History of Measurement Uncertainties

Step 1

Definition of Quantities

Situation	Input Quantity
Run to Run	Micro climate wind effect
	DRIVER #1: Deviation from centered driving
	DRIVER #2: Start of acceleration
	DRIVER #3: Speed variations of +/- 1km/h
	DRIVER #4: Load variations during cruising
	Varying background noise
	Variation on operating temperature of engine (WOT) and tyres (WOT&CRS) ==> See ISO 362-1 NOTE
Day to Day	Barometric pressure (Weather +/- 30 hPa)
	Air temperature effect on tyre noise (5-10°C)
	Air temperature effect on tyre noise (10-40°C)
	Varying background noise during measurement
	Air intake temperature variation
	Residual humidity on test track surface
Site to Site	Altitude (Location of Test Track) -100 hPa/1000m (from 1015 to 915 hPa)
	Test Track Surface
	Microphone Class 1 IEC 61672
	Sound calibrator IEC 60942
	Speed measuring equipment continuous at PP
	Acceleration calculation from vehicle speed measurement
Vehicle to Vehicle	Production Variation on Tyres; Aging of Tyres until delivery to customer (1dB after one year)
	Variation on Tyre Size and Brand (non-OEM)
	Production Variation in Power
	Battery state of charge for HEVs (3 dB(A))
	Production Variability of Sound Reduction Components
	Impact of variation of vehicle mass

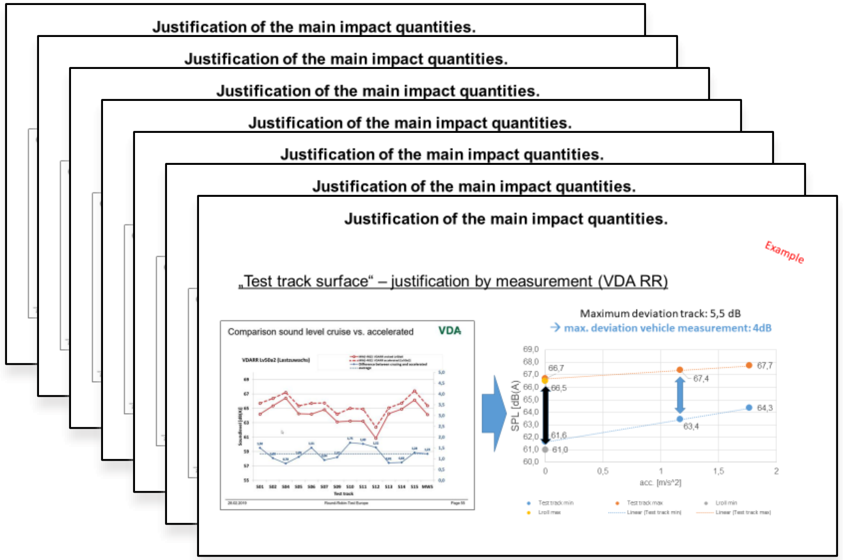
Step 2

Estimation of Deviation

Situation	Input Quantity	estimated deviations of the meas. result (peak-peak)		Impact on Lurb
		Lwot	Lcrs	
Run to Run	Micro climate wind effect	0,40	0,77	0,53
	DRIVER #1: Deviation from centered driving	0,50	0,50	0,50
	DRIVER #2: Start of acceleration	0,50	0,00	0,33
	DRIVER #3: Speed variations of +/- 1km/h	0,30	0,30	0,30
	DRIVER #4: Load variations during cruising	0,00	0,50	0,17
	Varying background noise	0,10	0,10	0,10
	Variation on operating temperature of engine (WOT) and tyres (WOT&CRS) ==> See ISO 362-1 NOTE	1,20	0,50	0,96
Day to Day	Barometric pressure (Weather +/- 30 hPa)	0,60	0,00	0,40
	Air temperature effect on tyre noise (5-10°C)	1,00	2,00	1,34
	Air temperature effect on tyre noise (10-40°C)	1,00	2,00	1,34
	Varying background noise during measurement	0,60	1,00	0,74
	Air intake temperature variation	1,50	0,00	0,99
	Residual humidity on test track surface	0,70	1,00	0,80
Site to Site	Altitude (Location of Test Track) -100 hPa/1000m (from 1015 to 915 hPa)	1,00	0,00	0,66
	Test Track Surface	3,50	5,00	4,01
	Microphone Class 1 IEC 61672	1,00	1,00	1,00
	Sound calibrator IEC 60942	0,80	0,80	0,80
	Speed measuring equipment continuous at PP	0,07	0,13	0,09
	Acceleration calculation from vehicle speed measurement	0,50	0,00	0,33
Vehicle to Vehicle	Production Variation on Tyres; Aging of Tyres until delivery to customer (1dB after one year)	0,75	1,50	1,00
	Variation on Tyre Size and Brand (non-OEM)	0,00	0,00	0,00
	Production Variation in Power	0,40	0,00	0,26
	Battery state of charge for HEVs (3 dB(A))	0,00	0,00	0,00
	Production Variability of Sound Reduction Components	1,00	0,50	0,83
	Impact of variation of vehicle mass	1,40	0,60	1,13

Step 3

Justification of Quantities



Justification of the main impact quantities.

