Transmitted by the Chair of TF MU

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agenda item 3)

Task Force
Measurement Uncertainty

Strategic Approach to Handle Measurement Uncertainties in UN Regulations

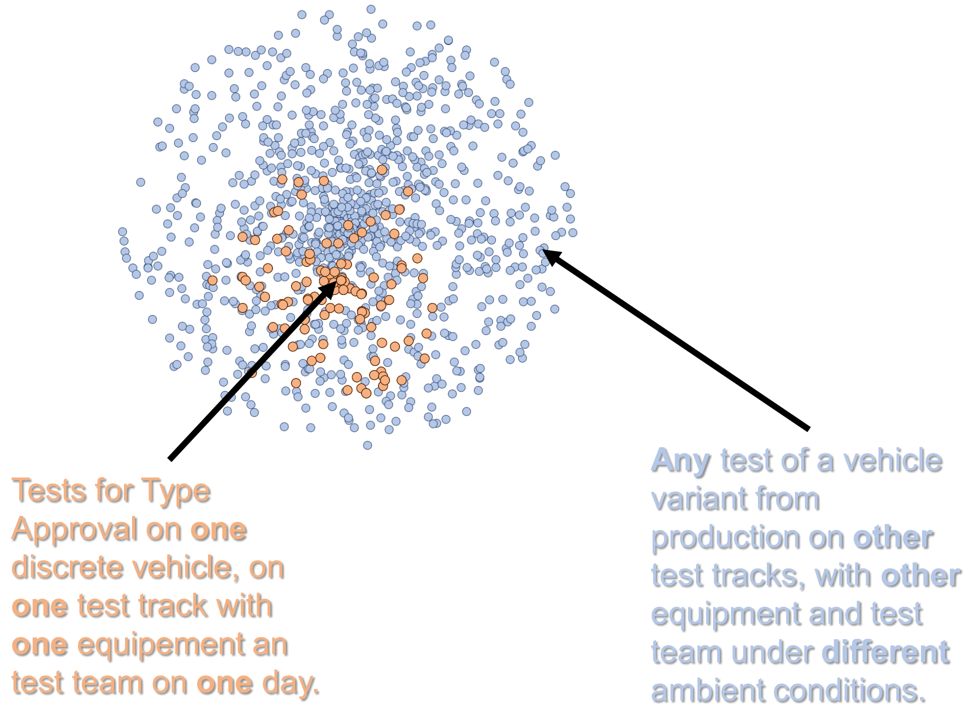
Application of the Concept to UN R51.03 and UN R117.02

GRBP 71 – January 2020

Task Force Measurement Uncertainty

- Measurement procedures are always affected by factors causing disturbances leading to variation in the results observed on the same subject. Source and nature of these perturbations are not completely known and can sometimes affect the end result in a non-predictable way
- The knowledge of the measurement uncertainty is important as it provides information about the precision and repeatability of measurements.
- A measured result shall be understood as an approximation to the true result, which by itself is unknown.
  - Two measurements are deemed to provide the same result, if their test results are within the given uncertainty.
  - Two vehicles are deemed to provide the same sound level, if their measurement results are within the given uncertainty.
- The measurement uncertainty may vary, dependent on the purpose of the test.
- The measurement uncertainties shall be minimized, by adequate measures, e.g. by narrowing ambient and test conditions or by applying corrections.
- Residual uncertainties which will always remain shall be covered by tolerances.

Uncertainty „Bubble“ for a measurement procedure which creates the basis for a UN Regulation.



ISO/IEC Guide 98-3 (Guide to the expression of Uncertainty in Measurement)

- The uncertainty of results obtained from measurements can be evaluated by the procedure given in **ISO/IEC Guide 98-3** (GUM) or by interlaboratory comparisons in accordance with **ISO 5725** (part 1 to 6)
- The procedure given in ISO 5725 (part 1 to 6) to estimate the uncertainties associated with the test procedures mentioned in UN Regulation No. 51.03 or No. 117.02 (for Rolling Sound) is not followed, as extensive inter- and intra-laboratory data are not available for the calculation of the uncertainties.
- Instead, the procedure given in ISO/IEC Guide 98-3 (GUM) can be followed to estimate the uncertainties associated with the test procedures mentioned above.
- The data for the calculation of the uncertainties are based on existing statistical data, analysis of tolerances and engineering judgement and can be grouped as follows for
  - the same vehicle
    - ✓ Run to Run
    - ✓ Day to Day
    - ✓ Site to Site
  - different vehicles of the same kind
    - ✓ New Vehicle to new Vehicle or, new Vehicle to used Vehicle

How are Uncertainties Handled Today in a Regulation?

- Regulations provide already provisions to ensure accurate testing. Without these provisions, test results would not be repeatable and would provide a variation, which is inacceptable for the purpose of regulation.

Area	Parameter	UN R117	UN R51.03
Equipment	Microphone	Type 1 microphone	Type 1 microphone
	Calibrator	Class 1 Calibrator	Class 1 Calibrator
	Calibration Tolerance	+0.5 dB(A)	+0.5 dB(A)
	Speed Measuring Device	+/- 1 km/h at PP'-line	+/- 0.2 km/h or +/- 0.5 km/h
	Engine Speed Measuring Device	----	< 2%
	Test Track	ISO 10844:2014	ISO 10844:2014
Test Conditions	Air Temperature	5°C to 40°C	5°C to 40°C
	Road Surface Temperature	5°C to 50°C	----
	Temperature Correction	Normalize C1 and C2 Tyres to 20°C	No Correction/Normalization
	Preparation for the Test	Tyres shall be warmed-up	Engine shall be brought to normal operation condition
	Speed Variation	+/- 1 km/h at PP'-line	+/- 1 km/h at PP'-line (acceleration test) +/- 1 km/h within aa' and BB' (cruise test)
	Wind Speed	< 5 m/s and suitable windscreen	< 5 m/s and suitable windscreen
	Background Noise	>10 dB(A)	>10 dB(A) plus correction up to 15 dB(A)
Tolerances	Measuring instrument inaccuracies	Reduce test result by 1 dB(A)	----
	CoP Tolerance	+1 dB(A) allowance	Shall not exceed the limit by more than 1 dB.

