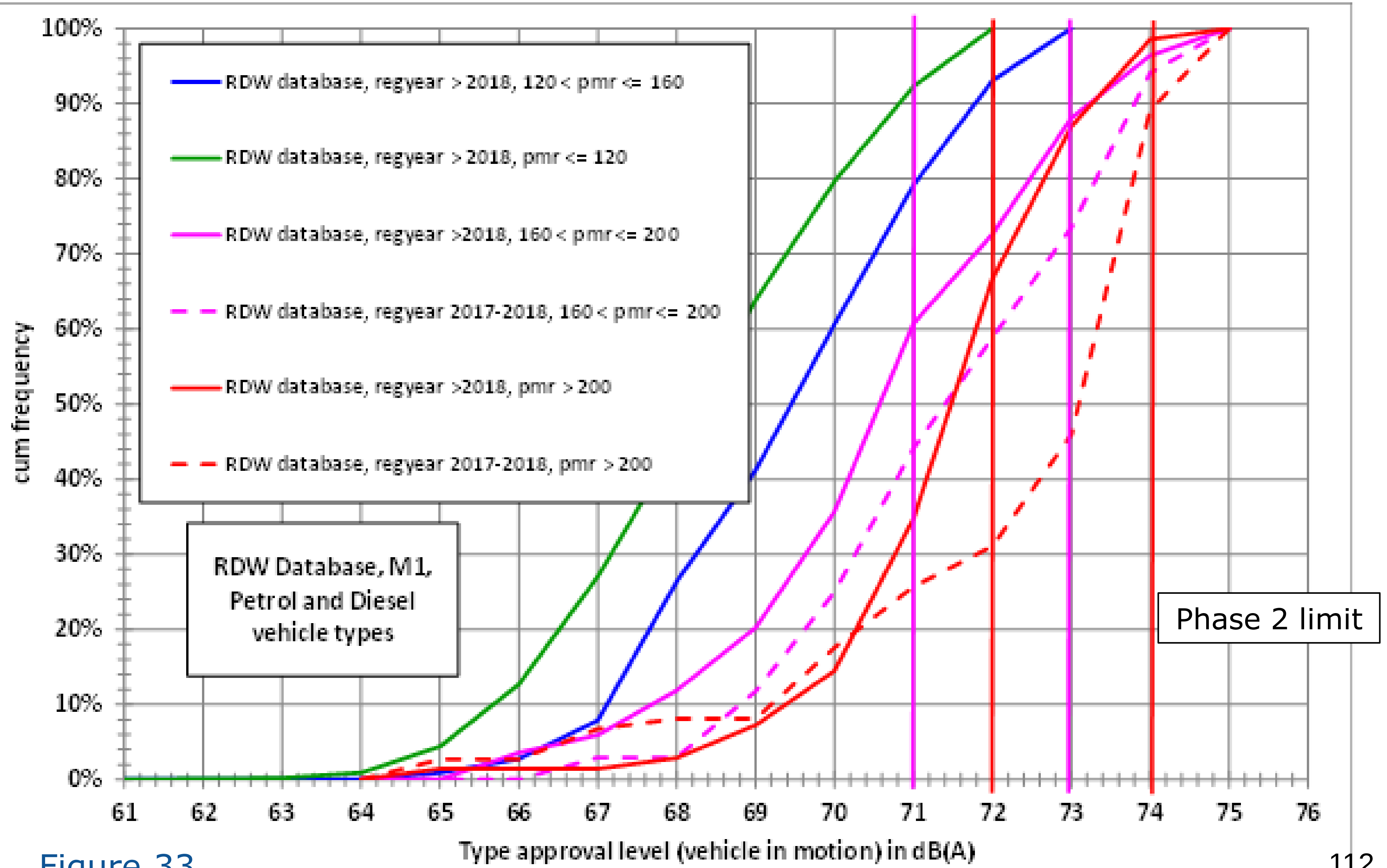


Figure 33

Proposal for phase 4 limit values

N1 vehicles

- *In Regulation (EU) No. 540/2014 N1 vehicles are subdivided into 2 subcategories with regard to their TPMLM : up to 2500 kg and above 2500 kg.*
- *The relevance of vehicles with GVM above 2500 kg for delivery in residential and urban areas has increased due to online shopping and the propulsion noise of these vehicles is of higher importance than for M1 vehicles due to the higher relative power demand and more frequent stopping.*
- *The L_{urban} frequency distributions for N1 vehicles from the RDW database are shown in Figure 34 for both subcategories and registration years >2018 and 2016-2018.*
- *Corresponding distributions for M1 vehicles with pmr <= 120 W/kg are shown for comparison.*
- *The trend towards lower L_{urban} values for vehicles registered in 2019 or 2020 compared to 2016-2018 is the same as for M1 vehicles and is most probably caused by the fact that new vehicle types have to fulfil phase 2 limits from 1st of July 2020 on.*

L_{urban} frequency distributions for N1 vehicles with TPMLM <= 2500 kg and TPMLM > 2500 kg for registration years >2018 and 2016-2018

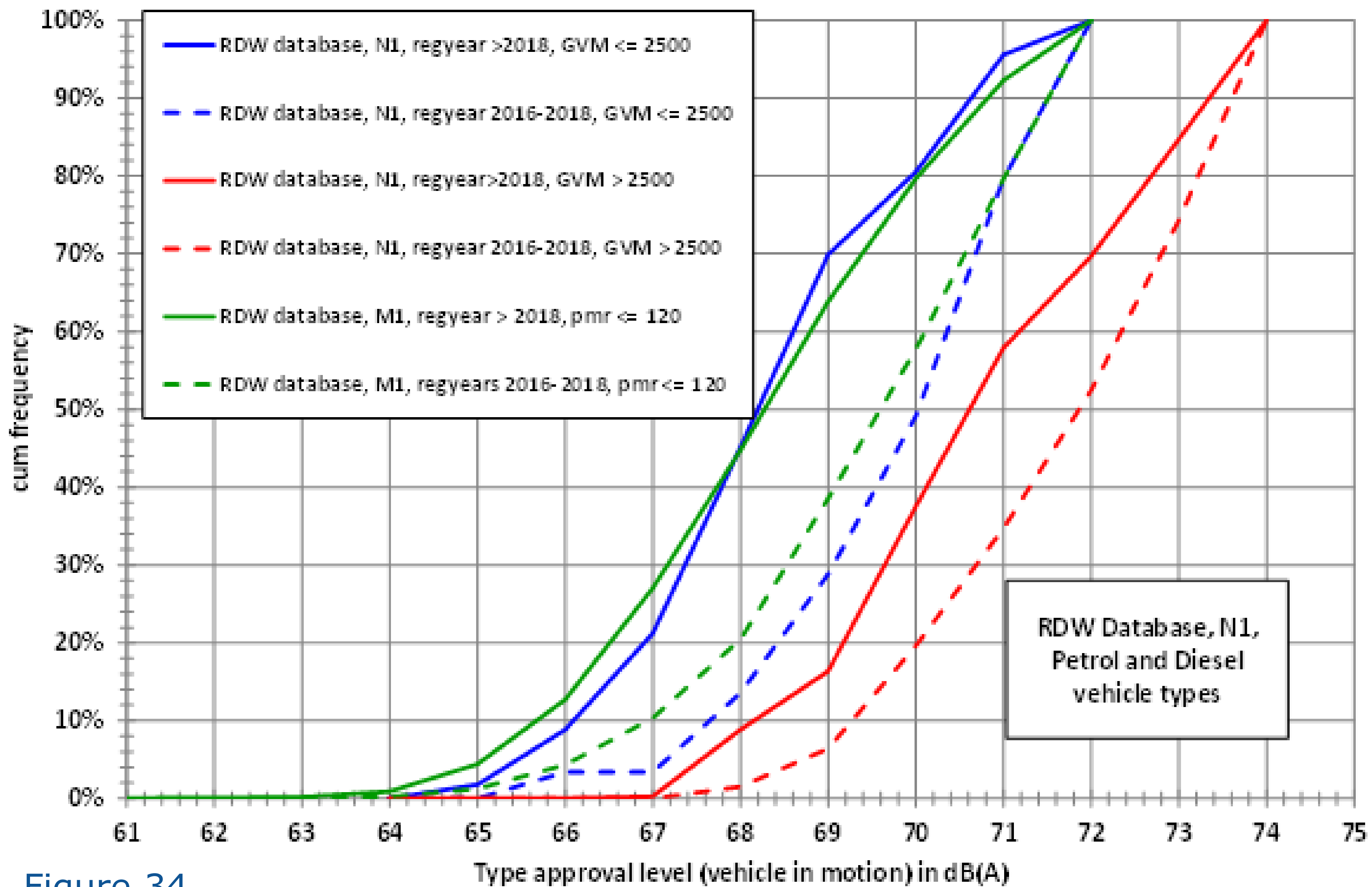


Figure 34

Proposal for phase 4 limit values

N1 vehicles

- *The distribution for N1 vehicles with TPMLM <= 2500 kg registered in 2019 or 2020 is almost identical with the corresponding M1 distribution, while the distribution for N1 vehicles with TPMLM > 2500 kg have 2.4 dB(A) higher values (50% percentiles).*
- *For N1 with TPMLM <= 2500 kg the phase 2 limits are already fulfilled for 95.6% of all vehicle types and the phase 3 limits for 69.9% of all vehicle types registered in 2019 and 2020. The corresponding percentages when applying the M1 limits are 80.5% and 45.1%.*
- *From this result it could be concluded that the N1 vehicles with TPMLM <= 2500 kg could get the same limit as the M1 vehicles with pmr <= 120 W/kg already for phase 3.*
- *But the vehicle from this subcategory that was tested during this study showed a 2 dB(A) higher L_{urban} value than the average of the 3 tested M1 vehicles with pmr <= 120 W/kg. Even if one considers that this N1 vehicle had the highest rolling sound levels at 50 km/h of all M1 and N1 vehicles a 1 dB(A) difference would remain.*

