Virtual testing within certification

ACOUTRAIN Final Conference
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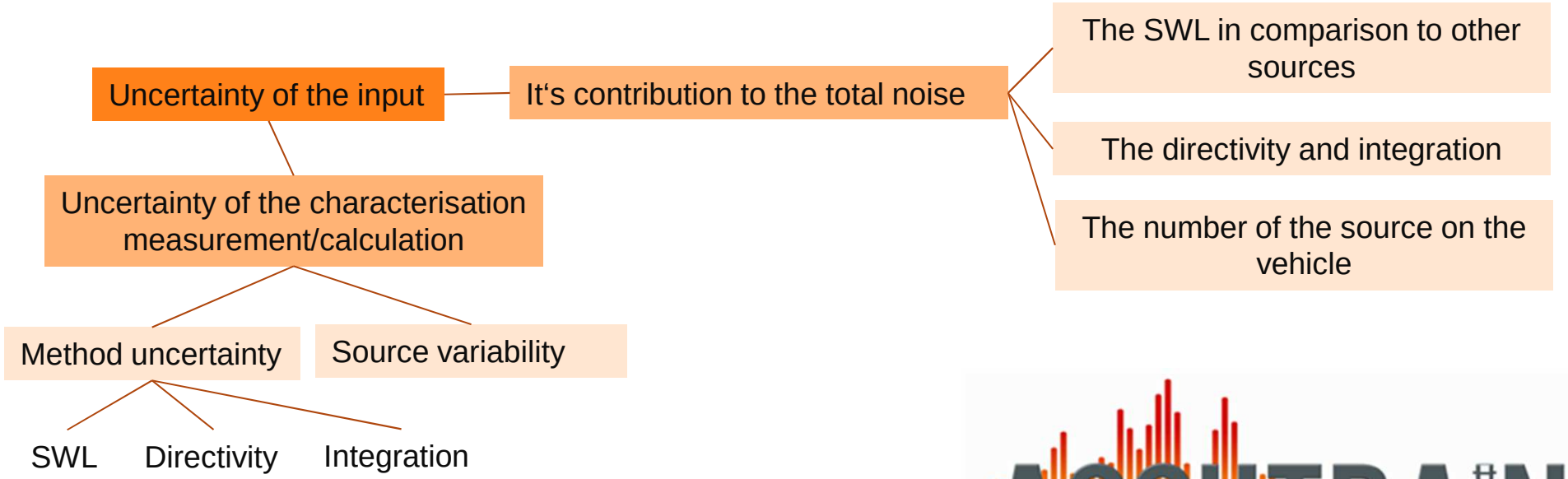
Definition of similarity between two vehicles

- The question whether two vehicles are similar enough for one to act as reference for the other has to be answered in an early phase in order to choose the right virtual testing approach.
- The differences between the two vehicles have to be limited since the validation with measurement data is only performed for the reference vehicle.
- Each modification of the second vehicle introduces an uncertainty.
- Which factors influence the uncertainty of the virtual vehicle emission calculation?



Definition of similarity between two vehicles

Example for a decision model:

Calculate the points for each modification →

Stationary noise		Points
Number of the modified source /car	=< 0.4	1
	0.4<>1	3
	=>1	5
Ranking of the source	1-4	5
	5-8	3
	>8	1
	Uncertainty	
	>2,5 dB	7
Assessment of modification	2,5-2	3
	2-1,5	2
	<1,5	1
Removal of source		0
Addition of shielding		0
Modification without effect on noise emission		0