- **However, even with all these provisions, uncertainties remain and must be assessed, especially when considering third party testing such as in-use conformity and market surveillance provide additional uncertainties.**

Uncertainty Estimate Based on the GUM Assessment Principles for UN R51.03

- By applying the principles of the GUM, on the type approval condition according to Annex 3 of UN R51.03, the <u>measurement uncertainty for a M1 passenger car</u> equipped with a combustion engine is provided by the table beside:

Summary Table for UN R51.03 and UN R117.02

Regulation	Subcategory	Overall Uncertainty CI 95%
UN R117	C1 Tyres	+/- 2.2 dB(A)
	C2 Tyres	+/- 2.2 dB(A)
	C3 Tyres	+/- 2.3 dB(A)
UN R51	M1, N1, M2 with M<3.500 kg	+/- 2.7 dB(A)
	N2, N3, M3 and M2 with M>3.500 kg	+/- 2.2 dB(A)

Example: Measurement Uncertainty Full Assessment for M1 ICE Vehicles Under UN R51.03

Situation	Input Quantity	Impact on Lurb	Probability Distribution	Standard deviation	Share [%]	Uncertainty Budgets: Type Approval	Uncertainty Budgets: CoP	Uncertainty Budgets: Field Tests
Run to Run	Micro climate wind effect	0,50	gaussian	0,125	0,9%			
	Deviation from centered driving	0,50	rectangular	0,144	1,2%			
	Start of acceleration	0,50	rectangular	0,144	1,2%			
	Speed variations of +/- 1km/h	0,30	rectangular	0,087	0,4%	0,28	0,28	0,28
	Load variations during cruising	0,37	gaussian	0,092	0,5%			
	Varying background noise	0,10	gaussian	0,025	0,0%			
	Variation on operating temperature of engine and tyres	0,25	rectangular	0,072	0,3%			
Day to Day	Barometric pressure (Weather)	0,66	gaussian	0,165	1,6%			
	Air temperature effect on tyre noise (5-10°C)	0,00	rectangular	0,000	0,0%			
	Air temperature effect on tyre noise (10-40°C)	1,34	rectangular	0,387	8,5%	0,59	0,59	0,62 1)
	Varying background noise	1,00	rectangular	0,289	4,8%			
	Residual humidity on test track surface	1,00	rectangular	0,289	4,8%			
Site to Site	Altitude (Location of Test Track)	0,66	rectangular	0,191	2,1%			
	Test Track Surface	4,01	gaussian	1,002	57,3%			
	Microphone Class 1 IEC 61672	0,60	gaussian	0,150	1,3%		0,53 2)	1,06
	Sound calibrator IEC 60942	0,80	gaussian	0,200	2,3%			
	Speed measuring equipment continuous at PP	0,30	rectangular	0,087	0,4%			
	Acceleration calculation from vehicle speed measurement	0,20	rectangular	0,058	0,2%			
Vehicle to Vehicle	Production Variation Tyre and Different Tyre	1,00	gaussian	0,250	3,6%			
	Production Variation in Power	0,40	rectangular	0,115	0,8%			
	Battery state of charge for HEVs	0,00	rectangular	0,000	0,0%		0,47	0,47
	Production Variability of Sound Reduction Components	0,00	gaussian	0,000	0,0%			
	Impact of variation of vehicle mass	1,30	rectangular	0,375	8,0%			
					100,0%			

Impacts estimated based on experiences of manufacturer

	Overall Uncertainty		Type Approval	CoP	Field Tests
Coverage Factor k=2 (95%)	2,65	Expanded uncertainty +/-	1,30	1,92	2,68

Remarks:

1) Test are allowed at temperatures below 10°C. In this case additional uncertainties must be kept in mind.

2) Site to Site variation for CoP is quoted less, as manufacturer will select the test site for their CoP tests.

Strategic Approach to Improve Measurement Uncertainties

- Measurement Uncertainties can be minimized by various additional measures

Pos.	Measure	Advantage	Drawback
1	Narrow the application range to minimize external influences	Scientifically most preferable to have uniform test conditions	Practically not possible for outdoor measurements, not realistic for real world conditions
2	Introduce compensation models	Allows larger application range	Not always applicable, introduces own uncertainties
3	Apply tolerances	Simple, considerable for non-type approval measurements	Could be understood as weakening of applied limits
4	Statistical compliance	Already introduced system for CoP	Some vehicles not fully compliant to the regulation
5	Repeat measurements under type approval conditions	Most accurate procedure	Difficult to arrange