Proposal for phase 4 limit values

N1 vehicles

- ***Therefore, it is proposed to apply a phase 4 limit value of 68 dB(A) for N1 vehicles with TPMLM <= 2500 kg , starting 4 years after the start of phase 3.***
- ***For N1 vehicles with TPMLM > 2500 kg it is proposed to keep the phase 3 limit also for a 4th phase.***

Proposal for phase 4 limit values

M2 vehicles

- *M2 vehicles are used for the carriage of passengers with a TPMLM up to 5000 kg.*
- *In Regulation (EU) No. 540/2014 M2 vehicles are subdivided into 3 subcategories with regard to their TPMLM:*
    1. up to 2500 kg,
    2. 2500 kg < TPMLM <= 3500 kg and
    3. > 3500 kg.
- *Subcategory 3 is subdivided into 2 rated power subclasses, but only for phase 2, so that this does not need to be considered here.*
- ***M2 vehicles with GVM <= 2500 kg do not exist in the databases, neither in the KBA database nor in the RDW database. Consequently, no proposals regarding limit values can be made and this subcategory could be deleted for the EU.***

Proposal for phase 4 limit values

M2 vehicles with 2500 kg < TPMLM <= 3500 kg

- *The RDW database contains only 1 vehicle, registered in 2016.*
- *The KBA database contains 6 vehicles; all of the same type, two each for the approval years 2016, 2017 and 2018 with L_{urban} = 74 dB(A); this is exactly the phase 1 limit value.* ***But since M2 vehicles in this subcategory are technically similar to N1 vehicles of the same TPMLM range it is proposed to apply the same limit value.***

M2 vehicles with 3500 kg < TPMLM <= 5000 kg

- *35 vehicle types were found in the RDW database with rated power values between 74 and 140 kW and registration years between 2012 and 2020. 91 vehicles were found in the KBA database with rated power values between 70 and 140 kW and approval years between 2016 and 2019.*
- *The type approval level distributions are shown in Figure 35. Figure 36 shows the type approval levels versus rated power (Pn).* ***A subdivision in Pn <= 135 kW and Pn > 135 kW is not justified and can be skipped in future as already done for phase 3.***

Type approval level distributions for M2 vehicles with 3500 kg < TPMLM (or GVM) <= 5000 kg from the RDW and KBA databases.

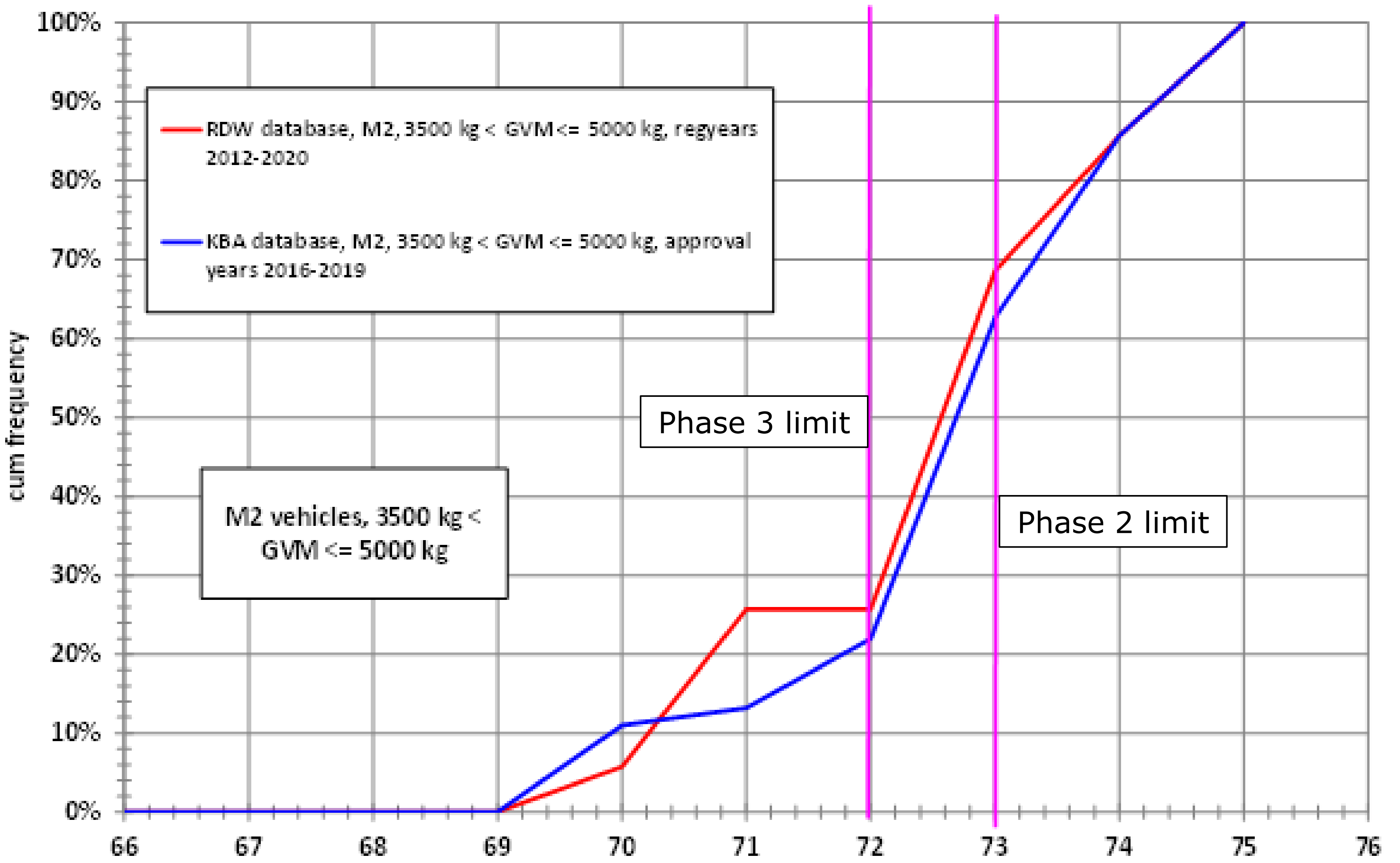


Figure 35

Type approval level versus rated power for M2 vehicles with 3500 kg < TPMLM <= 5000 kg from the RDW and KBA databases

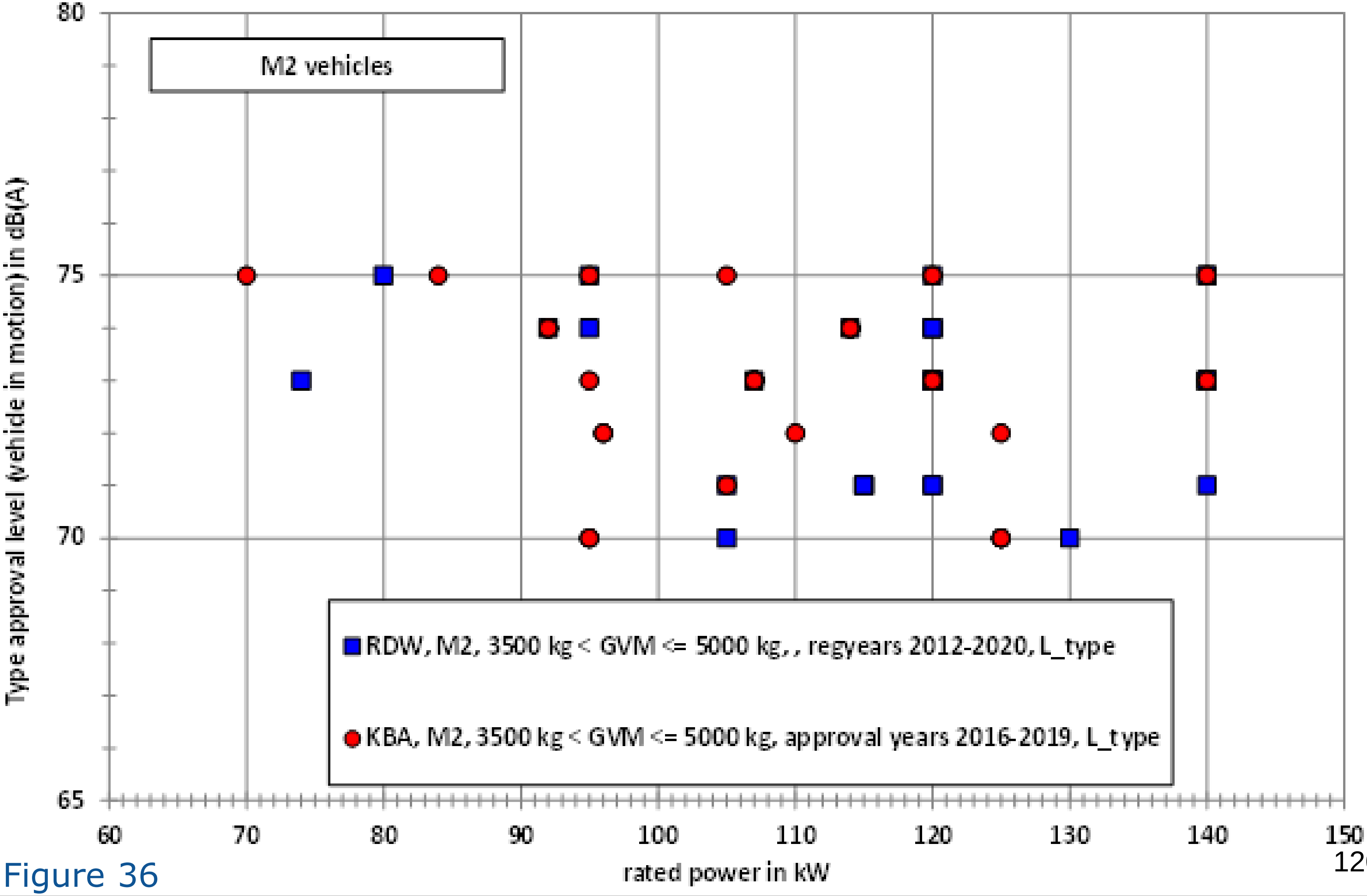


Figure 36

Proposal for phase 4 limit values

M2 vehicles with 3500 kg < TPMLM <= 5000 kg

- ***Taking into account that only less than 30% of the vehicle types in the databases fulfill the phase 3 limit values and that the M2 vehicles have only a small share on the vehicle stock no further limit value reduction after phase 3 is proposed.***