Justification by different approaches:

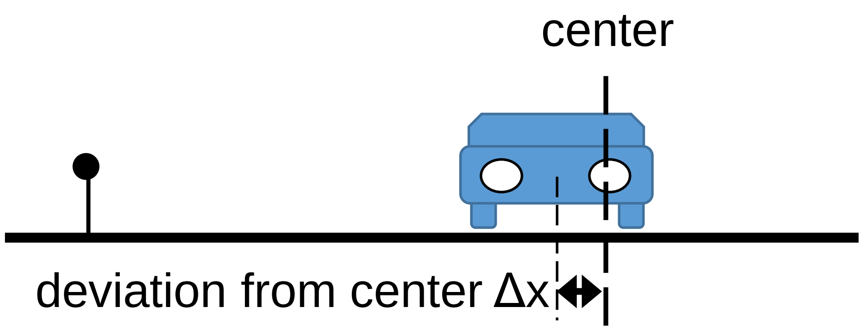
1. by **measurement** (or simulation) results from specific experiments, e.g. investigations on power train noise at indoor test bench

2. by classic **statistical methods** e.g. parameter studies and correlation analysis (ACEA Tyre study)

3. by **theoretical** derivations based on physical relations e.g. distance law (deviation from centered driving)

Justification of the main impact quantities.

„deviation from centered driving“ – justification by physical relation



Invers square law:

$$\Delta SPL = \boldsymbol{a} * \frac{10}{3} * \log\left(\frac{7{,}5m + \boldsymbol{\Delta x}}{7{,}5m}\right)$$

with:

a coefficient for dB/distance doubling

Δx deviation from center

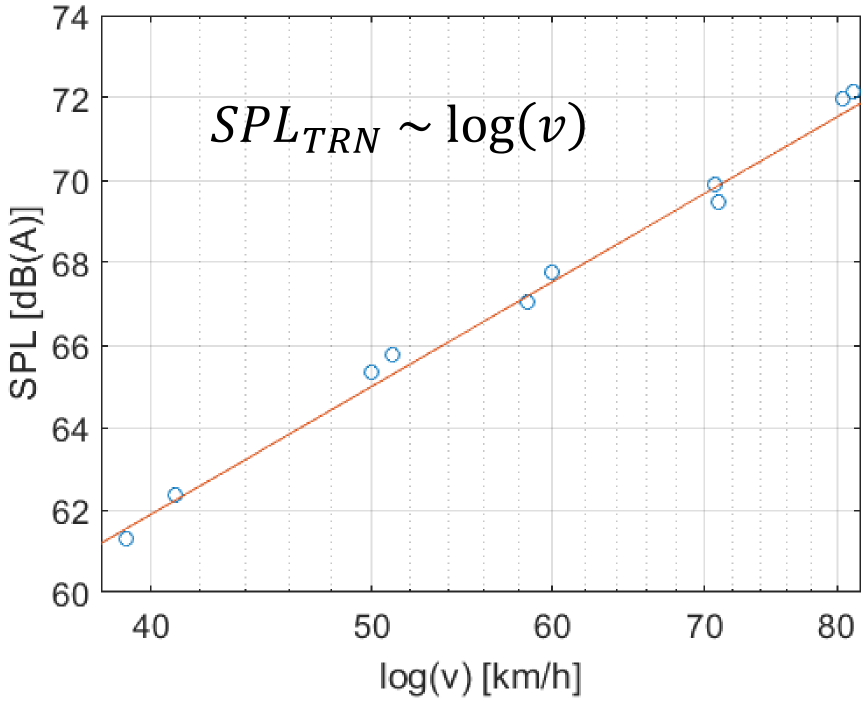
$$\Delta SPL = \mathbf{5} * \frac{10}{3} * \log\left(\frac{7{,}5m+\mathbf{0{,}5}m}{7{,}5m}\right) = \mathbf{0{,}5dB}$$

Assumption for the calculation: 5dB/distance doubling (monopol source under semi-free field conditions) and 0,5m for the deviation from center.

Justification of the main impact quantities.

„DRIVER#3: speed variations of +/- 1km/h“ – justification by empirical relation

$SPL_{tyre\ road\ noise}$ vs. vehicle speed (derived from R117)



$$SPL_{TRN} = a + b * \log\left(\frac{v}{50km/h}\right)$$

with:

a SPL_{TRN}@50km/h

b coefficient for speed dependency

$$\Delta SPL_{TRN} = \mathbf{30} * \log\left(\frac{51}{49}\right) = \mathbf{0{,}5dB}$$

Assumption for calculation: mean coefficient of the speed dependency is 30 (usually varies between 27 -33 for C1 tyres). Depending on the source distribution this effect influences the test result of crs and wot measurement.

Justification of the main impact quantities.

