History of Measurement Uncertainties

**Step 1**

**Definition of Quantities**

- Run to Run
  - Airflow climatic conditions
  - Surface temperature from monitored or calculated
  - Initial state of the environment
  - Estimation of deviation

- Day to Day
  - Temperature deviation from calendar
  - Temperature deviation from weather conditions
  - Deviation from the day before
  - Estimation of deviation

- Site to Site
  - Temperature deviation from weather conditions
  - Estimation of deviation

- Vehicle to Vehicle
  - Production parameter (on the test vehicle)
  - Production parameter (on the road)
  - Production parameter (on the production line)
  - Estimation of deviation

**Step 2**

**Estimation of Deviation**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Input Quantity</th>
<th>Uncertainty</th>
<th>SI Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run to Run</td>
<td>airflow climatic conditions</td>
<td>3.40</td>
<td>m/s</td>
</tr>
<tr>
<td>Day to Day</td>
<td>environmental temperature</td>
<td>4.60</td>
<td>°C</td>
</tr>
<tr>
<td>Site to Site</td>
<td>measurement device accuracy</td>
<td>5.60</td>
<td>°C</td>
</tr>
<tr>
<td>Vehicle to Vehicle</td>
<td>production parameter</td>
<td>6.60</td>
<td>°C</td>
</tr>
</tbody>
</table>

**Step 3**

**Justification of Quantities**

- Justification of the main impact quantities
- Justification of the main impact quantities
- Justification of the main impact 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

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

\[ \text{SPL}_{\text{tyre road noise}} \text{ vs. vehicle speed (derived from R117)} \]

\[ \text{SPL}_{\text{TRN}} = a + b \times \log \left( \frac{v}{50\text{km/h}} \right) \]

with:

- \( a \): SPL\(_{\text{TRN}}@50\text{km/h} \)
- \( b \): coefficient for speed dependency

\[ \Delta \text{SPL}_{\text{TRN}} = 30 \times \log \left( \frac{51}{49} \right) = 0,5\text{dB} \]

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

\[ \Delta SPL = 0.7 \text{dB} \]
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)

\[ \Delta SPL = 0.8 \text{ dB} \]

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)

<table>
<thead>
<tr>
<th></th>
<th>Barometric Pressure</th>
<th>Power variation</th>
<th>Acceleration variation</th>
<th>Lurban [dB(A)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day to day</td>
<td>Weather +/- 30 hPa</td>
<td>60hPa</td>
<td>7.7%</td>
<td>7.7%</td>
</tr>
<tr>
<td>Site to site</td>
<td>Altitude -1000m</td>
<td>100hPa</td>
<td>13.5%</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

\[ \Delta SPL = 0.4 \text{ dB} \]
\[ \Delta SPL = 0.7 \text{ dB} \]

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

- 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

\[ \Delta SPL = 0,7 \text{ dB} \]
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)

\[ \Delta SPL = 0.7 \text{ dB} \]
Justification of the main impact quantities.

„Test track surface“ – justification by measurement (VDA RR) \( \Delta SPL = 4.0 \, \text{dB} \)

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 today’s speed measuring systems: approx.:

\[ +/- 0.2 \text{ km/h} \]

\[ \Delta SPL_{TRN} = 30 \times \log\left(\frac{50.2 \text{ km/h}}{49.8 \text{ km/h}}\right) = 0.1 \text{ dB} \]

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

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)

argumentation chain:

„test gear change“

Δm_{FZG} \rightarrow \Delta a \rightarrow \Delta \text{test gear} \rightarrow \Delta \text{engine speed} \rightarrow \Delta \text{SPL}

\[ \Delta \text{SPL} = 1.6 \text{dB} \]

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.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Input Quantity</th>
<th>estimated deviations of the main, most (peak peaks)</th>
<th>Impact on Lurb</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run to Run</td>
<td>Micro climate wind effect</td>
<td>0,40, 0,77</td>
<td>0,53</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>DRIVER #1: Deviation from centered driving</td>
<td>0,50, 0,50</td>
<td>0,50</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>DRIVER #2: Start of acceleration</td>
<td>0,50, 0,00</td>
<td>0,33</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>DRIVER #3: Speed variations of +/- 1km/h</td>
<td>0,30, 0,30</td>
<td>0,30</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>DRIVER #4: Load variations during cruising</td>
<td>0,00, 0,50</td>
<td>0,17</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Varying background noise</td>
<td>0,10, 0,10</td>
<td>0,10</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>Variation on operating temperature of engine (WOT) and tyres (WOT&amp;CRS)</td>
<td>1,20, 0,50</td>
<td>0,96</td>
<td>done</td>
</tr>
<tr>
<td>Day to Day</td>
<td>Barometric pressure (Weather +/- 30 hPa)</td>
<td>0,60, 0,00</td>
<td>0,40</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Air temperature effect on tyre noise (5-10°C)</td>
<td>1,00, 2,00</td>
<td>1,34</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>Air temperature effect on tyre noise (10-40°C)</td>
<td>1,00, 2,00</td>
<td>1,34</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>Varying background noise during measurement</td>
<td>0,60, 1,00</td>
<td>0,74</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Air intake temperature variation</td>
<td>1,50, 0,00</td>
<td>0,99</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>Residual humidity on test track surface</td>
<td>0,70, 1,00</td>
<td>0,80</td>
<td>done</td>
</tr>
<tr>
<td>Site to Site</td>
<td>Altitude (Location of Test Track) -100 Wp/1000m (from 1015 to 915 hPa)</td>
<td>1,00, 0,00</td>
<td>0,66</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Test Track Surface</td>
<td>3,50, 5,00</td>
<td>4,01</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Microphone Class 1 IEC 61672</td>
<td>1,00, 1,00</td>
<td>1,00</td>
<td>open</td>
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<tr>
<td></td>
<td>Sound calibrator IEC 60942</td>
<td>0,80, 0,80</td>
<td>0,80</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>Speed measuring equipment continuous at PP</td>
<td>0,07, 0,13</td>
<td>0,09</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Acceleration calculation from vehicle speed measurement</td>
<td>0,50, 0,00</td>
<td>0,33</td>
<td>open</td>
</tr>
<tr>
<td>Vehicle to Vehicle</td>
<td>Production Variation on Tyres; Aging of Tyres until delivery to customer (1dB after one year)</td>
<td>0,75, 1,50</td>
<td>1,00</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Variation on Tyre Size and Brand (non-OEM)</td>
<td>0,00, 0,00</td>
<td>0,00</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Production Variation in Power</td>
<td>0,40, 0,00</td>
<td>0,26</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>Battery state of charge for HEVs (14 dB(A))</td>
<td>0,00, 0,00</td>
<td>0,00</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td>Production Variability of Sound Reduction Components</td>
<td>1,00, 0,50</td>
<td>0,83</td>
<td>open</td>
</tr>
<tr>
<td></td>
<td>Impact of variation of vehicle mass</td>
<td>1,40, 0,60</td>
<td>1,13</td>
<td>done</td>
</tr>
</tbody>
</table>

Status of completeness: appr. 60%
Justification of the main impact quantities.

backup