Proposal for phase 4 limit values

M3 vehicles

- *M3 vehicles are used for the carriage of passengers with a TPMLM above 5000 kg.*
- *In Regulation (EU) No. 540/2014 M3 vehicles are subdivided into 3 subcategories with regard to their rated power values (Pn):*

1. Pn <= 150 kW,
2. 150 kW < Pn <= 250 kW,
3. Pn > 250 kW.

Proposal for phase 4 limit values

M3 vehicles with Pn <= 150 kW

- *The KBA database does not contain any data for M3 vehicles with Pn <= 150 kW, but 130 vehicles with registration years between 2013 and 2020 were found in the RDW database.*
- *The rated power values range from 105 to 140 kW and the TPMLM values from 5300 to 8160 kg. These vehicles are technically similar to the M2 vehicles with 3500 kg < TPMLM <= 5000 kg and N2 vehicles.*
- *Their importance for the whole vehicle fleet is negligible and their type approval level distribution is close to the distribution for the M2 subcategory mentioned in the sentence before (see Figure 37).*
- ***Therefore, it is proposed to set a phase 4 limit value of 72 dB(A), starting 4 years after phase 3.***

Type approval level distributions for M3 vehicles with Pn <= 150 kW and M2 vehicles with 3500 kg < TPMLM <= 5000 kg from the RDW database

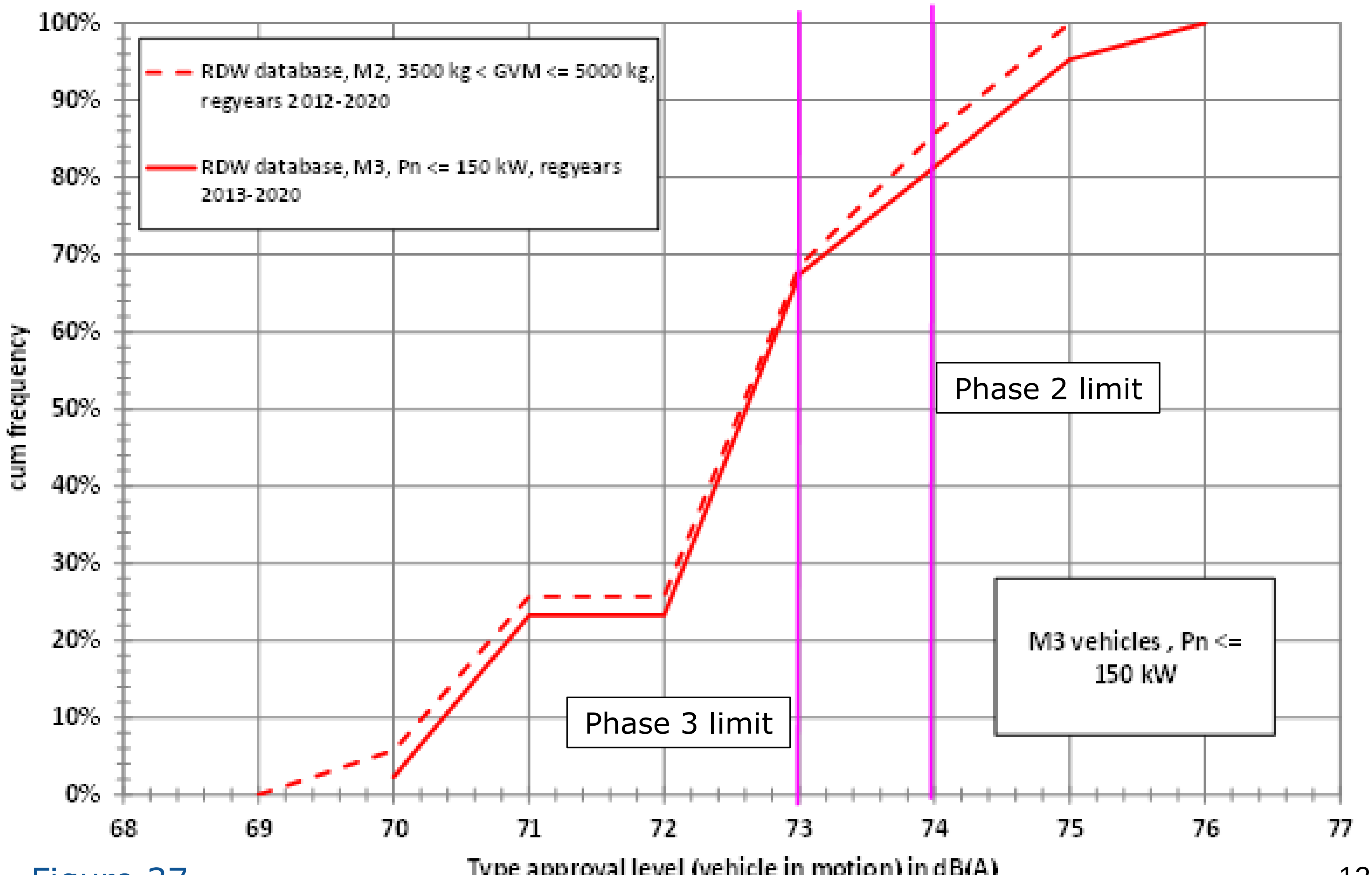


Figure 37

Proposal for phase 4 limit values

M3 vehicles with 150 kW < Pn <= 250 kW

- *The RDW database contains 57 vehicle types with Pn from 166 to 243 kW, TPMLM from 12000 to 28745 kg and registration years between 2011 und 2019.*
- *The KBA database contains 103 vehicle types with Pn from 151 to 243 kW, TPMLM from 10500 to 30000 kg and registration years between 2016 und 2019.*
- *The type approval level distributions are shown in Figure 38. The levels are significantly higher than for M3 vehicle types with Pn <= 150 kW and the RDW and KBA distributions are close together and almost parallel from the phase 1 limit down to type approval levels of 75 dB(A). From this value on there is a gap in the KBA distribution (no vehicle types with 74 and 75 dB(A) but 18 vehicle types with 73 dB(A) and 11 vehicle types with 72 dB(A)).*
- *The 72 dB(A) vehicle types are variants of a city bus dedicated for urban public transport. The extremely low sound level is most probably the result of additional reduction measures required by fleet owners. The RDW database contains variants of this model with type approval levels of 75 and 77 dB(A).*

Type approval level distributions for M3 vehicles with 150 kW < Pn <= 250 kW from the RDW and KBA databases