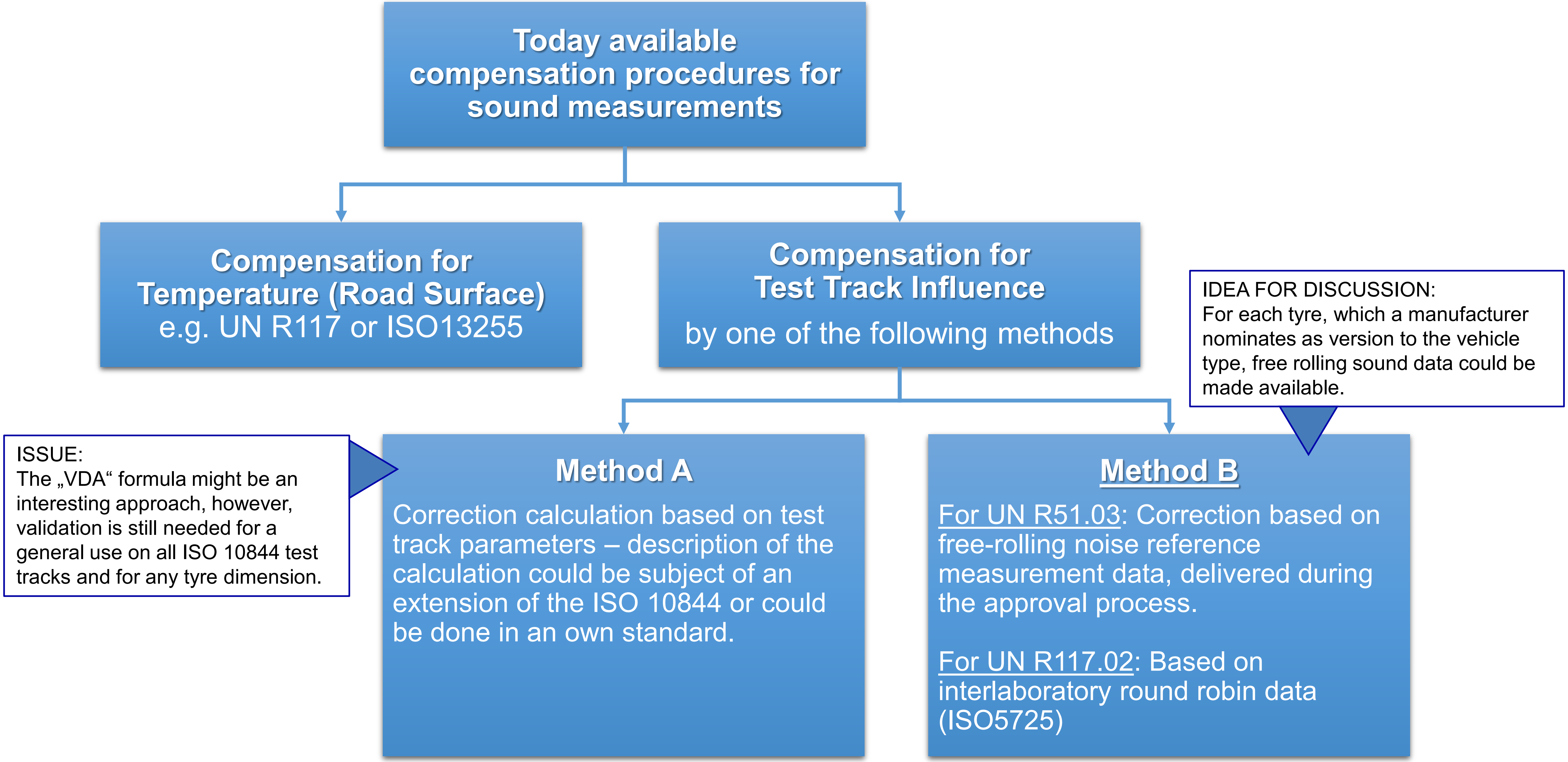
- ➢ A mix of these measures can balance the request for a large control range to reflect real world conditions and to keep the precision of the test method in a technically and politically acceptable range.
- ➢ Limits have an impact on the source distribution of vehicles and components. Different source compositions will result different sensitivities on uncertainty parameters.
- ➢ Enforcement of limits shall consider such sensitivities.

Improvement of Measurement Uncertainties

- The comparison of UN R117.02 and UN R51.03 show, that by harmonizing requirements, the level of uncertainty can already be approved.
- Red colour indicated improvements, by already existing measures, green colour introduces new provisions.

Area	Parameter	UN R117	UN R51.03
Equipment	Microphone	Type 1 microphone	Type 1 microphone
	Calibrator	Class 1 Calibrator	Class 1 Calibrator
	Calibration Tolerance	+0.5 dB(A)	+0.5 dB(A)
	Speed Measuring Device	**+/- 0.2 km/h or +/- 0.5 km/h**	+/- 0.2 km/h or +/- 0.5 km/h
	Engine Speed Measuring Device	----	< 2%
	Test Track	ISO 10844:2014	ISO 10844:2014
		Compensation for test track influence	**Compensation for test track influence**
Test Conditions	Air Temperature	5°C to 40°C	5°C to 40°C
	Road Surface Temperature	5°C to 50°C	**5°C to 50°C**
	Temperature Correction	Normalize C1, C2 **and C3 Tyres** to 20°C	**Apply correction on tyre rolling sound**
	Preparation for the Test	Tyres shall be warmed-up, **what does warm-up mean?**	Engine shall be brought to **normal** operation condition, **extend to vehicle specfific requirements, not only engine**
	Speed Variation	+/- 1 km/h at PP'-line	+/- 1 km/h at PP'-line (acceleration test) +/- 1 km/h within AA' and BB' (cruise test)
	Wind Speed	< 5 m/s and suitable windscreen	< 5 m/s and suitable windscreen
	Background Noise	>10 dB(A) **plus correction up to 15 dB(A)**	>10 dB(A) plus correction up to 15 dB(A)
Tolerances	Measuring instrument inaccuracies	Reduce test result by 1 dB(A)	----
	CoP Tolerance	+1 dB(A) allowance	Shall not exceed the limit by more than 1 dB.

Compensation for Influence Factors UN R117 and UN R51 – Temperature and Test Track



Improved Uncertainty Estimate After Corrections for Temperature and Test Track

- By reducing the uncertainty budgets for the two parameters on which a compensation has been applied, the overall uncertainty is reduced.
- The shares of uncertainty budgets become more harmonized, which make a test procedure more robust.

Situation	Input Quantity	Impact on Lurb	Probability Distribution	Standard deviation	Share [%]	Uncertainty Budgets		
						Type Approval	CoP	Field Tests
Run to Run	Micro climate wind effect	0,50	gaussian	0,125	2,2%	0,28	0,28	0,28
	Deviation from centered driving	0,50	rectangular	0,144	2,9%			
	Start of acceleration	0,50	rectangular	0,144	2,9%			
	Speed variations of +/- 1km/h	0,30	rectangular	0,087	1,0%			
	Load variations during cruising	0,37	gaussian	0,092	1,2%			
	Varying background noise	0,10	gaussian	0,025	0,1%			
	Variation on operating temperature of engine and tyres	0,25	rectangular	0,072	0,7%			
Day to Day	Barometric pressure (Weather)	0,66	gaussian	0,165	3,8%	0,48	0,48	0,52
	Air temperature effect on tyre noise (5-10°C)	0,00	rectangular	0,000	0,0%			
	Air temperature effect on tyre noise (10-40°C)	0,67	rectangular	0,193	5,2%			
	Varying background noise	1,00	rectangular	0,289	11,5%			
	Residual humidity on test track surface	1,00	rectangular	0,289	11,5%			
Site to Site	Altitude (Location of Test Track)	0,66	rectangular	0,191	5,0%		0,22	0,44
	Test Track Surface	1,17	gaussian	0,292	11,8%			
	Microphone Class 1 IEC 61672	0,60	gaussian	0,150	3,1%			
	Sound calibrator IEC 60942	0,80	gaussian	0,200	5,5%			
	Speed measuring equipment continuous at PP	0,30	rectangular	0,087	1,0%			
	Acceleration calculation from vehicle speed measurement	0,20	rectangular	0,058	0,5%			
Vehicle to Vehicle	Production Variation Tyre and Different Tyre	1,00	gaussian	0,250	8,7%		0,47	0,47
	Production Variation in Power	0,40	rectangular	0,115	1,8%			
	Battery state of charge for HEVs	0,00	rectangular	0,000	0,0%			
	Production Variability of Sound Reduction Components	0,00	gaussian	0,000	0,0%			
	Impact of variation of vehicle mass	1,30	rectangular	0,375	19,5%			
					100,0%			

