SOPRANOISE Final Results and Outcomes

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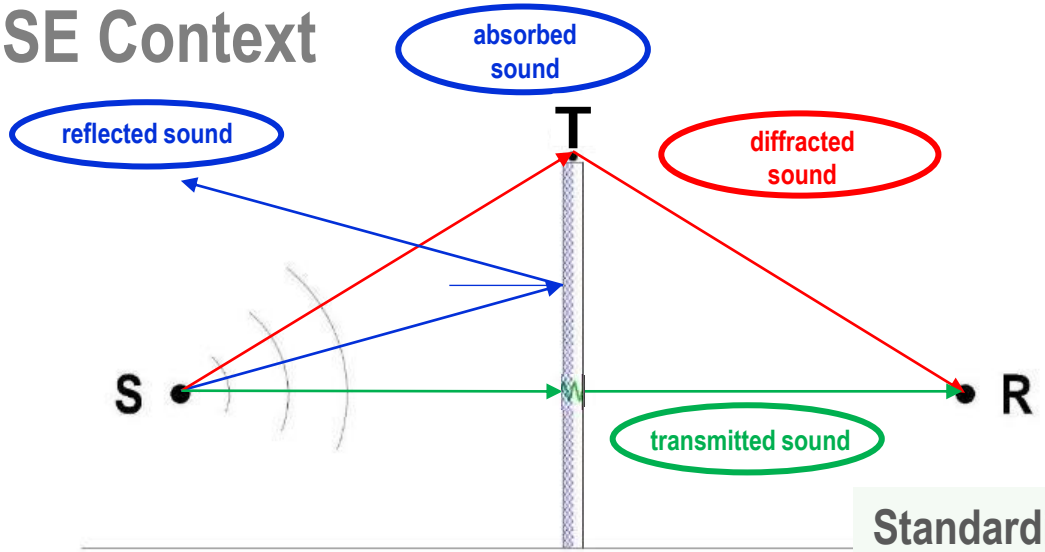
Content of the Presentation

1. SOPRANOISE : Context, Objectives, Structure
2. WP2: State of the Art, Database, Effect of Degradations
3. WP3: In-Situ Inspection Tools
4. WP4: Quick Method
5. WP5: Guidance for NB Use
6. Conclusions

SOPRANOISE Context



NB overall acoustic performance (IL) depends on:

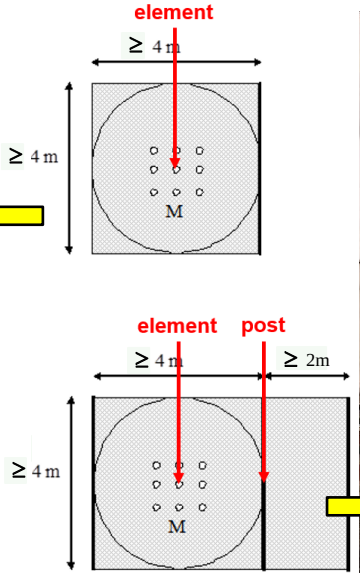
- NB location (S respect to T & R) and its geometry (L & H)
- NB intrinsic / product performances (sound absorption, sound diffraction, sound insulation)

Standardized test methods:

- to **certify products**, but also
- to **test installed products (products & installation)**