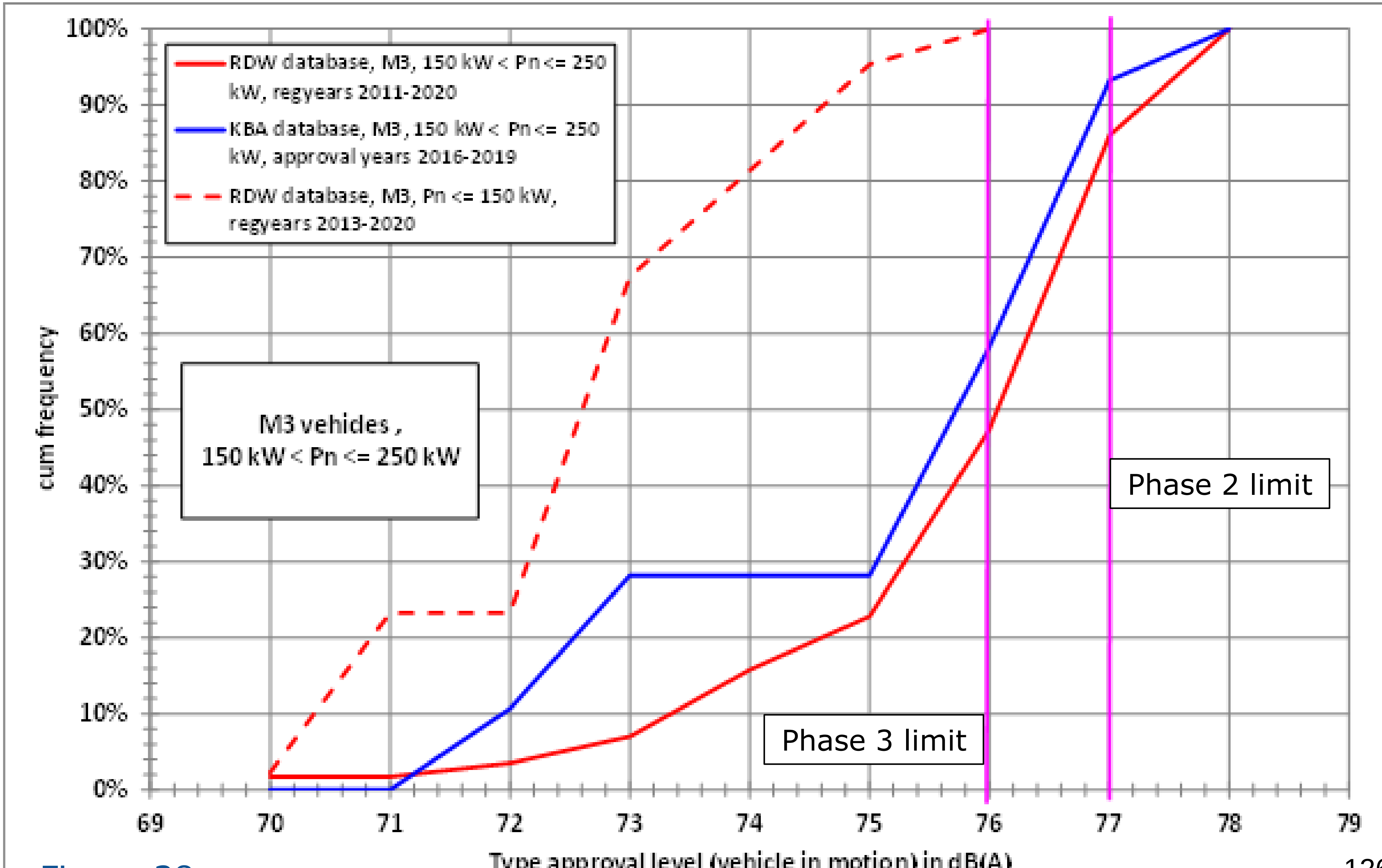


Figure 38

Proposal for phase 4 limit values

M3 vehicles with 150 kW < Pn <= 250 kW

- *The 73 dB(A) vehicle types are variants of two buses dedicated for urban public transport. There are other variants of these buses in the KBA database with 76 and 77 dB(A). In the RDW database is a Citaro bus variant with even 70 dB(A) but also with 76 and 77 dB(A).*
- *If one disregards these vehicle types in the distributions because they are the results of customer requirements rather than general technical development the phase 2 limits are already fulfilled by 85% (RDW) or 90% (KBA) of the vehicle types.*
- *The percentages for the phase 3 limits are 43.4% (RDW) or 41.9% (KBA) respectively.* ***On the other hand, it can be concluded from Figure 38 that the type approval levels of M3 vehicle types with 150 kW < Pn <= 250 kW are 3 dB(A) higher than those of M3 vehicle types with Pn <= 150 kW.***
- *The above mentioned facts show that it is obviously feasible to further reduce the type approval levels even below the phase 3 limit values, but it is questionable whether the customer required levels could be generalized without further analysis of the economic impact and whether such low values could also be required for coaches.*

Proposal for phase 4 limit values

M3 vehicles with 150 kW < Pn <= 250 kW

- ***Therefore, it is proposed to keep the 3 dB(A) limit value distance to the lower rated power subcategory and set a limit value of 75 dB(A) (-1 dB(A) compared to phase 3) for a 4th phase, starting 4 years after the start of phase 3.***

Proposal for phase 4 limit values

M3 vehicles with Pn > 250 kW

- *The RDW database contains 121 vehicle types with Pn from 260 to 390 kW, TPMLM from 17800 to 33500 kg and registration years between 2016 und 2019.*
- *The KBA database contains vehicle types with approval years between 2016 and 2019 with sample sizes above 100 for each approval year with Pn from 260 to 375 kW, TPMLM from 19000 to 33500 kg. The vehicle types in this subcategory consists of public transport buses (mainly intercity buses) and coaches.*
- *The type approval level distributions are shown in Figure 39.*
- *The trend towards lower type approval levels with increasing approval year as for M1 and N1 vehicle types cannot be found for this M3 subcategory.*
- *But a similar split of a model into variants with different type approval levels can be found as in the previous subcategory.*

Type approval level distributions for M3 vehicles with Pn > 250 kW from the RDW and KBA databases

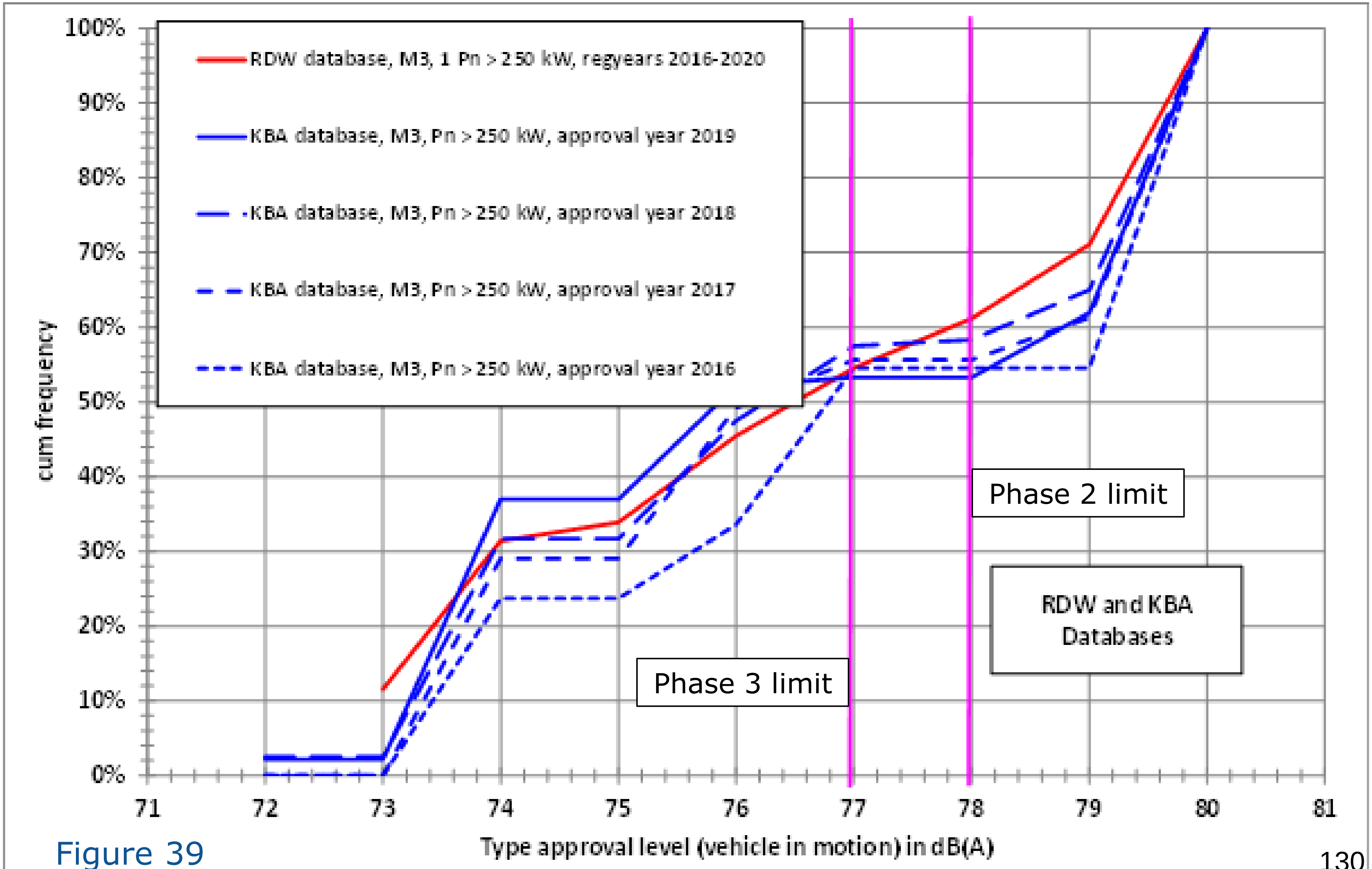


Figure 39

Proposal for phase 4 limit values

M3 vehicles with Pn > 250 kW

- ***One can conclude from the discussion above, that a 1 dB(A) limit value reduction for phase 4 seems to be appropriate. A proposal for a higher limit value reduction for phase 4 would require more information about the economic implications.***

Proposal for phase 4 limit values

N2 vehicle

- *N2 vehicles are vehicles used for the carriage of goods with a TPMLM above 3500 kg but not exceeding 12000 kg. In Regulation (EU) No. 540/2014 N2 vehicles are subdivided into 2 subcategories with regard to their rated power (Pn):*

  1. Pn <= 135 kW,
  2. Pn > 135 kW.

- *The KBA statistics are not considered here because they are dominated by vehicle types from one manufacturer only. Therefore, the following discussion focusses on the RDW data results.*
- *Table 12 shows the joint frequency distribution of type approval levels and rated power values for N2 vehicle types from the RDW database for the registration years 2019 and 2020.* ***The cells highlighted in yellow represent downsized N3 vehicle types. Their share is 21% of all N2 vehicle types.***

Joint frequency distribution of type approval levels and rated power values for N2 vehicle types from the RDW database for the approval years 2019 and 2020

	Type approval level in dB(A)												
Pn in kW	68	69	70	71	72	73	74	75	76	77	78	79	Totals
84								1					1
90					1								1
96						1							1
100						2	3		2				7
105			3				1	3					7
107									2				2
110		1			2	8	3	2		2	8		26
114						3							3
115					1			2		4	2		9
118								5			3	3	11
120	3			4		2	4	5	3				21
125			2		2		2				4		10
129							3	3			2		8
130	1	6	6	2	2	14	1			4	2	1	39
132							13	4			11		28
135											7	1	8
137											7		7
140				5		2	1	6	3	3	4		24
150					8			1				2	11
155									10				10
157												6	6
158										7		2	9
162								4					4
170									2				2
172												3	3
180										4			4
184								4					4
188										1	4	1	6
194												1	1
210											1		1
272										1			1
278										1			1
283										1			1
306										1			1
328												1	1
330									1	1			2
331										1			1
336									1				1
Totals	4	7	11	11	16	32	31	40	24	31	55	21	283

Downsized N3 vehicle types

Table 12

Proposal for phase 4 limit values

N2 vehicle

- *The type approval level distributions of N2 vehicle types in different rated power subcategories are shown in Figure 40.*
- *Since the KBA database allows the differentiation between on-road and off-road versions of a vehicle type, the type approval distributions of the same vehicle in different versions (Pn, TPMLM etc.) are shown in addition.*
- *Since there are no significant differences between vehicle types with rated power values between 136 kW and 150 kW and vehicle types with rated power values of 135 kW or below,* ***it can be concluded that a power borderline of 150 kW would be more appropriate than the current 135 kW borderline****.*
- ***Furthermore, the results for the MB Sprinter in on-road and off-road versions confirms that a higher limit value for off road vehicles seems still to be justified.***
- ***The results of the 3 N2 vehicles tested within this study confirm the findings from the type approval database analysis.***