„Load variations during cruising“ – justification by calculation

Influence of vehicle speed and engine load variation on cruise test result

$\Delta load$ →

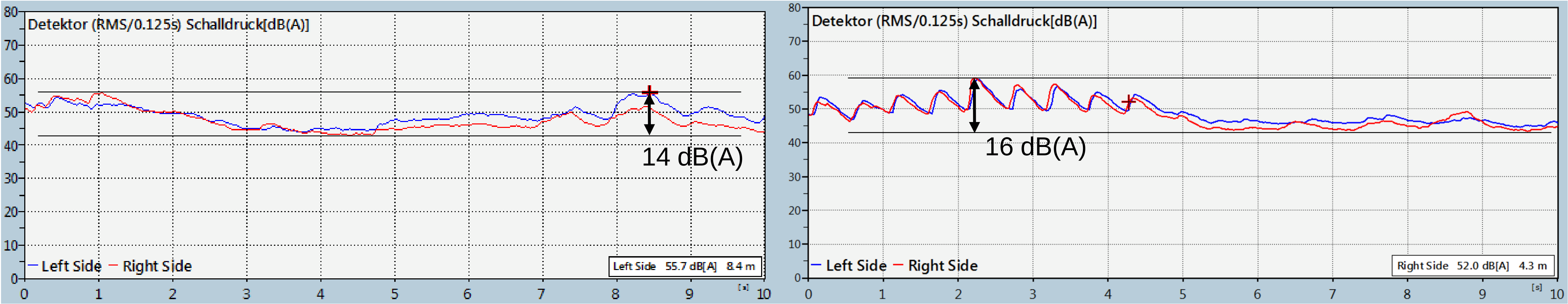
	GEAR 3				GEAR 4			
	1	2	3		1	2	3	
Vaa	**50,0**	**49,0**	**51,0**	km/h	**50,0**	**49,0**	**51,0**	km/h
Vbb	**50,0**	**51,0**	**49,0**	km/h	**50,0**	**51,0**	**49,0**	km/h
igear	**26,1**	26,1	26,1		**38,6**	38,6	38,6	
amax,gear	**2,34**	2,34	2,34	m/s²	**1,58**	1,58	1,58	m/s²
atest	0,00	0,31	-0,31	m/s²	0,00	0,31	-0,31	m/s²
load	0%	13%	0%	%	0%	20%	0%	%
Nbb	1916	1954	1877	rpm	1295	1321	1269	rpm
alpha	**90%**	90%	90%	%	**90%**	90%	90%	%
Ltr,50	**66,0**	66,3	65,7	dB(A)	**66,0**	66,3	65,7	dB(A)
Lpt,50	56,5	56,7	56,2	dB(A)	52,7	52,9	52,6	dB(A)
Ldyn,nl	41,5	41,6	41,3	dB(A)	38,4	38,5	38,2	dB(A)
dLdyn	**25,0**	25,0	25,0	dB(A)	**25,0**	25,0	25,0	dB(A)
Ldyn	41,5	56,9	41,3	dB(A)	38,4	56,4	38,2	dB(A)
Lsum	**66,5**	**67,2**	**66,2**	dB(A)	**66,2**	**66,9**	**65,9**	dB(A)
dL	**0,0**	**0,7**	**-0,3**	dB(A)	**0,0**	**0,7**	**-0,3**	dB(A)

→ $\Delta SPL =$ **0,7dB**

tbd“

Justification of the main impact quantities.

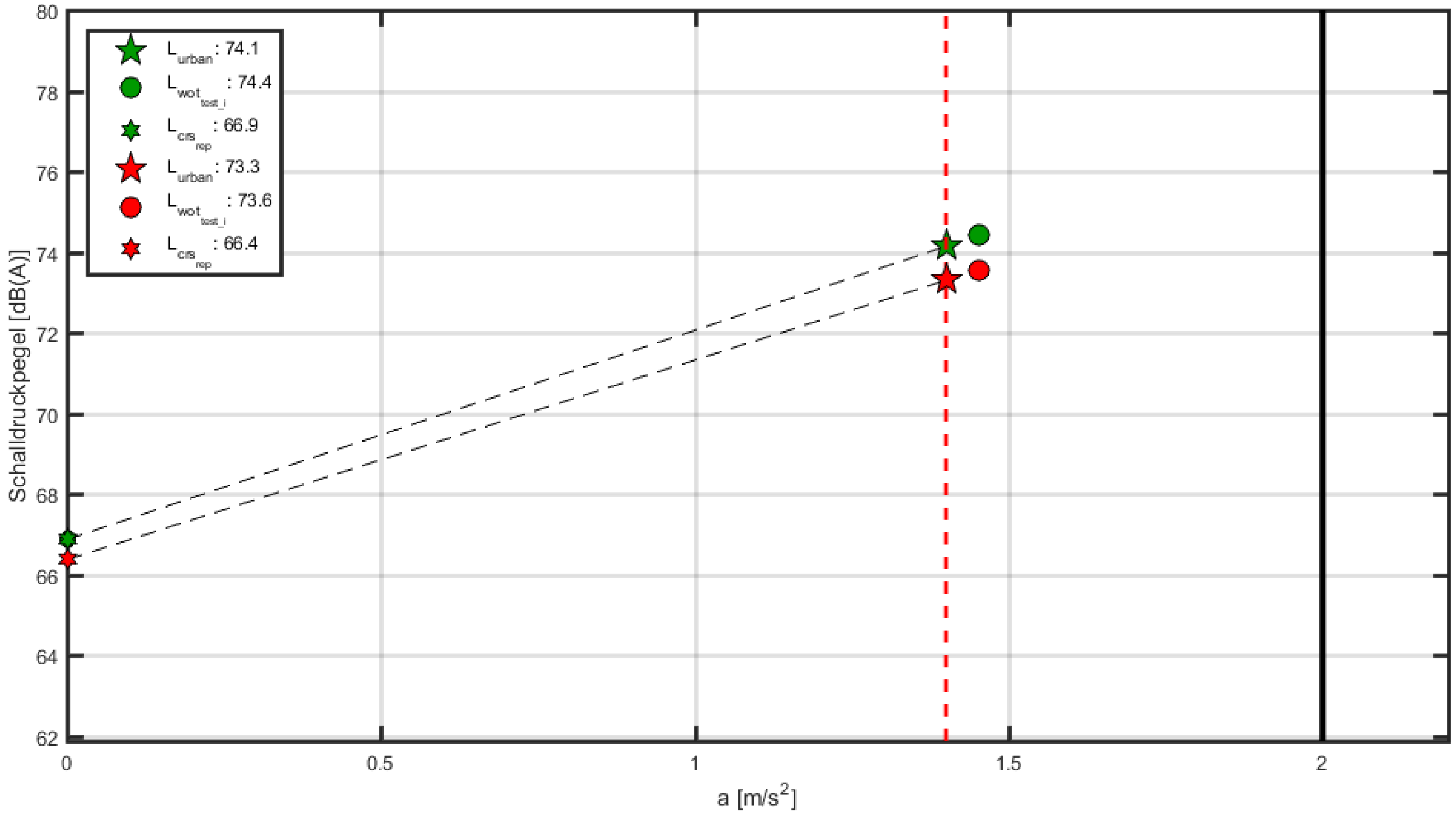
„Varying background noise“ – justification by measurement



- Background noise with minimum sound pressure levels 40 - 45 dB(A)
- Transient broadband events with up to 60 dB(A) → insufficient SNR, but hardly noticeable during pass-by measurements
- background corrections or disregard of measurements eventually not carried out

Justification of the main impact quantities.