→ Sum < Limit value? → Yes → Similar

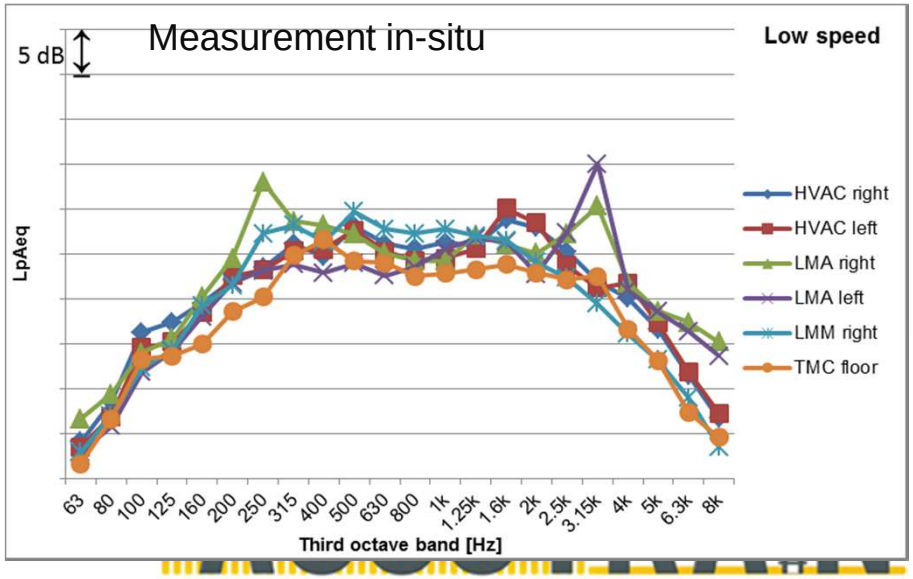
Sum < Limit value? → No → Not similar

Acoustic ranking of sources

A ranking was performed for the NAT sources within the validation of the procedure.

- Based on the sound power level but also the installation effect and directivity should be taken into account.
- It gives the impression that the HVAC is the dominating source, but it was shown that much of the sound energy is directed upwards.
- Instead the stationary noise measurement results show that the return air fan is important
- The SPL-measurement in-situ with the microphone directly in front of some of the sources shows another ranking.

Sources					
	Stationary	**LwA (dBA)**	**Quantity**	**Installation**	**Directivity**
1	HVAC		8	Roof	Upwards
2	TMC roof	-5,6	2	Roof	Side
3	TMC bogie	-8,4	8	Bogie	Side, partly behind skirt
4	LM-LMA	-9,8	3	Roof	Round
5	Driver's HVAC	-10,1	2	Front	Round
6	LMM	-10,3	1	Roof	Round
7	Transformer	-12,7	2	Roof	Round
8	Return air fan	-13,7	16	Roof	Side



How do you prove that rolling noise is dominating?

Proposal:

<u>Definition of “dominating”</u>
The contribution of the other sources to the total level at pass-by by less than 1 dB(A) at a track corresponding to TSI requirements.

<u>How to prove that the rolling noise is dominating?</u>

- The pass-by noise with only rolling noise is calculated for a TSI-track.
- Sources that are running at pass-by are characterised.
- If the sum of the sources is more than 6 dB below the pass-by noise it can be concluded that the rolling noise is dominating.
- A virtual vehicle model can be used.

The transposition method

The transposition method (presented in Session 3) is an alternative within the Virtual testing approach.
It takes place between 2 track conditions.

Requirements:
- The rolling noise should be the only noise source to be considered for pass-by noise.
- Measurement of vehicle pass-by (on any track) should be performed.

- The rolling noise calculation is validated with the pass-by measurement.
- The wheel model thus validated can be re-used with another track (a TSI-compliant track / the virtual TSI-reference track) in the simulation model.

Alternatively to calculations, transposition method can also be carried out by applying transfer measurements.

The definition of a virtual TSI –reference track

Which track input should be used when calculating rolling noise in a virtual certification procedure?

There are four proposals that have been discussed in Acoutrain:

- **Minimum requirements of the TSI-track according to ISO3095**
  + Is already defined and accepted
  - Is theoretical
  - Will lead to an overestimation of the calculated noise in comparison to measurements at real TSI-tracks.
- **Define a track inputs based on measurement statistics of real TSI tracks**
  + Higher equality between measurement and virtual testing procedures
  - Requires the set up of a database and further research

The definition of a virtual TSI –reference track

- **Use track characterisation data from any track that fulfils the TSI-requirement**

  \+ Simple

  \- If not regulated it is likely that everyone wants to use the best track in Europe, which leads to lower results in comparison to measurements on any real track that fulfils the TSI-requirement