SOPRANOISE Context

certification

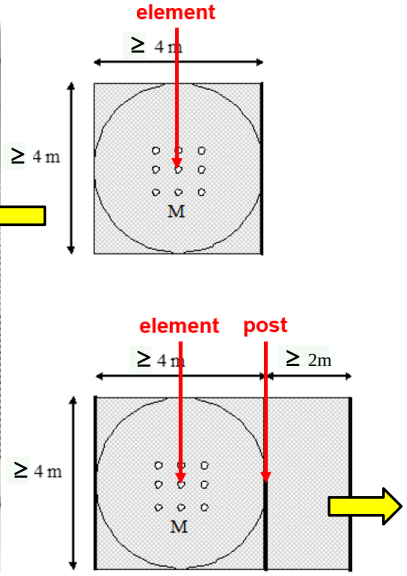


EN 1793-5 sound reflection DL_{RI}

EN 1793-6 airborne sound insulation DL_{SI}

SOPRANOISE Context

certification



EN 1793-5 sound reflection DL_{RI}

EN 1793-6 airborne sound insulation DL_{SI}

SOPRANOISE Context

EN 1793-5 & -6 can thus also be used along roads for approvals

SOPRANOISE

Securing and
Optimizing the
Performance of
Road tr**A**ffic noise barriers with
New meth**O**ds and **I**n- **S**itu **E**valuation

alongside roads

⇒ need for faster, safer, less expensive methods

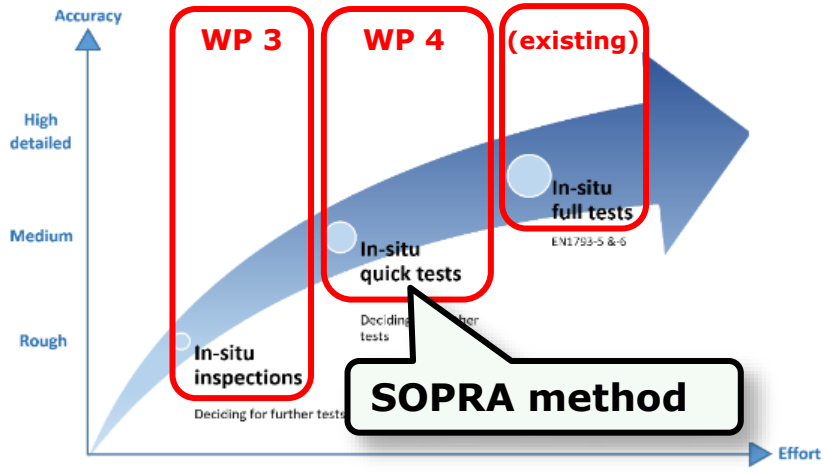
SOPRANOISE Objectives

Main objective is to **characterize Noise Barriers intrinsic** following a **"progressive engineering approach"**:

SOPRANOISE 3-step approach

- From the easiest but possibly least accurate way, …
- Up to the most accurate, but possibly quite long, difficult and costly way **(EN 1793-5 & 6)**

- By Adding 2 new steps:
  - **In-situ inspections** : **WP 3**
  - Filling the "gap" in between with: faster, safer **"quick tests"** : **WP 4**