„variation on temperature of engine and tyres " – justification by measurement



Variation of approx. 100 °C on exhaust system (KAT Temp.)
+
Variation of 10°C test track temp (derived from R117)

$\Delta SPL =$ **0,8 dB**

High-performance vehicles in particular can have a large dependency on component temperatures of the power train. Here, too, the source distribution decides how large the influence on the end result is.

Justification of the main impact quantities.

„barometric pressure“ – justification by physical relation)

	Barometric Pressure		Power variation	Acceleration variation	Lurban [dB(A)]
Day to day	Weather +/- 30 hPa	60hPa	7.7%	7.7%	0.4dB
Site to site	Altitude -1000m Location of Test Track	100hPa	13.5%	13.5%	0.7dB

$\Delta SPL =$ **0,4 dB**

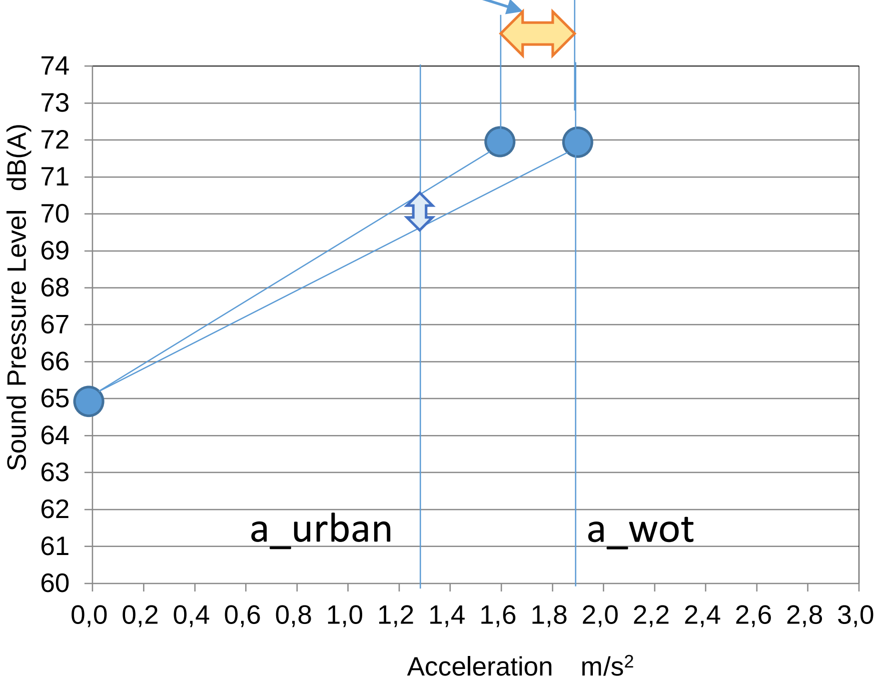
$\Delta SPL =$ **0,7 dB**

ISO1585 paragraph 6.3.1

Correction of engine power; $P = \alpha_a p$

Correction factor for spark-ignition engines;

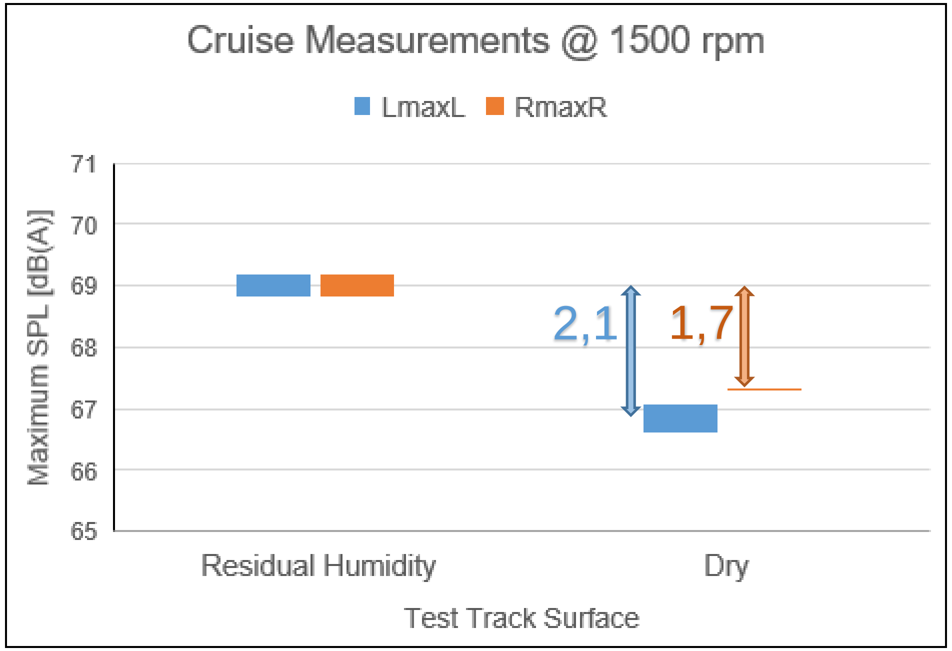
$$\alpha_a = \left(\frac{p_{ref}}{p}\right)^{1.2} \left(\frac{T}{T_{ref}}\right)^{0.6}$$