- **Completely remove the noise emission of the track to only evaluate the vehicle**

  \+ Only validates the vehicle noise

  \- Does not correspond to reality

  \- New definition of the TSI-Limiting values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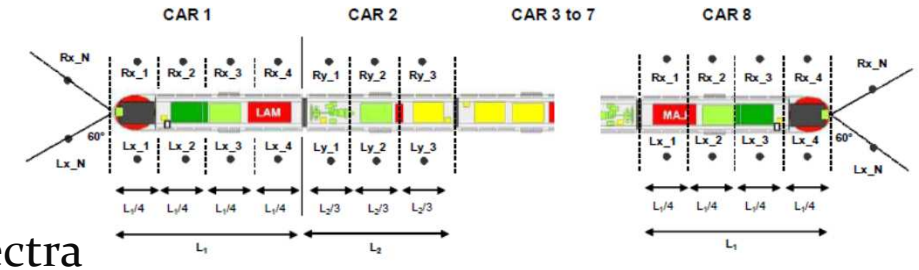
Validation of VV – Stationary test

Measurement: Parameters to be taken into account for validation

Stationary test for NOI TSI certification is used for VV validation.



Measured acoustic quantity:

$L^{i}_{pAeq;T,}$ (see ISO3095) +1/3rd octave band spectra

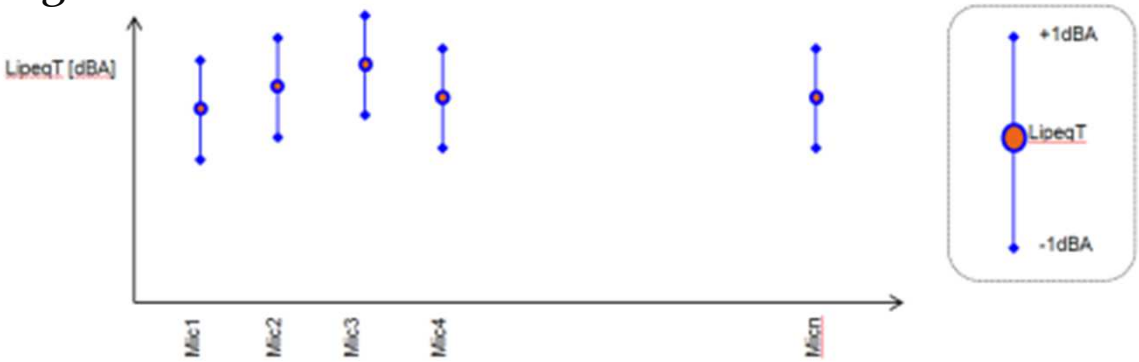
Validation metric & criterion

Max. deviation in $L^{i}_{pAeq;T,}$ for each microphone positions shall be within +/-X* dB(A)

Max. deviation in <LpAeq,T> Unit shall be within +/-Y* dB(A)

Max. deviation in <LpAeq,T> Unit for each third octave band shall be within +/-Z* dB(A)

(*) limit to be defined after completing the uncertainty propagation study



Model update loop

Results should be checked microphone per microphone to identify the one with the highest deviation.
Together with a frequency analysis it should allow the source of deviation to be identified: Which noise source seems to be problematic?

1- Check its running conditions: is it for instance a traction source which can not be reliably characterized except on the running train?
2- New lab test could be performed
3- Integration effect should be re-measured
4- Additional tests could be carried out with a dedicated microphone antenna around the source mounted on the train (as in NAT measurement campaign)

➔ New source (different from the previous…) or different position to be implemented in the VV
Comparison of the updated VV to real measurement

Traction equipment

Traction equipment is not validated with standstill test.

- In this Hybrid approach-case the vehicle at stand-still acts as a reference to the same vehicle at pass-by.
- Uncertainties are introduced when calculating pass-by noise without validation.
- The maximum acceptable uncertainty limits the application.
- The validation at stationary shows that the model basically corresponds to the real vehicle.
- For the pass-by noise calculation model rolling noise and traction equipment is added to the virtual vehicle model.
- The added uncertainty may be too high for self ventilated cooling systems.
- Noise sources at stationary should be updated to the pass-by operational condition. The characterisation method should be identical for both conditions.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Model update loop at stationary

For the validation of the virtual vehicle at standstill, the same procedure then the one presented before (VV validation for the hybrid approach) should be used.