Impacts estimated based on experiences of manufacturer

was: 2.65 dB(A)

Coverage Factor k=2 (95%)		Expanded uncertainty +/-	Type Approval	CoP	Field Tests
	1,70		1,11	1,52	1,75

Summary Table for UN R51.03 and UN R117.02

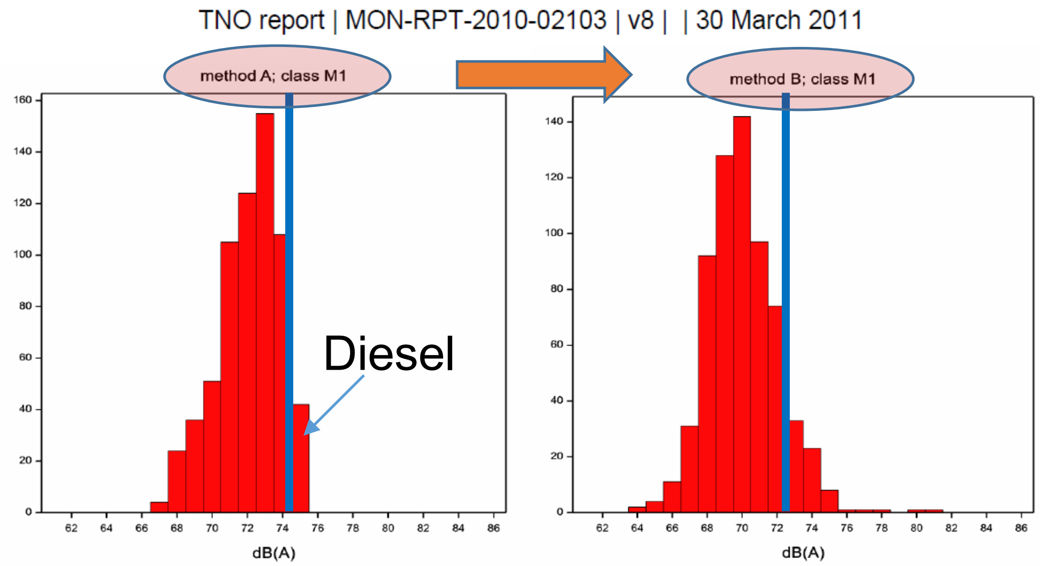
Regulation	Subcategory	Overall Uncertainty CI 95%	Improved Uncertainty
UN R117.04	C1 Tyres	+/- 2.2 dB(A)	t.b.d.
	C2 Tyres	+/- 2.2 dB(A)	t.b.d.
	C3 Tyres	+/- 2.3 dB(A)	t.b.d.
UN R51.03	M1, N1, M2 with M<3.500 kg	+/- 2.7 dB(A)	+/- 1.70 dB(A)
	N2, N3, M3 and M2 with M>3.500 kg	t.b.d.	t.b.d.

Remarks:
1) Test are allowed at temperatures below 10°C. In this case additional uncertainties must be kept in mind.
2) Site to Site variation for CoP is quoted less, as manufacturer will select the test site for their CoP tests.

EU COMMISSION STUDY VENOLIVA (GRB-54-01)
on Vehicle Noise Limits for EU Noise Legislation and for UN R51.03

The VENOLIVA STUDY of the European Commission from 2011 on the introduction of the new test procedure (method B) concludes a <u>higher sensitivity with regard to measurement accuracy and ambient conditions</u> compared to the old test procedure (method A).

➔ see VENOLIVA STUDY chapter 10.3
Evaluation of test method B



The VENOLIVA STUDY suggests to <u>establish the limits</u> vehicles (M1 vehicles at 72dB(A)) <u>under the assumption that manufacturer will „learn to take the best conditions into account“</u>.

➔ See VENOLIVA STUDY chapter 8.6
Optimisation of vehicles to the test method

The likely <u>impact of a higher measurement uncertainty by</u> a system like <u>„market surveillance“ was NOT considered</u>, when the limits were established for UN R51.03.

Proposal for Consideration

- The Measurement Uncertainty shall be handled dependent on the purpose of the test.
- **When considering a test on a discrete vehicle:**
  - Type Approval: **NO CHANGE TO THE CURRENT SYSTEM**
  - CoP: **NO CHANGE TO THE CURRENT SYSTEM**
    (1 dB tolerance is applied to quote for mass production variation)
  - Verification Tests: **INTRODUCE AN ADDITIONAL TOLERANCE**
    (e.g. 1 dB on top to CoP tolerance to quote for increased uncertainty)

- **When considering the conformity of a vehicle type in a general manner:**
  - Statistical Compliance : ➔ If one vehicle fails, two more vehicles shall be tested (UN R51.03)
  - Repetition of Type Approval Condition:
    ➔ Repeat the test at the test facility on which the original type approval test was performed.