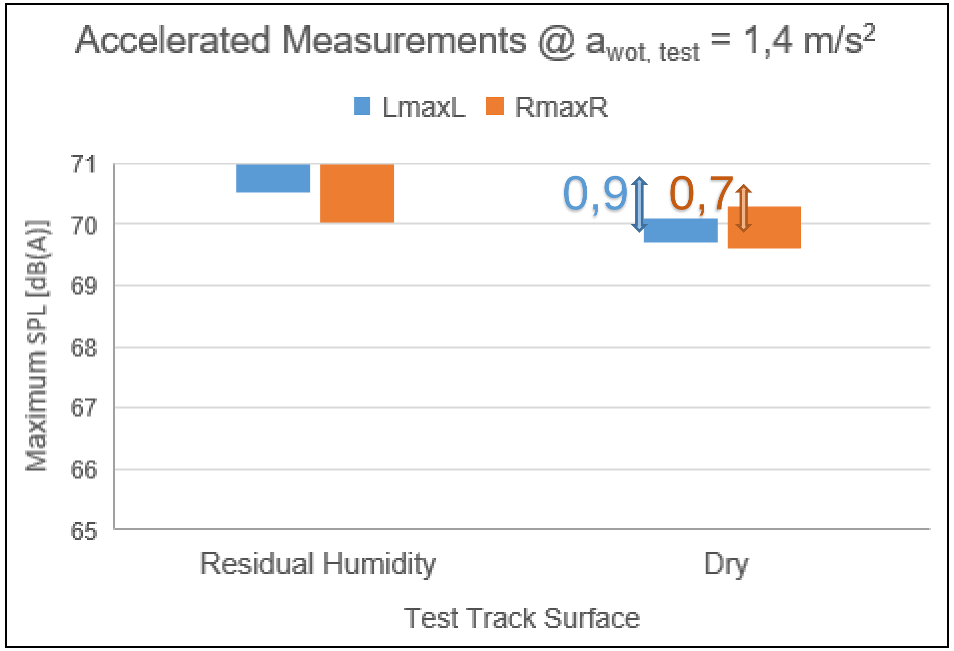


The influence of barometric pressure can be calculated by using ISO 1585 “Engine test code – Net Power” (or R85)

Justification of the main impact quantities.

„Residual humidity on test track surface“ – justification by measurement





$\Delta SPL =$ **0,7 dB**

- 3 Measurements in each operating condition, Runs with residual humidity: test track surface between AA‘ and BB‘ almost 100% dry
- All measurements performed on the same day according to R51.03, Annex 3 (Tyre dimensions: 285/40 ZR21; 315/35 ZR21)
- Residual humidity on one side of the line CC‘ only can lead to Run-to-Run deviations

Justification of the main impact quantities.

„Altitude (Location of Test Track) -100 hPa/1000m (from 1015 to 915 hPa) “ – justification by …

redundant– see slide „Barometric pressure“ (no. 7)

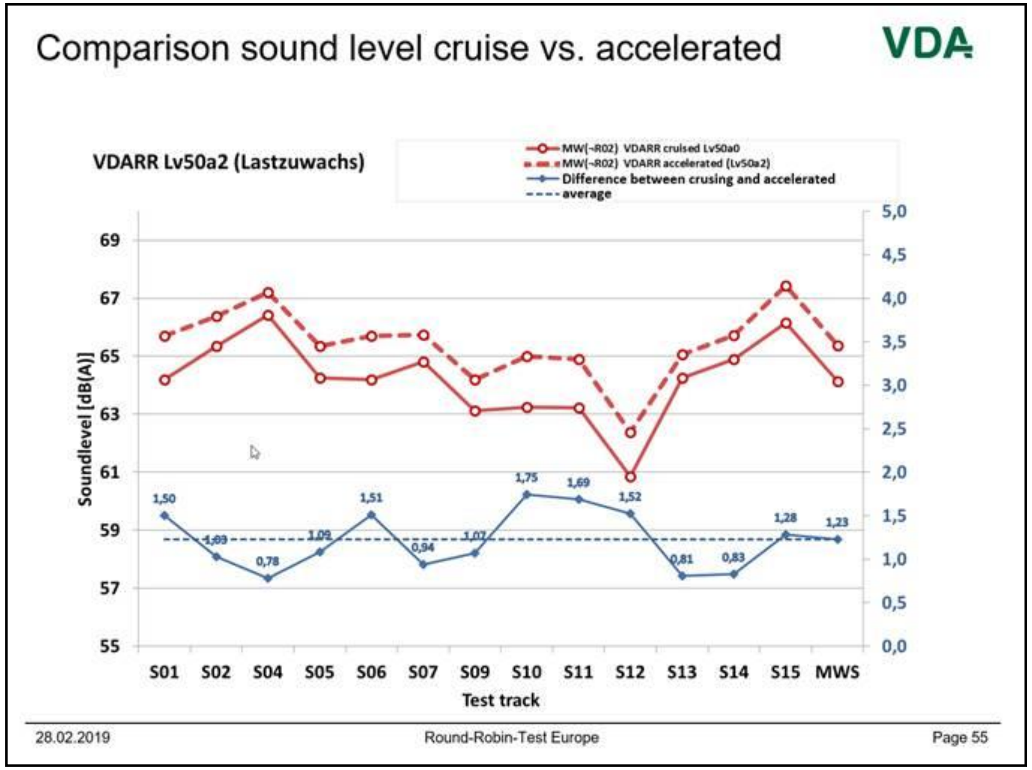
$\Delta SPL =$ **0,7 dB**

…

Justification of the main impact quantities.