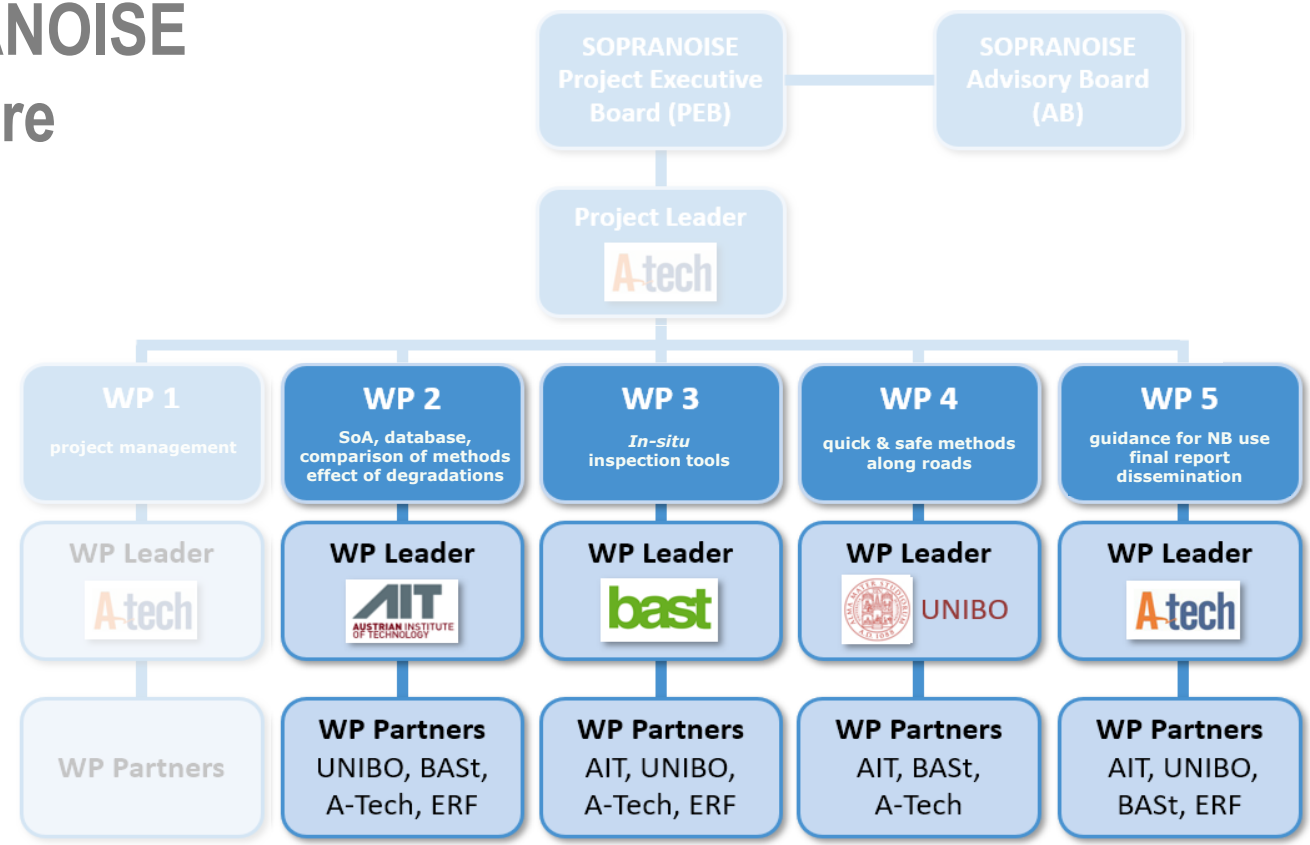


SOPRANOISE Objectives

Also **to improve knowledge** about NB performances:

- WP2 : State of the Art and database of the intrinsic acoustic performances of existing NB in EU with relevant analysis
- WP5 : Guidance for NB use

SOPRANOISE Structure



WP2 - State of the Art, Database, Effect of Degradations

To improve knowledge about NB performances:

- relevant **database of the intrinsic acoustic performances of existing NB in EU**

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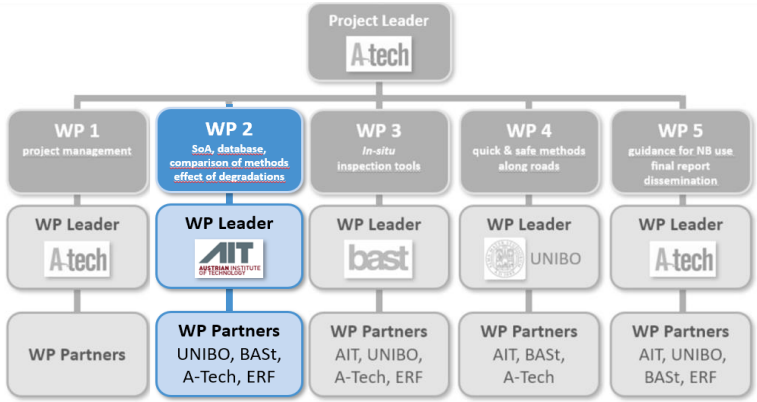


WP2 - State of the Art, Database, Effect of Degradations

The general objective of WP 2 was **to provide both theoretical and practical background information** on measurement methods characterizing the acoustic performance of noise barriers and on meaningful results