Type approval level distributions for N2 vehicles from the RDW database

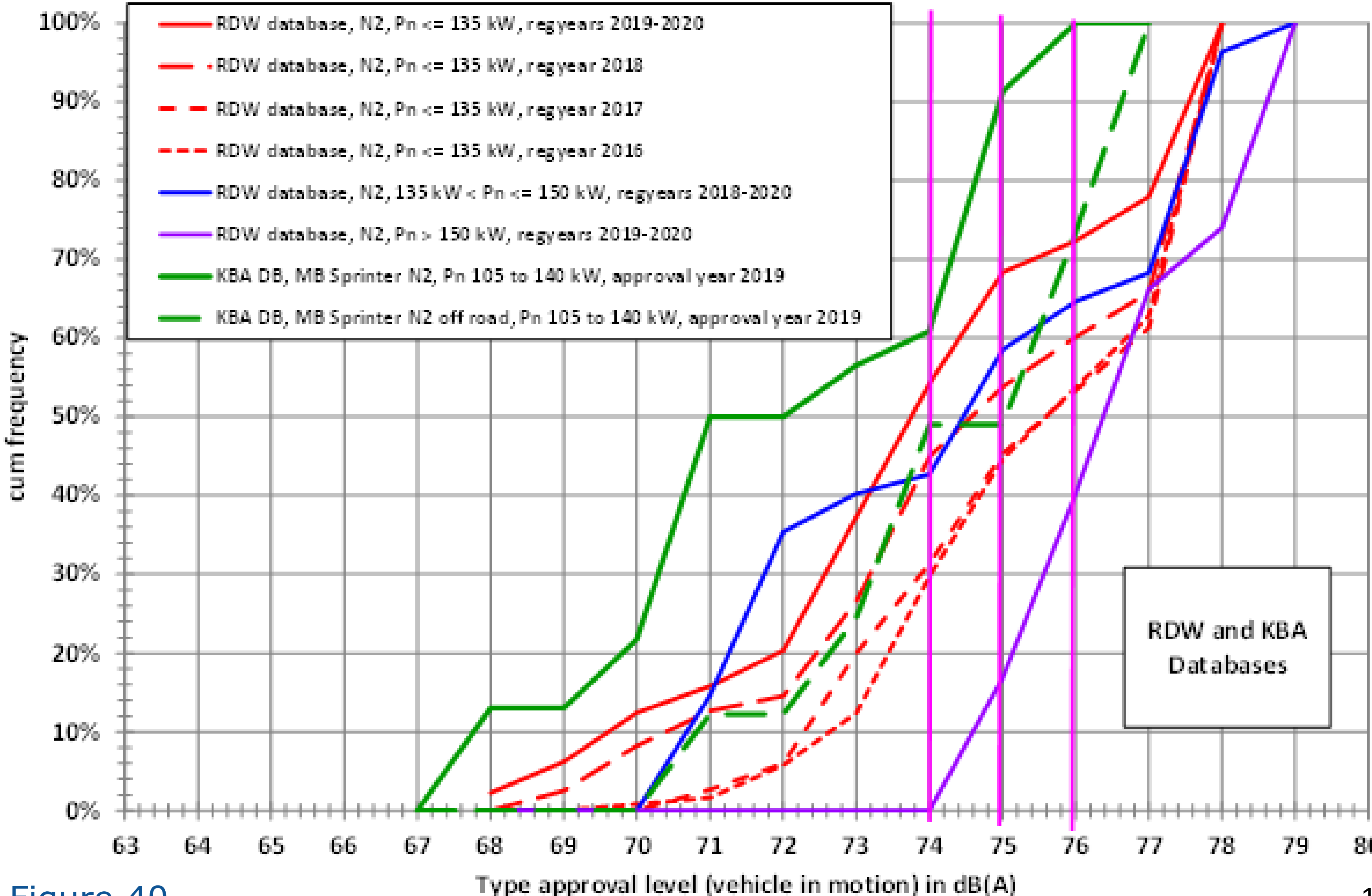


Figure 40

Proposal for phase 4 limit values

N2 vehicle

- ***It is therefore proposed to change the subcategorisation for N2 vehicles to the following subcategories for phase 4 as follows:***

  1. Pn <= 150 kW,

  2. Pn > 150 kW.

- ***Since a limit value of 74 dB(A) is already fulfilled by more than 73% of the vehicle types with Pn <= 150 kW, a limit value of 73 dB(A) is proposed for the new subcategory 1 and to keep the limit value for the new subcategory 2 at 75 dB(A) for phase 4.***

- ***Alternatively, one could merge both subcategories, apply the above mentioned limit value and add a footnote analogous to the M1 pmr <= 120 W/kg subcategory:***

- ***(1) N2 vehicles derived from N3 vehicles with a total permissible laden mass of 12000 kg and a rated power above 150 kW have to fulfil the limit values of N3 (Pn <= 250 kW).***

Proposal for phase 4 limit values

N3 vehicle

- *N3 vehicles are vehicles used for the carriage of goods with a TPMLM above 12000 kg. In Regulation (EU) No. 540/2014 N3 vehicles are subdivided into 3 subcategories with regard to their rated power (Pn):*

  1. Pn <= 150 kW,
  2. 150 kW < Pn <= 250 kW,
  3. Pn > 250 kW

Proposal for phase 4 limit values

N3 vehicles Pn <= 150 kW

- *This Pn subcategory contains borderline vehicles between N2 and N3 with Pn between 130 and 137 kW and TPMLM values between 12000 kg and 15000 kg.*
- ***The RDW database** contains for the registration years 2017-2020:*
  - **9 variants** of the Mercedes-Benz Atego with Pn = 130 kW, TPMLM values between 12000 kg and 15000 kg and type approval values of 77 or 78 dB(A),
  - **3 variants** of the DAF LF 180 FA with Pn = 135 kW and TPMLM values between 12000 kg and 16000 kg and a type approval value of 78 dB(A),
  - **6 variants** of an IVECO vehicle type with Pn = 137 kW and TPMLM values between 12000 kg and 14000 kg and a type approval value of 78 dB(A).
- ***The KBA database** contains only **14 variants** of the Mercedes Benz Atego with Pn = 130 kW, a TPMLM value of 16000 kg and type approval values of 77 or 78 DB(A) for the approval years 2017-2019.*

Proposal for phase 4 limit values

N3 vehicles Pn <= 150 kW

- *None of these vehicles already fulfill the phase 3 limit and less than 50% fulfill the phase 2 limit (43% in the KBA database and 26% in the RDW database).*
- *Obviously, it seems to require more effort to reduce the noise emission for engines that are designed for rated power values above 150 kW so that they fulfill the lower limit of this rated power subcategory.*
- ***And since it can be concluded from the database results that this N3 subcategory has no relevance for the N3 vehicle market/stock it is proposed to apply the same limit value as for N2 vehicles with Pn > 150 kW.***

Proposal for phase 4 limit values

N3 vehicles with 150 kW < Pn <= 250 kW, subcategory N3-2

- *The RDW database contains vehicle types of this subcategory from different manufacturers with engine capacities between 4500 and 10837 cm³, TPMLM between 12000 and 35000 kg, rated power values between 152 and 250 kW and type approval levels from 76 to 81 dB(A) for registration years from 2017 to 2020.*
- *The type approval level distributions of these vehicle types are shown in Figure 41.*
- *60% of all N3-2 vehicle types registered in 2020 (all GVM values) meet the phase 2 limit (79 dB(A)), the phase 3 limit (77 dB(A)) is met by 30%.*
- *Figure 42 shows the L_{50} (50% percentile of the type approval level distributions) values, and the percentages of phase 2 and phase 3 compliant vehicle types in dependence of the approval year.*

Type approval level distributions for N3 vehicles with 150 kW < Pn <= 250 kW from the RDW database