„Test track surface“ – justification by measurement (VDA RR)

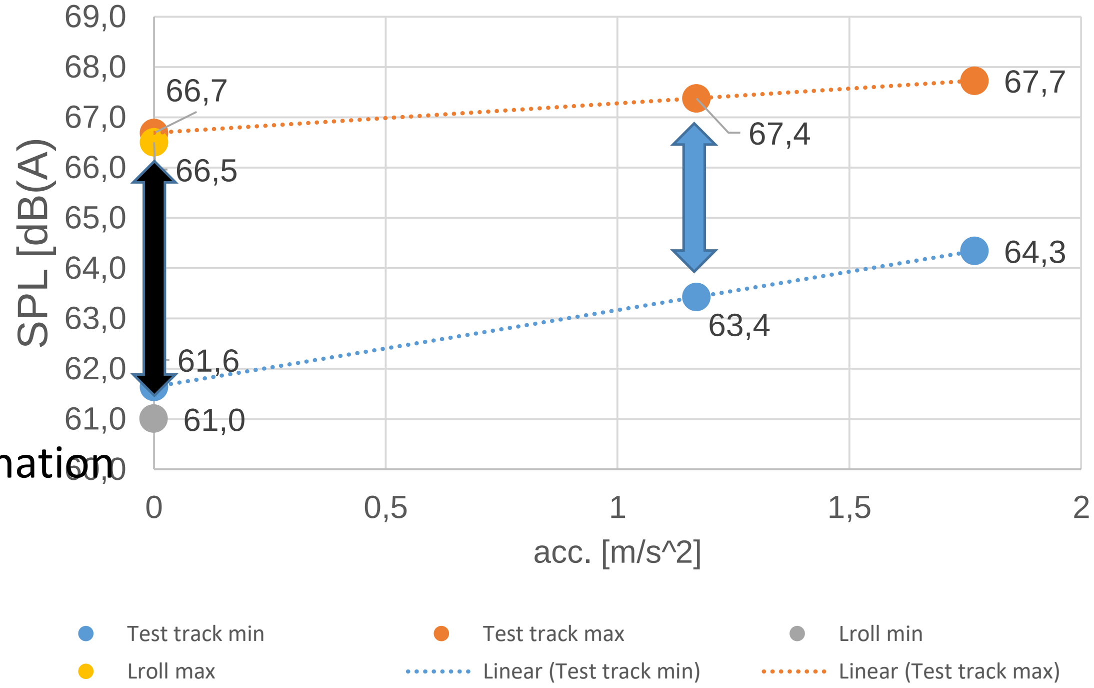
$\Delta SPL =$ **4,0 dB**



explanation

Maximum deviation track: 5,5 dB

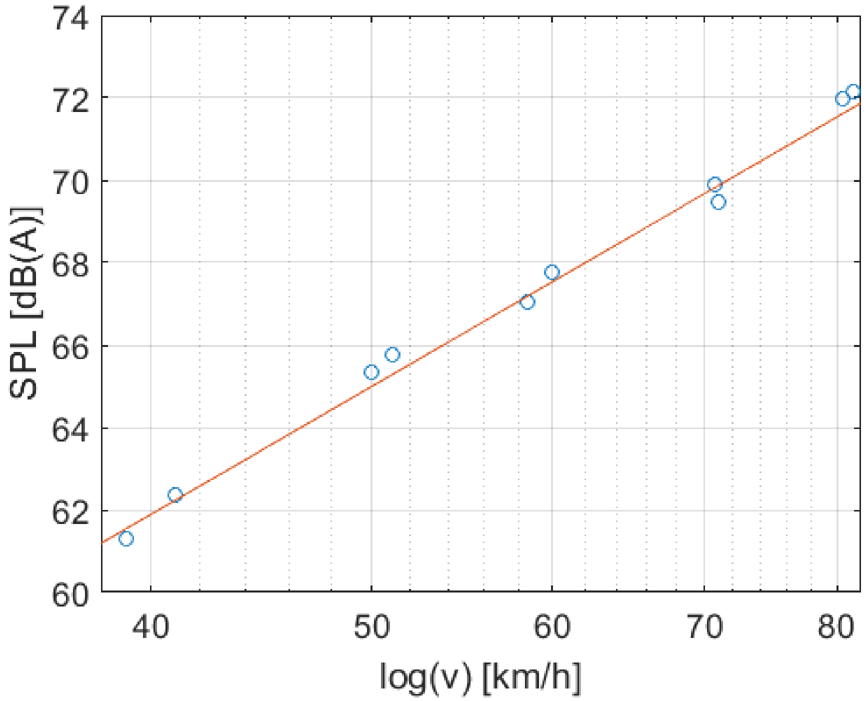
→ **max. deviation vehicle measurement: 4dB**



Different test tracks surfaces lead to different tyre road noises. Depending on the source distribution they influence the test result of crs and wot measurement differently.

Justification of the main impact quantities.

„speed measuring equipment at PP" – justification by empirical relation



Same approach as „DRIVER#3: speed variations of +/- 1km/h"

Precision of todays speed measuring systems: approx.:

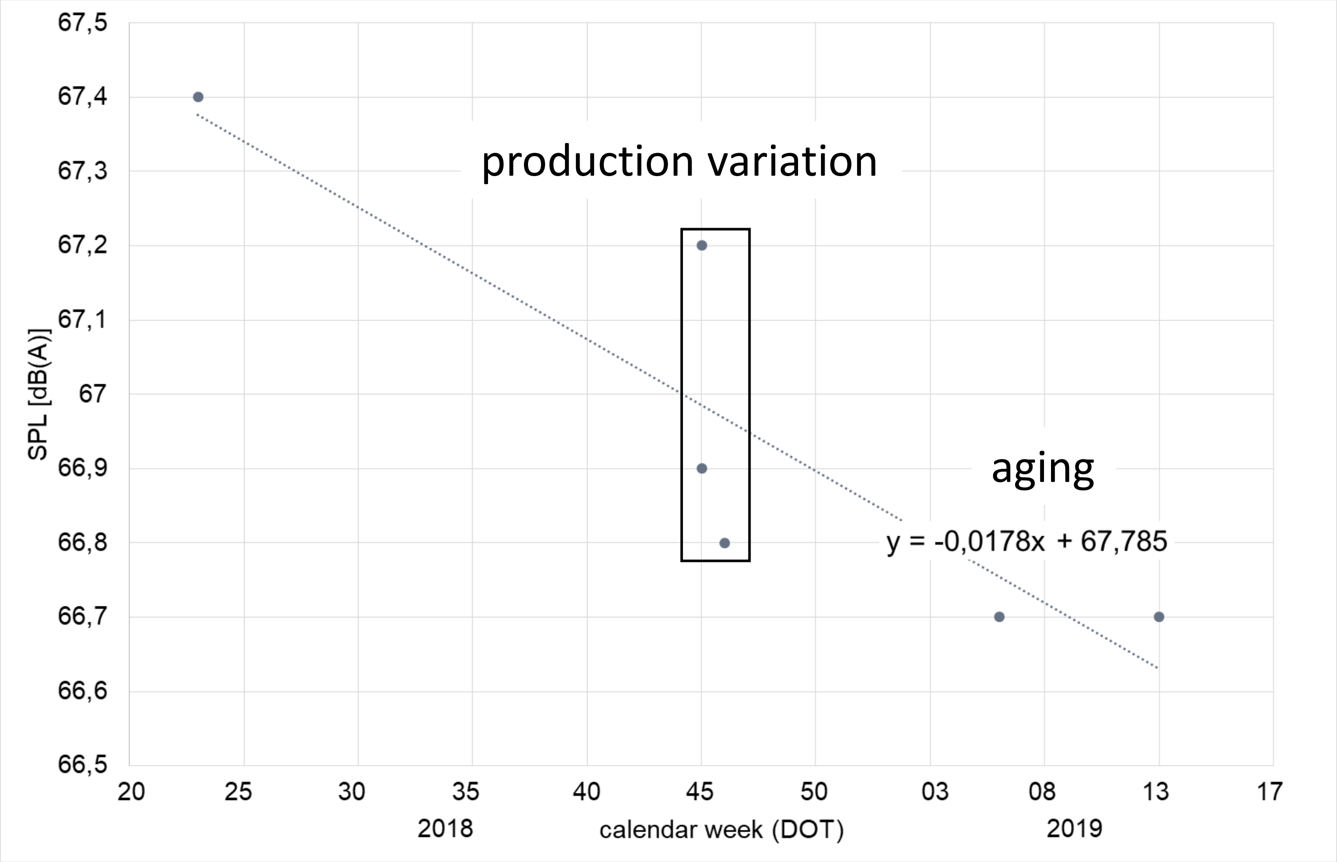
+/-0,2 km/h

$$\Delta SPL_{TRN} = \mathbf{30} * \log\left(\frac{50{,}2 km/h}{49{,}8 km/h}\right) = \mathbf{0{,}1 dB}$$

See „DRIVER#3: speed variations of +/- 1km/h"

Justification of the main impact quantities.

„Production variation on tyres; Aging of tyres until delivery to customer“ – justification by measurement



aging: ≈ **1 dB/ year**

+

prod. variation: ≈ **0,5 dB**

= **1,5 dB** (CRS)

The variation of 0,75 dB in WOT measurement assumes a source distribution between tyre road and power train noise.

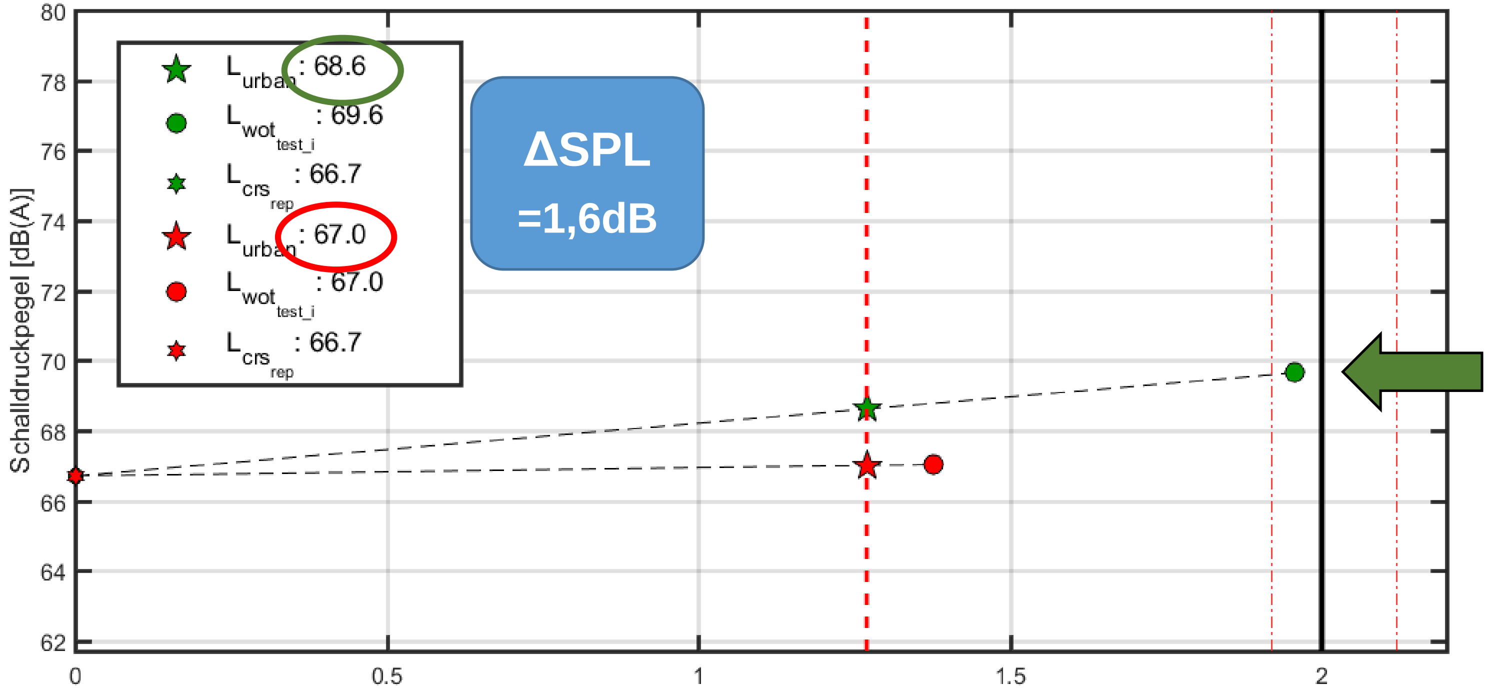
Justification of the main impact quantities.