BACKUP MATERIAL

Uncertainty Estimate Based on the GUM Assessment Principles for UN R117

- By applying the general numerical approach with the GUM, for carrying out calculations required as part of an evaluation on measurement uncertainty, the actual uncertainty for tyre rolling sound measurements according to UN R117 are provided by the table below:

	Uncertainty categories	Systematic or Random	Standard Uncertainty [dB] 95% confidence interval	Description
1	Test Repeatability *(day by day)*	Random	± 0.6 [b]	Result variability once tyres, track, acquisition system, vehicle and modus operandi are the same (Day and driver might be different)
1.1	Test Repeatability *(run to run)*	Random	± 0.3 [b]	Result variability for consecutive test once tyres, track, acquisition system, vehicle and modus operandi are the same
1.2	Track Humidity	Random	Unknown	Definition of "dry" is quite vague Humidity may affect more R51 Drive-by than R117
1.3	Speed effect	Random	± 0.13	Minimum requirement for sensor accuracy in R117 is ± 1km/h Tyre noise vs speed sensitivity= 0.2 dB/km/h PtoP =0.2 dB* 2km/h=0.4 dB (± 0.13)
1.4	Temperature influence *(after temperature correction)*	Random	± 0.3 [b]	Despite temperature correction a residual error remains (Formula not fully correct). Only applicable for C1/C2 tyres
2	Temperature influence (without temperature correction)	Systematic	± 0.6	The systematic error is removed in Reg.117 (except for C3) but not in Reg.51 Reg. 117 allows following temperature ranges: air 5>, <40 surface temperature >5,<50 Estimated peak to peak by Reg.117 formula =1.8 dB (± 0.6 dB)
3	Track to Track	Systematic	± 1.8 [a]	Estimated by VDA round robin test results
4	Tyre to tyre	Random	± 0.5 [b]	Uncertainty due to production variability (Different plants, different period…..) Excluding ageing effect
5	Sound meter-to sound meter	Random	± 0.4 [a]	Measurement system shall meet class 1 requirements
6	Vehicle influence	Systematic / Random	± 1.0 [b]	Possibility to use different vehicles. Uncertainty takes into consideration differences on: Wheel adjustment, Suspension, Tyre load and inflation, Body-road clearance, shadowing and reflecting properties, Rim, Transmission noise, Bearings, Brake noise (brakes not completely released), Body shape - aerodynamic noise around the vehicle body and extra equipment
	Total Uncertainty C1/C2 tyres		± 2.2 dB	**Combined standard uncertainty** **$U = \sqrt{(u_1^2+u_3^2+u_4^2+u_5^2+u_6^2)}$**
	Total Uncertainty C3 tyres		± 2.3 dB	**Combined standard uncertainty** **$U = \sqrt{(u_1^2+u_2^2+u_3^2+u_4^2+u_5^2+u_6^2)}$**

[a] Values retrieved in literature

[b] Estimation based on experience of some ETRTO members

Uncertainty Estimate Based on the GUM Assessment Principles for UN R51.03

- By applying the general numerical approach with the GUM, for carrying out calculations required as part of an evaluation on measurement uncertainty, the actual uncertainty for UN R51.03 **for electric vehicles** is provided by the table beside:

Situation	Input Quantity	estimated deviations of the meas. result (peak-peak)		Impact on Lurb	probability distribution	variance	standard deviation	contribution [%]
		Lwot	Lcrs					
Run to run	Micro climate wind effect	0,5	0,5	0,50	gaussian	0,016	0,125	0,5%
	Deviation from centered driving	0,5	0,5	0,50	rectangular	0,021	0,144	0,7%
	start of acceleration	0,5	0,5	0,50	rectangular	0,021	0,144	0,7%
	speed variations of +/- 1km/h	0,3	0,3	0,30	rectangular	0,008	0,087	0,3%
	Load variations during cruising	0,3	0,5	0,37	gaussian	0,008	0,092	0,3%
	Varying background noise	0,1	0,1	0,10	gaussian	0,001	0,025	0,0%
	variation on operating temperature of engine and tyres	0,25	0,25	0,25	rectangular	0,005	0,072	0,2%
Day to day	Barometric pressure	1	0	0,66	gaussian	0,027	0,165	0,9%
	Air temperature effect on tyre noise (5-10°C)	0	0	0,00	rectangular	0,000	0,000	0,0%
	Air temperature effect on tyre noise (10-40oC)	1	1	1,00	rectangular	0,083	0,289	2,9%
	Varying background noise	1	1	1,00	rectangular	0,083	0,289	2,9%
	Residual humidity on test track surface	1	1	1,00	rectangular	0,083	0,289	2,9%
Site to site	Altitude	0,66	0,66	0,66	rectangular	0,036	0,191	1,2%
	Test Track Surface	6	5	5,66	gaussian	2,003	1,415	68,7%
	Microphone Class 1 IEC 61672	0,6	0,6	0,60	gaussian	0,023	0,150	0,8%
	Sound calibrator IEC 60942	0,8	0,8	0,80	gaussian	0,040	0,200	1,4%
	Speed measuring equipment continuous at PP	0,3	0,3	0,30	rectangular	0,008	0,087	0,3%
	Acceleration, calculated from vehicle speed measurement	0,2	0,2	0,20	rectangular	0,003	0,058	0,1%
V to Vehicle	Tyre	1	1	1,00	gaussian	0,063	0,250	2,1%
	Production Variation in Power	0,4	0,4	0,40	rectangular	0,013	0,115	0,5%
	Battery state of charge for HEVs	2	1	1,66	rectangular	0,230	0,479	7,9%
	Production variation of vehicle mass	1,3	1,3	1,30	rectangular	0,141	0,375	4,8%
					Total	2,92	1,71	100,0%

Coverage factor	Expanded uncertainty +/-
k=2 (95%)	3,41

Impact based on experiences of manufacturer

UN R117.02 / UN R51.03 Compensation of the Pass-by Noise

Temperature Correction, based on the road surface temperature

Correction according to UN R117.02 for free rolling

4.3. Temperature correction

For Class C1 and Class C2 tyres, the final result shall be normalized to a test surface reference temperature ϑ_{ref} by applying a temperature correction, according to the following:

$$L_R(\vartheta_{ref}) = L_R(\vartheta) + K(\vartheta_{ref} - \vartheta)$$

Where:

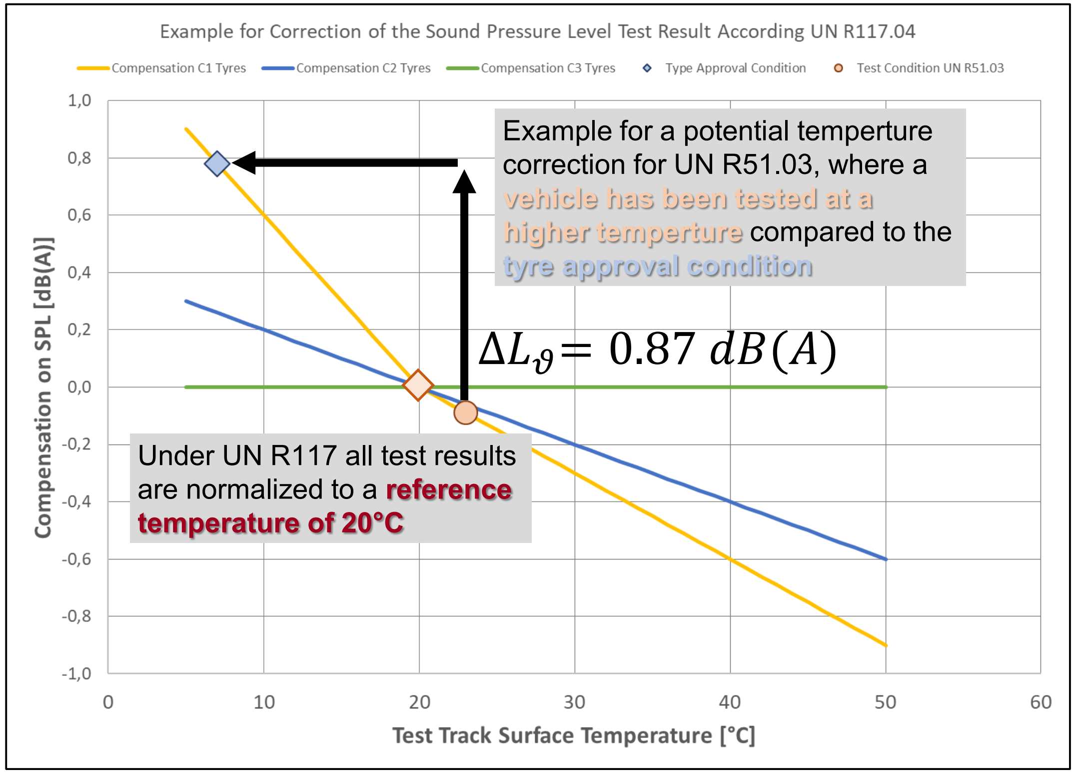
ϑ = the measured test surface temperature,

ϑ_{ref} = 20 °C,

For Class C1 tyres, the coefficient K is: -0.03 db(A)/°C, when $\vartheta > \vartheta_{ref}$

and -0.06 dB(A)/°C when $\vartheta < \vartheta_{ref}$

For Class C2 tyres, the coefficient K is -0.02 dB(A)/°C



- ➢ In UN R117.02, the temperature correction is based on the test track surface temperature. The temperature correction is only applied to C1 and C2 tyres. This is actually not requested to be reported in UN R51.03.
- ➢ In UN R117.02, the temperature correction is made to a reference temperature of 20°C. For the application in UN R51.03, the temperature correction shall be done to the temperature stated in the test report of the type approval test.

ISO/TS 13471-2:Temperature Correction Procedure:

ISO 14371-02 proposes a temperature correction based on the **air temperature**. A correction is proposed for any tyre, so as well for C3 tyres.

Temperature correction shall be applied as follows. Each measured noise level, L_{Amax}, where appropriate determined according to ISO 11819-1, ISO 13325 or appropriate parts of ISO 362, shall be corrected by adding the term $C_{T,\mathrm{t}}$, using Formula (1):

$$C_{T,\mathrm{t}} = -\gamma_{\mathrm{t}} \left(T - T_{\mathrm{ref}} \right) \quad (1)$$

where

$C_{T,\mathrm{t}}$ is the noise level L_{Amax} correction for temperature (T) for tyre or vehicle class (t), in dB, to be added to the measured noise level;

γ_{t} is the temperature coefficient for tyre or vehicle class t (either C1, C2, C3 for tyre class, or either P or H for vehicle class in SPB measurements), in dB/°C;

T is the air temperature (T) during the ~~CPX~~ noise measurement, in °C;

T_{ref} is the reference air temperature = 20,0 °C.

Subcategory	Temperature Coefficient
C1 & C2Tyres	**-0.10 dB/°C**
C3 Tyres	**-0.06 dB/°C**

Compensation for the Influence of the Test Track – Method A

<u>Method A</u>, based on a universal formula

$$\Delta L_{COR} = \gamma_1 \times \left(MPD^{\varepsilon 1} - MPD_{REF}{}^{\varepsilon 1}\right) + \gamma_2 \times \left((g \times MPD)^{\varepsilon 2} - (g \times MPD)_{REF}{}^{\varepsilon 2}\right) + \gamma_3 \times \left(\alpha^{\varepsilon 3} - \alpha_{REF}{}^{\varepsilon 3}\right)$$

CORRECTION (TEST TRACK & TEMP CORRECTION)		
ΔL_{COR} (inclusive ΔL_{δ})	**-0,7**	**dB(A)**

This information is derived from test track properties, determined periodically according ISO 10844 standard (to be implemented

APPLIED GENERAL DATA		
Torque-Effekt Tyre	1	dB(A)

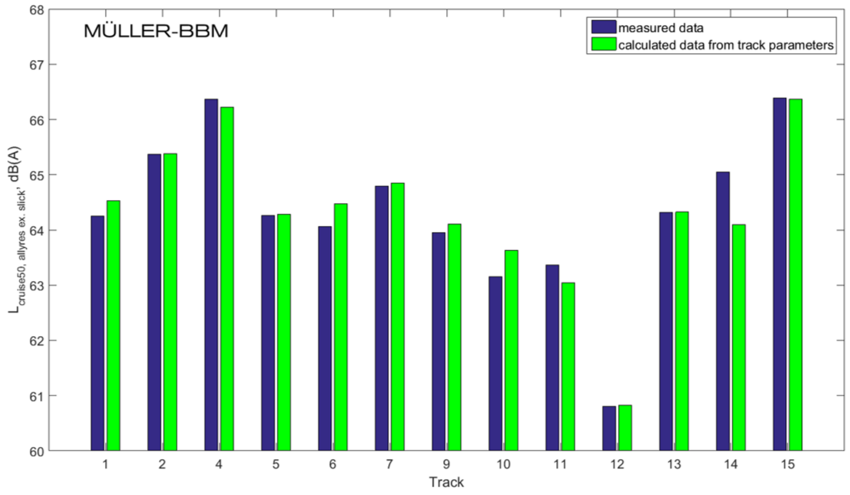
This is an empirial values to cover torque effect under acceleration condition