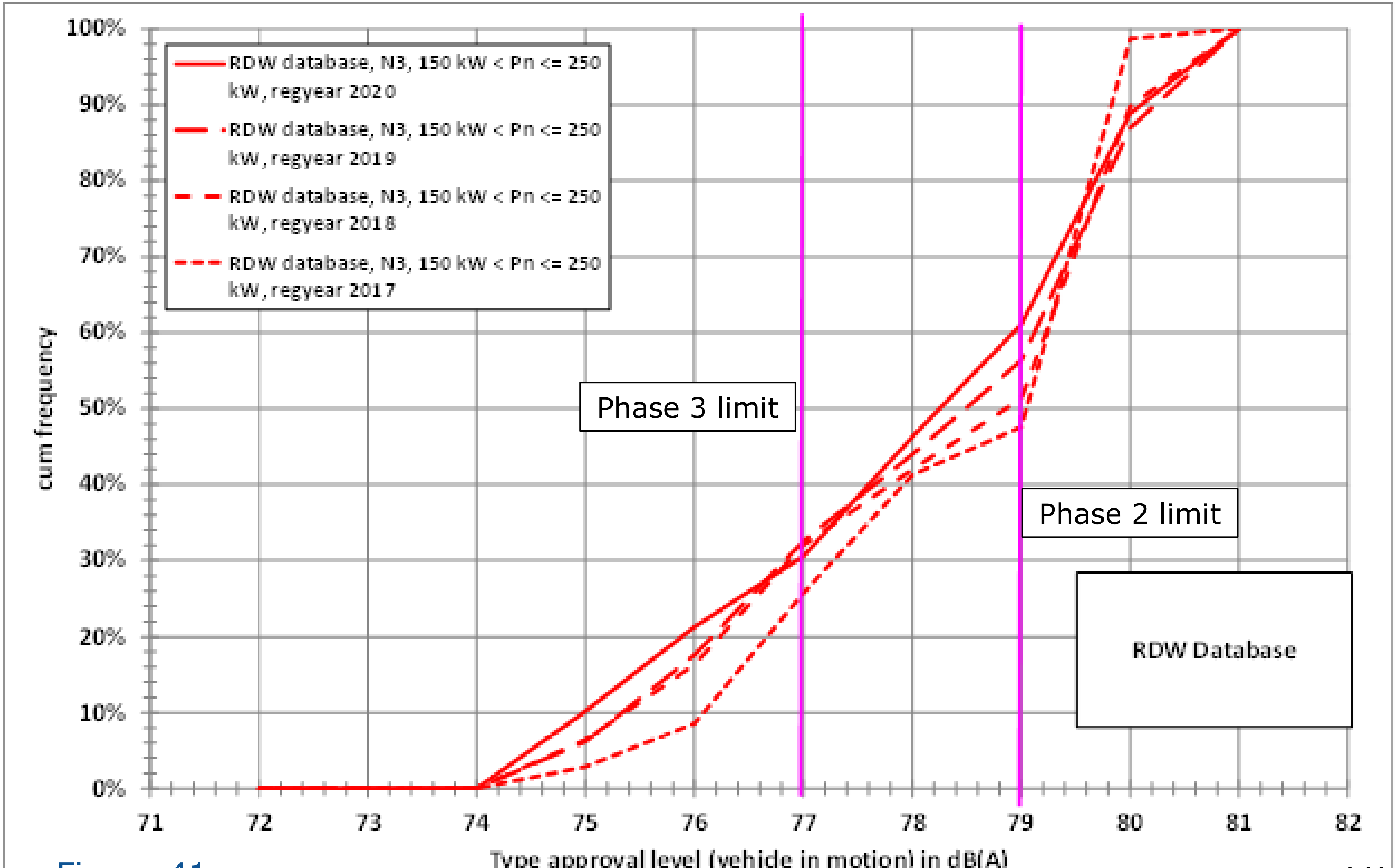


Figure 41

L_{50} (50% percentile of the type approval level distributions), and percentages of phase 2 and phase 3 compliant vehicle types in the RDW database for N3 vehicles with 150 kW < Pn <= 250 kW in dependence of the approval year

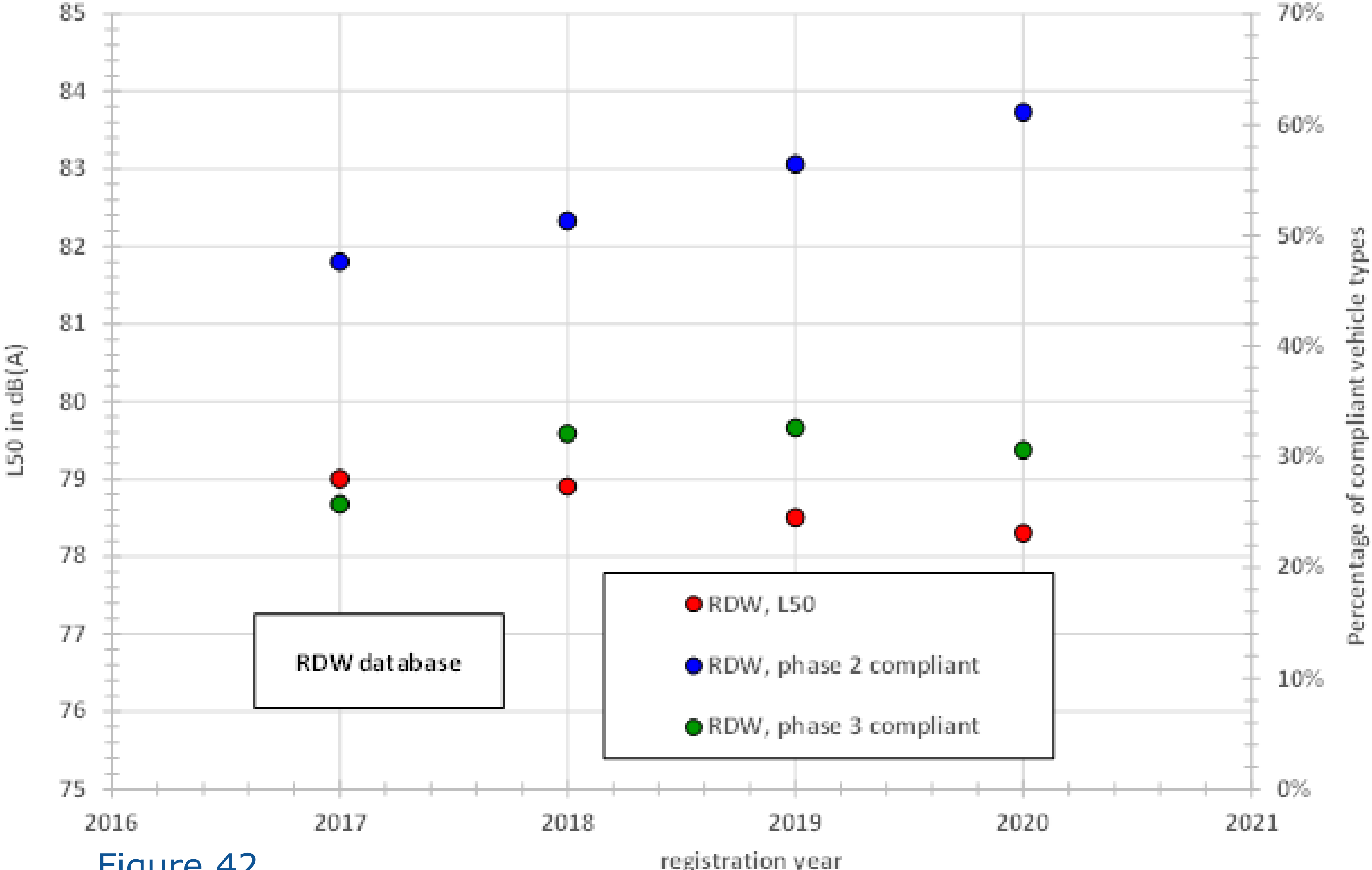


Figure 42

Proposal for phase 4 limit values

N3 vehicles with 150 kW < Pn <= 250 kW, subcategory N3-2

- *Between 2017 and 2020 there is a trend to increasing percentages for phase 2 compliant vehicles and a corresponding trend to decreasing L_{50} values, but the phase 3 compliant vehicle percentages seem to remain at around 30%.*
- *It is obviously not so easy to achieve phase 3 compliant type approval levels in this subcategory and it seems that the 30% of phase 3 compliant vehicle types that came into the market 6 to 8 years before the start of phase 3 (2026) are not driven by the limit values but by other factors.*
- *An indication for this is the fact that these vehicle types are special variants of vehicle models whose other variants have type approval levels around the phase 2 limit (78 to 80 dB(A)).*
- ***Since the difference between the phase 3 and phase 1 limit values is 4 dB(A) no further reduction for a phase 4 is proposed. A further limit value reduction for phase 4 would require more information about the technical solutions and the economic implications.***

Proposal for phase 4 limit values

N3 vehicles with Pn > 250 kW, subcategory N3-3

- *The RDW database contains vehicle types of this subcategory from different manufacturers with engine capacities between 6871 and 16353 cm³, TPMLM between 12000 and 72000 kg, rated power values between 251 and 573 kW and type approval levels from 75 to 82 dB(A) for registration years from 2017 to 2020.*
- *The type approval level distributions of these vehicle types (subcategory N3-3) are shown in Figure 43. The distributions from the Pn subcategory N3-2 are shown for comparison.*
- ***A 2 dB(A) difference in the limit values for phases 2 and 3 between the N3-2 and N3-3 subcategories is not justified at all**. The phase 2 limit of 81 dB(A) is already met by all N3-3 vehicle types except one. 2/3 of all N3-3 vehicle types fulfill already the phase 3 limit. The phase 2 limit of the N3-2 subcategory (79 dB(A)) is met by 60% of the N3-2 vehicle types and even 68% of the N3-3 vehicle types.*
- *The percentages for the phase 3 limit are 30% for N3-2 and 46% for N3-3 vehicle types.*

Type approval level distributions for N3 vehicles with Pn > 250 kW (red lines) from the RDW database