„variation vehicle mass " – justification by measurement (simulation)

Example

argumentation chain:
„test gear change"

Δm_{FZG} → **Δa** → **Δtest gear** → **Δengine speed** → **ΔSPL**



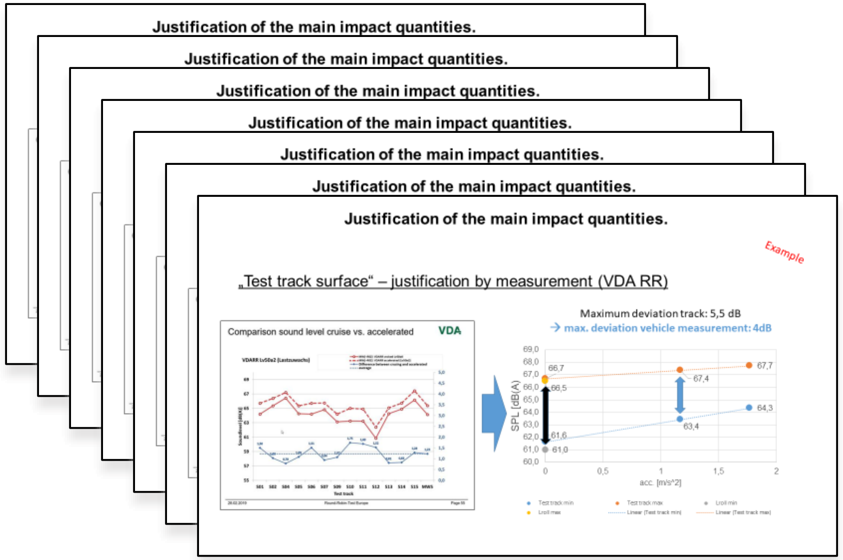
gear i becomes valid

The main impact of the variation of the vehicle mass is on acceleration behavior and can cause a test gear change.
The test gear change leads to another test engine speed and another sound emission.

Justification of the main impact quantities.

Situation	Input Quantity	estimated deviations of the meas. result (peak-peak)		Impact on Lurb	Status
		Lwot	Lcrs		
Run to Run	Micro climate wind effect	0,40	0,77	0,53	open
	DRIVER #1: Deviation from centered driving	0,50	0,50	0,50	done
	DRIVER #2: Start of acceleration	0,50	0,00	0,33	open
	DRIVER #3: Speed variations of +/- 1km/h	0,30	0,30	0,30	done
	DRIVER #4: Load variations during cruising	0,00	0,50	0,17	done
	Varying background noise	0,10	0,10	0,10	done
	Variation on operating temperature of engine (WOT) and tyres (WOT&CRS) ==> See ISO 362-1 NOTE	1,20	0,50	0,96	done
Day to Day	Barometric pressure (Weather +/- 30 hPa)	0,60	0,00	0,40	done
	Air temperature effect on tyre noise (5-10°C)	1,00	2,00	1,34	open
	Air temperature effect on tyre noise (10-40°C)	1,00	2,00	1,34	open
	Varying background noise during measurement	0,60	1,00	0,74	done
	Air intake temperature variation	1,50	0,00	0,99	open
	Residual humidity on test track surface	0,70	1,00	0,80	done
Site to Site	Altitude (Location of Test Track) -100 hPa/1000m (from 1015 to 915 hPa)	1,00	0,00	0,66	done
	Test Track Surface	3,50	5,00	4,01	done
	Microphone Class 1 IEC 61672	1,00	1,00	1,00	open
	Sound calibrator IEC 60942	0,80	0,80	0,80	open
	Speed measuring equipment continuous at PP	0,07	0,13	0,09	done
	Acceleration calculation from vehicle speed measurement	0,50	0,00	0,33	open
Vehicle to Vehicle	Production Variation on Tyres; Aging of Tyres until delivery to customer (1dB after one year)	0,75	1,50	1,00	done
	~~Variation on Tyre Size and Brand (non-OEM)~~	~~0,00~~	~~0,00~~	~~0,00~~	
	Production Variation in Power	0,40	0,00	0,26	open
	~~Battery state of charge for HEVs (3 dB(A))~~	~~0,00~~	~~0,00~~	~~0,00~~	
	Production Variability of Sound Reduction Components	1,00	0,50	0,83	open
	Impact of variation of vehicle mass	1,40	0,60	1,13	done

Status of completeness: appr. 60%



Justification of the main impact quantities.

backup