Validation of VV – Pass-by test

Measurement: parameters to be taken into account for validation

Complete pass-by noise tests according to ISO3095 are to be performed with the real reference vehicle.

For the set-up of the model additional measurements have to be performed:

- Wheel roughness measurement according to the ACOUTRAIN proposal
- Rail roughness measurement according to ISO 13610
- Track decay rate measurement according to En15461
- Ground characterization according to the American ANSI/ASA S1.18-2010

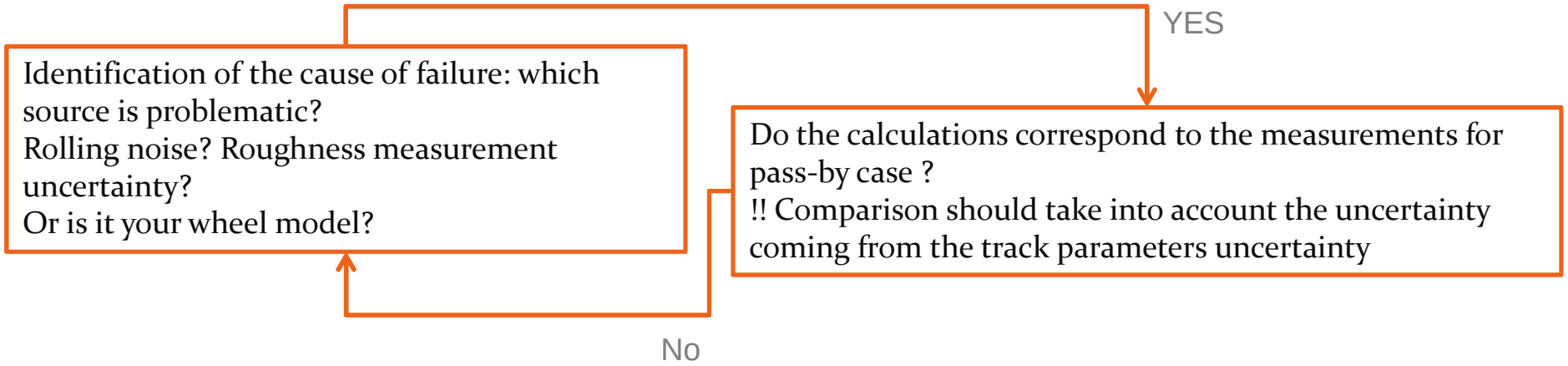
The pass-by measurement should be repeated 3 times, the criterion spread below 3 dB to be fulfilled. Measurement on a track with TSI-compliant roughness or TDR is not necessary, but the track should be compliant to ISO 3095 requirements except for these requirements.

Validation metric & criterion

Max. deviation between measured and calculated pass by noise in $L_{pAeq;Tp}$ < +/-X* dB(A)
Max. deviation between measured and calculated pass by noise spectra in third octave bands < +/- Y* dB(A)

(*) limit to be defined after completing the uncertainty propagation study

Model update loop at pass-by



If a deviation is seen between real test and model for pass-by tests, then:

- Rolling noise source should be checked proprietarily:
  - Particularly track parameters uncertainty should be taken into account because they can explain some deviation.
  - Similarly, wheel numerical modelling should verified

•Depending on frequency bands where failure occurs, then traction noise and equipment noise can also be questioned. Operation conditions should be verified for the pass-by: do we take into account this source in the correct operation conditions?

- For traction noise, the noise source characterization can also be questioned because of difficulty we have for measuring these sources in lab.

Integration effect characterization

Deliverable 3.7 gives recommendations for integration effect characterization, with comparison of several assessment methods:

- Analytical formulation
- Boundary element calculation
- Ray tracing calculation
- On-train measurement

However, these recommendations have not been tested in the application cases implemented in ACOUTRAIN and integration effect could not be taken into account for the NAT model.
These methodologies need to be elaborated further before being implemented in a virtual testing process.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