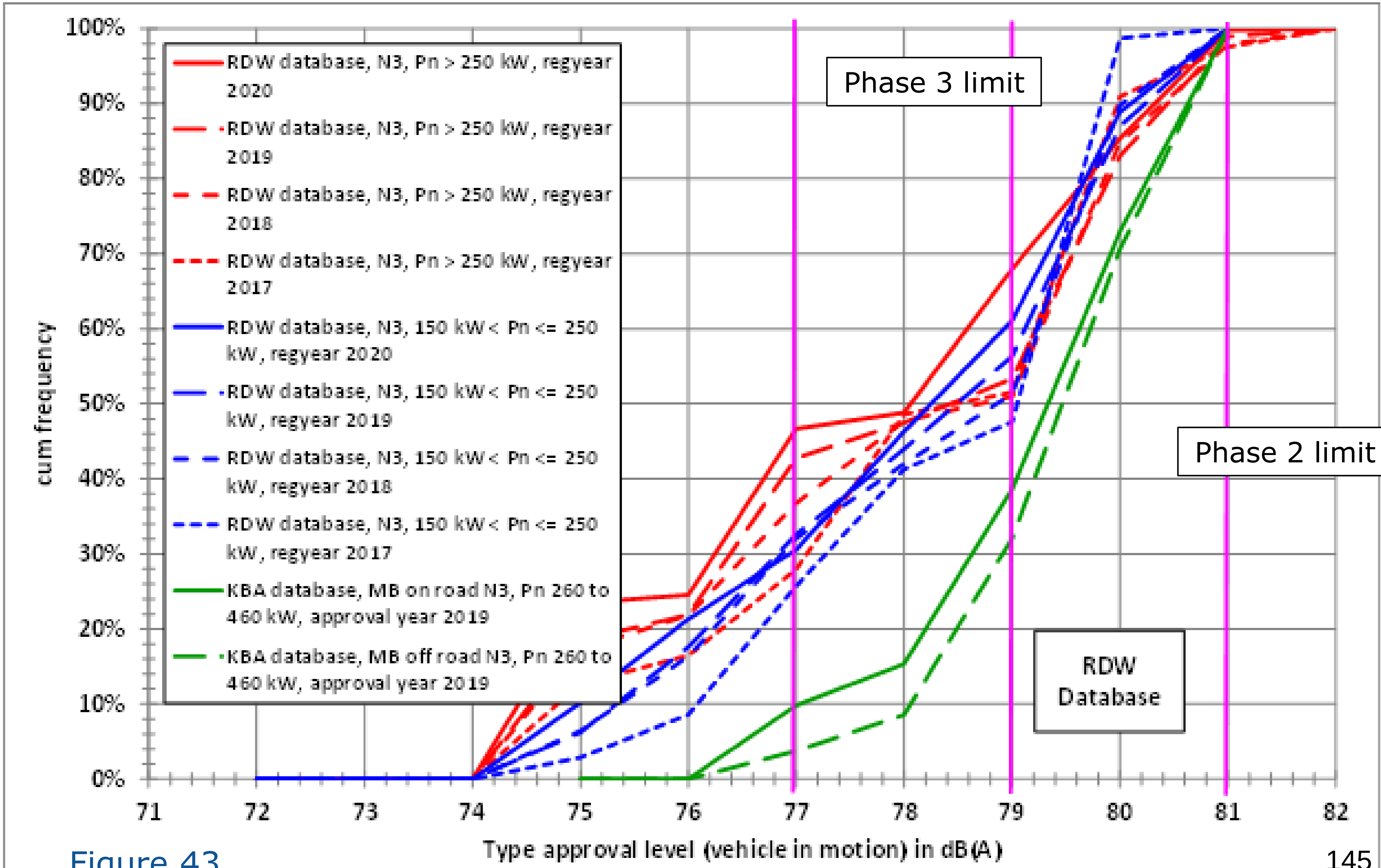


Figure 43

Proposal for phase 4 limit values

N3 vehicles with Pn > 250 kW, subcategory N3-3

- *The difference in L_{50} percentiles for both subcategories for the registration year 2020 is only 0.2 dB(A) with the higher level for the lower Pn subclass.*
- ***Therefore, it is proposed to merge both Pn subclasses and keep the phase 3 limit of the N3-2 subclass for both. This could already be done for phase 3 but should at least be done for a phase 4.***

Content

1. Introduction,
2. Feedback gathering and literature review,
3. Testing of vehicles’ sound emission values,
4. Cost benefit analysis,
5. Proposal for phase 4 limit values,
6. Discussion about amendments of the measurement method and ASEP requirements.

Amendments of the measurement method and ASEP requirements

Measurement method, M1, M2 with TPMLM <= 3500 kg and N1

- *For M1, M2 vehicles with TPMLM <= 3500 kg and N1 vehicles the situation is as follows:*
- *The test result is calculated as weighted average of WOT acceleration tests and constant speed tests.*
- *The rationale behind is the approximation of a partial load acceleration test in the speed range around 50 km/h which is seen as typical acceleration condition for urban streets.*
- *The approximation method was based on statistical analyses of in-use driving behaviour data measured in the time period 1995 to 2005.*
- *The ASEP requirements are currently amended for revision 4 of R 51.*

Amendments of the measurement method and ASEP requirements

Measurement method, M1, M2 with TPMLM <= 3500 kg and N1

The achieved acceleration $a_{wot\ test}$ is then used for the calculation of the partial power factor k_p (see paragraph 3.1.2.1.3.) instead $a_{wot\ ref}$.

$a_{wot\ test}$ is specified in paragraph 3.1.2.1.2 of annex 3 to this regulation.

(end of quote)

- *The equations for $a_{wot\ ref}$, a_{urban} and nBB',max versus pmr are shown in Figure 44.* ***The acceleration curves are not modified in the draft for revision 4 but the nBB',max limitation in revision 4 compared to nBB',max = rated speed in revision 3 is in favour of high powered vehicles and could allow higher sound emissions in real traffic.***

$a_{wot\ ref}$, a_{urban} and nBB',max versus pmr

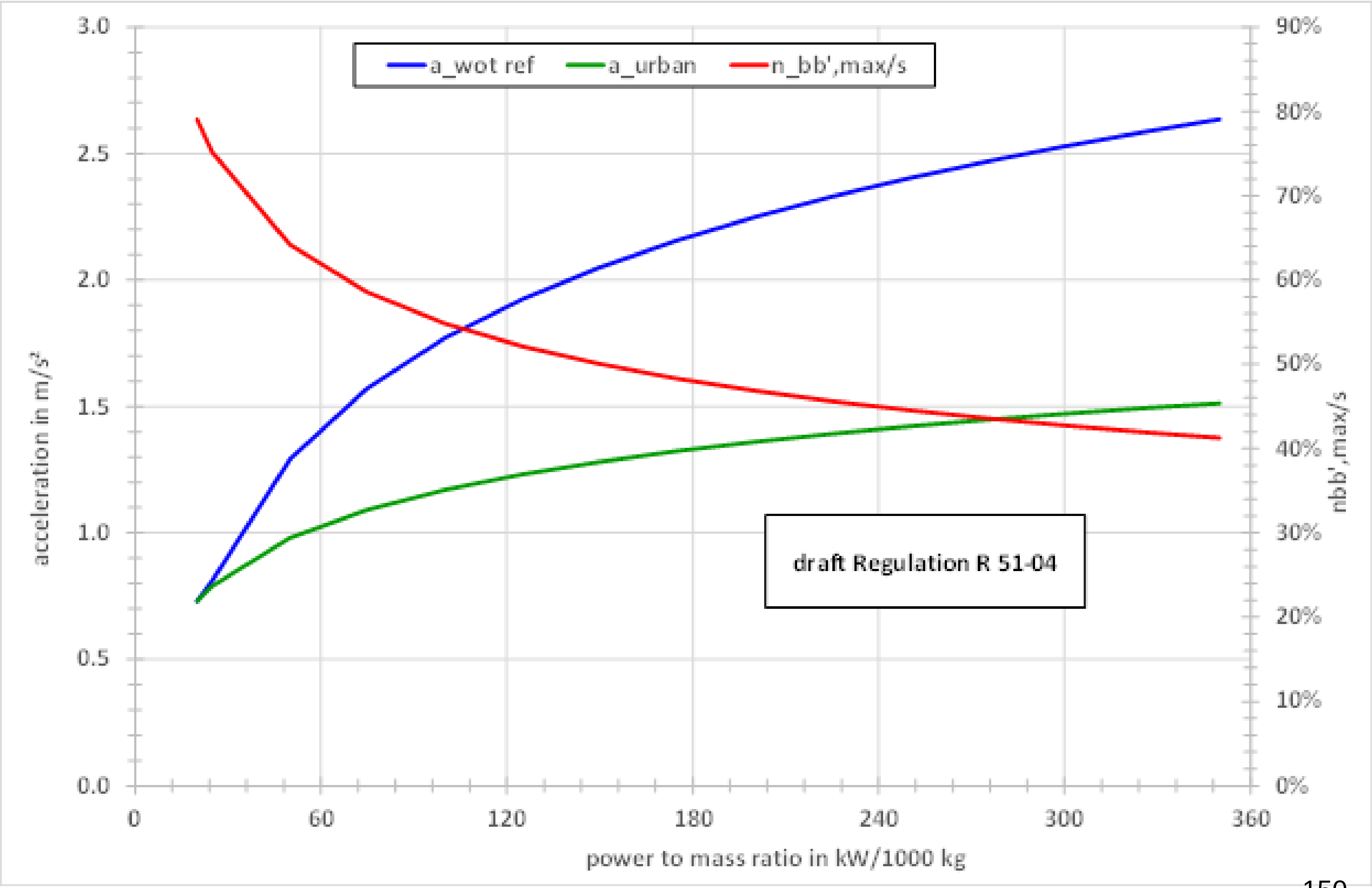


Figure 44

Amendments of the measurement method and ASEP requirements

Measurement method, M1, M2 with TPMLM <= 3500 kg and N1

- ***Two points must be mentioned and proposed for amendment:***
  1. The statistical basis for $a_{wot\ ref}$, a_{urban} and nBB',max,
  2. the limitation of $a_{wot\ test}$ to 2 m/s².
- *As already mentioned, the statistical basis for $a_{wot\ ref}$, a_{urban} and nBB',max, is in-use driving behaviour data from 1995 to 2005, about 20 years ago.*
- *The pmr of the vehicles under discussion have been increased significantly and this trend is not yet broken (see Figure 45 and Figure 46). The average values for M1 vehicles increased from 62 W/kg to 70 W/kg between 2005 and 2020.*
- *And since it is known from in-use driving behaviour data analyses that the acceleration in real traffic increase with pmr, depending on the driving behaviour, it is recommended to scrutinise the validity of the equations for $a_{wot\ ref}$, a_{urban} and nBB',max using in-use driving behaviour from recent or ongoing projects.*