TEST DATA (SUBJECT TO CORRECTION)		
δ_{TEST}	15	°C
$L_{TR,TEST}$	66,5	dB(A)
$L_{CRS,REP}$	67,0	dB(A)
$L_{WOT,REP}$	71,0	dB(A)
$v_{BB,CRS,REP}$	50,0	km/h
$v_{BB,WOT,REP}$	55,0	km/h
$k_{P,TEST}$	0,33	
$L_{URBAN,TEST}$	**69,7**	**dB(A)**

APPLIED CORRECTION (TEST TRACK & TEMPERATURE)		
$L_{TR,CRS}$	66,5	dB(A)
$L_{PT,CRS}$	57,4	dB(A)
$L_{TR,CRS,COR(TEX,\delta)}$	67,2	dB(A)
$L_{CRS,REP,COR}$	**67,6**	**dB(A)**
$L_{TR,WOT}$	68,9	dB(A)
$L_{PT,WOT}$	66,9	dB(A)
$L_{TR,WOT,COR(TEX,\delta)}$	69,6	dB(A)
$L_{WOT,REP,COR}$	**71,4**	**dB(A)**

$L_{URBAN,TEST,COR}$	**70,2**	**dB(A)**

The factors γ_i and the exponents ε_i will need further investigation and



Compensation for the Influence of the Test Track – Method B

REFERENCE DATA (FROM TYRE INFORMATION)		
$L_{TR,REF}$	66,6	dB(A)
$\delta_{REF,TYRE}$	20	°C
Tyre Class	C1	

SELECT COMPENSATION METHOD		
Compensation Method	UN R117.04	
Tyre Class	Coefficients	
	$\delta TEST \leq \delta REF$	$\delta TEST > \delta REF$
C1	-0,06	-0,03

REFERENCE DATA (FROM TYPE APPROVAL)		
$\delta_{REF,TA}$	10	°C
$L_{TR,REF}$ corrected to $\delta_{REF,TA}$	**67,2**	**dB(A)**

APPLIED GENERAL DATA		
Torque-Effekt Tyre	1	dB(A)

REPORTED TEST DATA (SUBJECT TO CORRECTION)		
δ_{TEST}	25	°C
$L_{TR,TEST}$	66	dB(A)
$L_{TR,TEST}$ corrected to $\delta_{REF,TA}$	**66,8**	**dB(A)**
$L_{CRS,REP}$	67,0	dB(A)
$L_{WOT,REP}$	71,0	dB(A)
$v_{BB,CRS,REP}$	50,0	km/h
$v_{BB,WOT,REP}$	55,0	km/h
$k_{P,TEST}$	0,33	
$L_{URBAN,TEST}$	**69,7**	**dB(A)**

CORRECTION (TEST TRACK & TEMP CORRECTION)		
δL_{COR} (normalized to $\delta_{REF,TA}$)	**-0,45**	**dB(A)**

CORRECTED DATA (TEST TRACK & TEMPERATURE)		
$L_{TR,CRS}$	66,8	dB(A)
$L_{PT,CRS}$	54,5	dB(A)
$L_{TR,CRS,COR(TEX,\delta)}$	67,2	dB(A)
$L_{CRS,REP,COR}$	**67,4**	**dB(A)**
$L_{TR,WOT}$	69,1	dB(A)
$L_{PT,WOT}$	66,5	dB(A)
$L_{TR,WOT,COR(TEX,\delta)}$	69,6	dB(A)
$L_{WOT,REP,COR}$	**71,3**	**dB(A)**
$L_{URBAN,TEST,COR}$	**70,0**	**dB(A)**

Method B, based on available tyre rolling sound reference information

Tyre Class	No	ISO 13471-02		UN R117.04	
		$\delta TEST \leq \delta REF$	$\delta TEST > \delta REF$	$\delta TEST \leq \delta REF$	$\delta TEST > \delta REF$
C1	1	-0,10	-0,10	-0,06	-0,03
C2	2	-0,10	-0,10	-0,02	-0,02
C3	3	-0,06	-0,06	0,00	0,00

- The tyre rolling sound information should be determined in the course of homologation.
- The data might be determined independent from the type approval test for the vehicle to which the tyre might be mounted.
- The same tyre might be used for different vehicle types.

Update of the Uncertainty Sheets based on the Compensation

- By applying a compensation for the temperature the originally estimated uncertainty will become lower.
    - However, there is no universal „true“ compensation model.
    - The temperature sensitivity of a tyre is dependent on the design and materials used in the tyre.
    - As no discrete results exist, a conservative guess is made, that the uncertainty is reduced by 50%, e.g. for UN R51.03 from 2 dB(A) to 1 dB(A).
- The test track compensation is as well subject to uncertainties.
    - Even when using measurements of the same tyre on the test tracks, the residual uncertainty will apply to both measurement.
    - By good engineering judgement, the uncertainty is considered to be lowed from 5 dB(A) under cruise condition to 1.5 dB(A) for both combustion engine vehicles and those with electric propulsion.
- **The following slides show the result of the compensation ➔**

Improved Uncertainty Estimate After Corrections for Temperature and Test Track (UN R51.03)

- By applying the general numerical approach with the GUM, for carrying out calculations required as part of an evaluation on measurement uncertainty, the actual uncertainty for UN R51.03 **for electric vehicles** is provided by the table beside:

Situation	Input Quantity	estimated deviations of the meas. result (peak-peak)		Impact on Lurb	probability distribution	variance	standard deviation	contribution [%]
		Lwot	Lcrs					
Run to run	Micro climate wind effect	0,5	0,5	0,50	gaussian	0,016	0,125	1,3%
	Deviation from centered driving	0,5	0,5	0,50	rectangular	0,021	0,144	1,8%
	start of acceleration	0,5	0,5	0,50	rectangular	0,021	0,144	1,8%
	speed variations of +/- 1km/h	0,3	0,3	0,30	rectangular	0,008	0,087	0,6%
	Load variations during cruising	0,3	0,5	0,37	gaussian	0,008	0,092	0,7%
	Varying background noise	0,1	0,1	0,10	gaussian	0,001	0,025	0,1%
	variation on operating temperature of engine and tyres	0,25	0,25	0,25	rectangular	0,005	0,072	0,4%
Day to day	Barometric pressure	1	0	0,66	gaussian	0,027	0,165	2,4%
	Air temperature effect on tyre noise (5-10°C)	0	0	0,00	rectangular	0,000	0,000	0,0%
	Air temperature effect on tyre noise (10-40oC)	1	1	1,00	rectangular	0,083	0,289	7,2%
	Varying background noise	1	1	1,00	rectangular	0,083	0,289	7,2%
	Residual humidity on test track surface	1	1	1,00	rectangular	0,083	0,289	7,2%
Site to site	Altitude	0,66	0,66	0,66	rectangular	0,036	0,191	3,1%
	Test Track Surface	2,5	1,5	2,16	gaussian	0,292	0,540	25,2%
	Microphone Class 1 IEC 61672	0,6	0,6	0,60	gaussian	0,023	0,150	1,9%
	Sound calibrator IEC 60942	0,8	0,8	0,80	gaussian	0,040	0,200	3,4%
	Speed measuring equipment continuous at PP	0,3	0,3	0,30	rectangular	0,008	0,087	0,6%
	Acceleration, calculated from vehicle speed measurement	0,2	0,2	0,20	rectangular	0,003	0,058	0,3%
V to Vehicle	Tyre	1	1	1,00	gaussian	0,063	0,250	5,4%
	Production Variation in Power	0,4	0,4	0,40	rectangular	0,013	0,115	1,1%
	Battery state of charge for HEVs	2	0,5	1,49	rectangular	0,185	0,431	16,0%
	Production variation of vehicle mass	1,3	1,3	1,30	rectangular	0,141	0,375	12,1%
					Total	1,16	1,08	100,0%

Coverage factor	Expanded uncertainty +/-
k=2 (95%)	2,15

was: 3.41 dB(A)

Impact based on experiences of manufacturer

VENOLIVA STUDY on UN R51.03 (EU COM 2011)

10.3 Evaluation of test method B

The practicability and manageability of method B was investigated by means of a small enquiry among a number of type approval authorities that had submitted significant numbers of test report files for the database. Based on the response from these type approval authorities the following conclusions can be drawn:

- The complexity of the new method B for light vehicles (M1, N1 and N2 < 3,5t) is approximately three times higher than of the current method A;
- For these vehicles **method B requires more attention to avoid errors and to achieve the necessary measurement accuracy** than method A;
- Depending on the type of measuring equipment (fully integrated or separate systems) the management of the test process may be rather time consuming;
- **Method B is more sensitive to environmental parameters**, because the test results for light vehicles are lower than for method A;
- Nevertheless, method B is considered reproducible and manageable;

The VENOLIVA STUDY of the European Commission from 2011 on the introduction of the new test procedure (method B) concludes a higher sensitivity with regard to measurement accuracy and ambient conditions compared to the old test procedure (method A)

VENOLIVA STUDY on UN R51.03 (EU COM 2011)

8.6 Optimisation of vehicles to the test method (M1 Vehicles)

- The current test method A has been in force for a very long period. **Vehicle manufacturers have learnt to take the test conditions and the type approval requirements into account** in the design process of the vehicles.
- **This adaptation or optimisation to the test method has not yet taken place for test method B**, which is new and was applied on a large scale for the first time during the monitoring period.
- The histograms for method A cut off sharply at the limit values, while the histograms for method B show a more natural tapering off to higher sound emission levels.
- Based on the differences between the histograms for test methods A and B for these vehicles it may be assumed that after some time the results of test method B will show a similar high end cut off as the results of test method A.
- The highest values will then be 72 or 73 dB(A).

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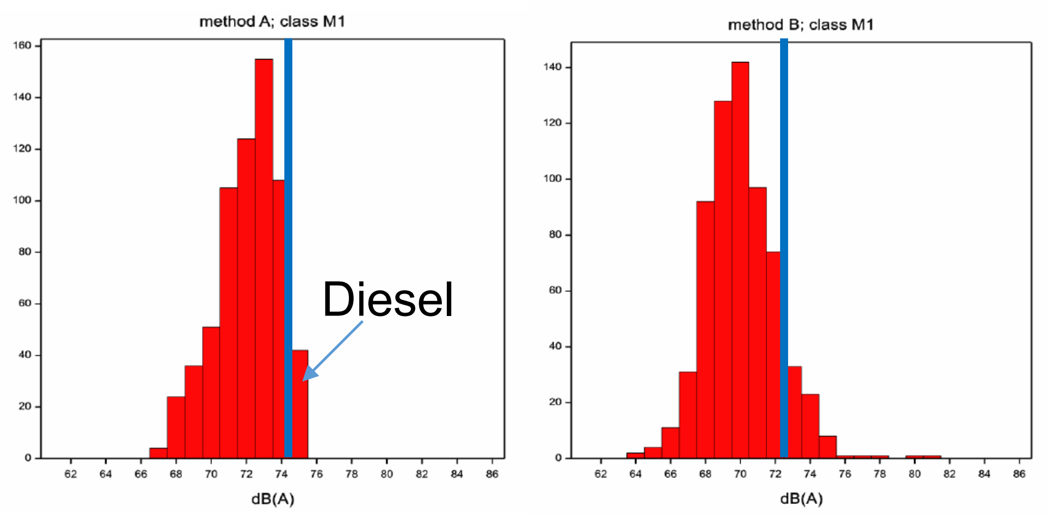

The basic limit for M1 vehicles was set to 72 dB(A) and included the assumption that manufacturer will „learn to take the best conditions into account“.