Average pmr values versus registration year from the RDW database

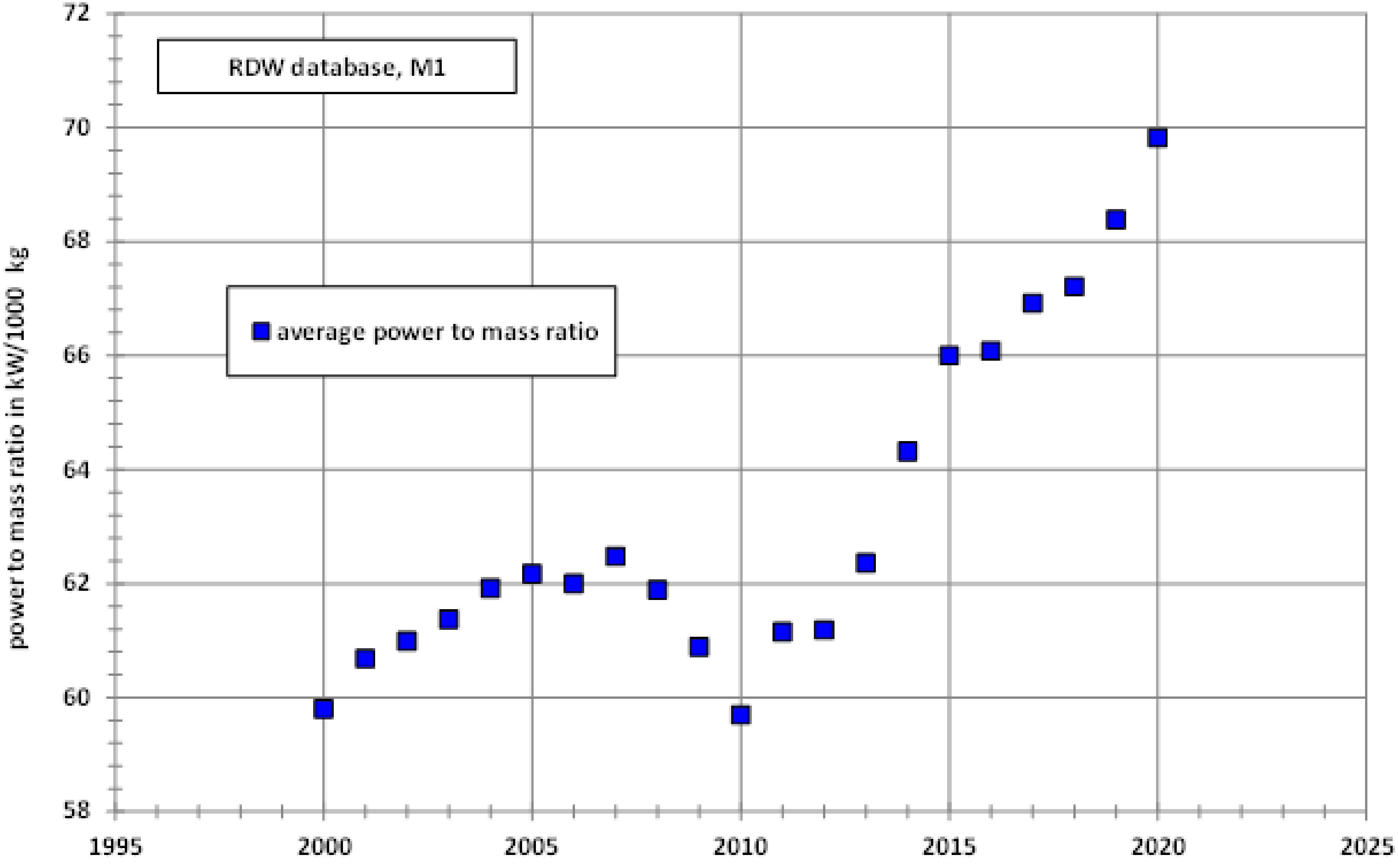


Figure 45

Distributions of pmr values for M1 vehicles from the RDW database for different registration years.

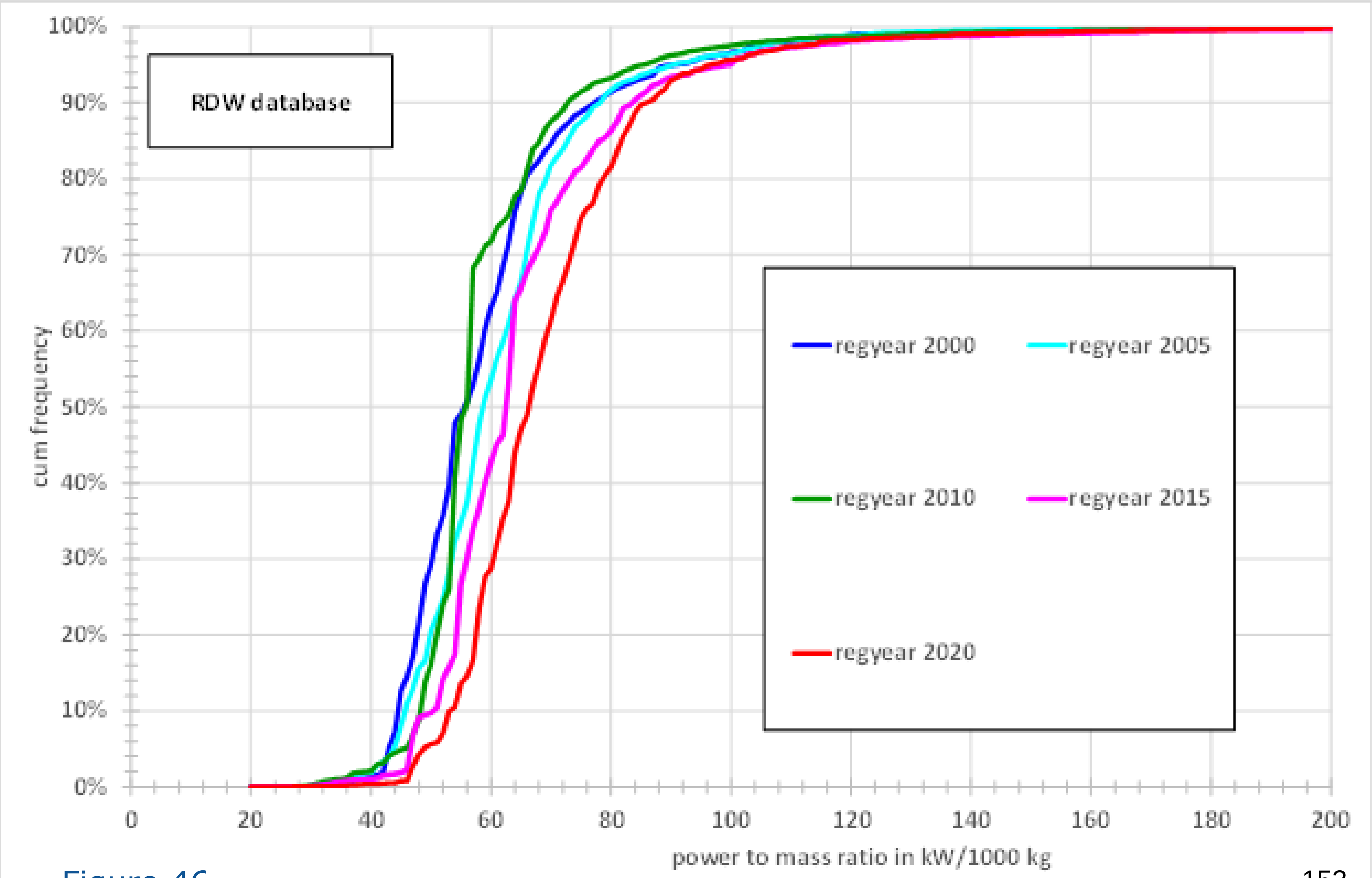


Figure 46

Amendments of the measurement method and ASEP requirements

Measurement method, M1, M2 with TPMLM <= 3500 kg and N1

- *But more important is the second point, the limitation of $a_{wot\ test}$ to 2 m/s². There is absolutely no evidence that this limitation is still justified.*
- *Calculations performed with the gearshift calculation tool for WLTP showed that 3rd and 4th gear would be used for this speed range and accelerations according to $a_{wot\ ref}$. And also the results of the UDRIVE project show that a 2 m/s² threshold is no longer justified.*
- ***In this context it should be mentioned that UNECE Regulation No. 41.04 for motorcycles uses the same approach for the determination of the test gears but without any limitation of $a_{wot\ test}$.***
- ***It is therefore recommended to align the gear selection requirements for the tests with UNECE Regulation No. 41.04 and skip the 2 m/s² limitation.***

Amendments of the measurement method and ASEP requirements

Measurement method, M1, M2 with TPMLM <= 3500 kg and N1

- ***A further alignment with UNECE Regulation No. 41.04 is recommended and this is the limitation of L_{wot}.***
- ***UNECE Regulation No. 41.04 specifies that L_{wot} must not exceed L_{urban} by more than 5 dB(A). This limitation is not needed under the current gear selection specifications because high L_{wot} values are prevented by the 2 m/s² acceleration limitation.***
- ***But it should be added when this limitation will be skipped in order to prevent too high L_{wot} values for vehicles with high pmr values compared to "normal" or average vehicles.***

Amendments of the measurement method and ASEP requirements

ASEP requirements

- *The ASEP requirements of UNECE Regulation No. 51.03 are specified in paragraph 6.2.3 of the main body and annex 7 (referred to as "current version" in the following).*
- *These specifications are currently amended. The actual amendment proposal is specified in Informal document GRBP-73-05 "Proposal for the 04 series of amendments to UNECE Regulation No. 51" (referred to as "new version" in the following).*
- *The header of paragraph 6.2.3 of UNECE Regulation No. 51.03 "Additional sound emission provisions" is changed in Informal document GRBP-73-05 to "Real Driving Additional Sound Emission Provisions". In UNECE Regulation No. 51.03 the application of ASEP is restricted to M1 and N1 vehicles equipped with an internal combustion engine.*
- ***In Informal document GRBP-73-05 it is extended to ICE or any other propulsion technology fitted with an exterior sound enhancement system.***

Amendments of the measurement method and ASEP requirements

ASEP requirements

- ***The most important modifications can be summarised as follows:***
- ***The control range in terms of vehicle speed, gear selection and driving conditions will be extended significantly with one exception: The acceleration limitation will be restricted.***
- ***The measurement distance is extended to AA′ to BB′ + 20 m in order to cover also backfire events.***
- ***An even more important modification is planned for the calculation of the results and the conformity checks. The current method foresees 3 alternative methods (Slope-Assessment, L_{urban} Assessment and Reference sound assessment) that can be chosen by the manufacturer.***

Amendments of the measurement method and ASEP requirements

ASEP requirements

- ***The new conformity checks are based on a Sound Expectation Model.***
- ***This method is even more complex than the current ones.***
- ***But all methods suffer from far too high tolerances especially for high powered vehicles, so that the effectiveness can be questioned.***
- ***Even with the amendments as described in informal document GRBP-73-05 the situation remains unsatisfactory as long as the tolerances allow sound emission values that are higher than the limit values for N3 vehicles with Pn > 150 kW.***
- ***It should not be accepted that a car can legally produce more noise than a heavy duty truck.***