- Task 2.1: Review of the **physical significance** of EN 1793-1, -2, -5 and -6 (report D2.1)
- Task 2.2: Update and analysis of **noise barrier database** including new current measurements (report D2.2)
- Task 2.3: Influence of **acoustic degradation** of noise barriers on the total noise reduction (report D2.2)

WP2 - SOPRANOISE Database

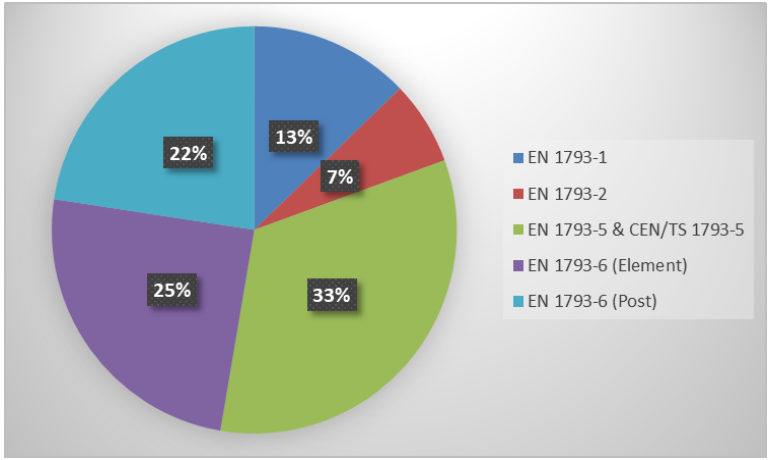
2.029: total number of different datasets collected

1.263: total number of validated data

448 different noise barriers

39 testing laboratories

9 different European countries (AT, BE, DE, ES, FR, IR, IT, NL, UK)



WP2 - SOPRANOISE Database

Data according to measurement methods under **diffuse sound field conditions**: **EN 1793-1 & 2**

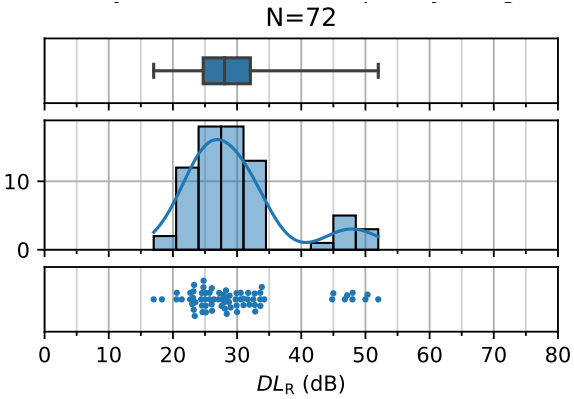
- **138** single-number ratings on sound absorption $DL_{\alpha,\ NRD}$
- **72** single-number ratings on airborne sound insulation DL_R

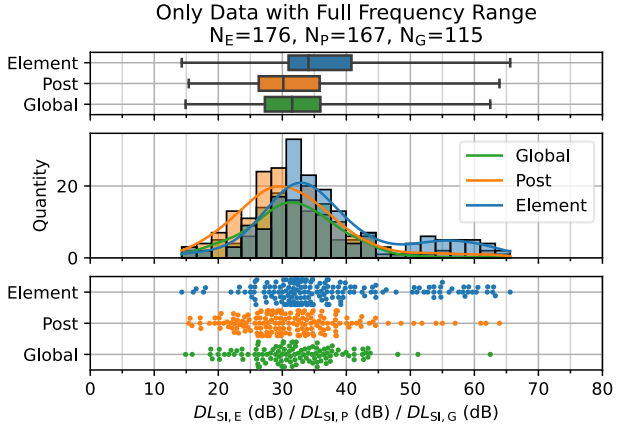
Data according to measurement methods under **direct sound field conditions**: **EN 1793-5 & 6**

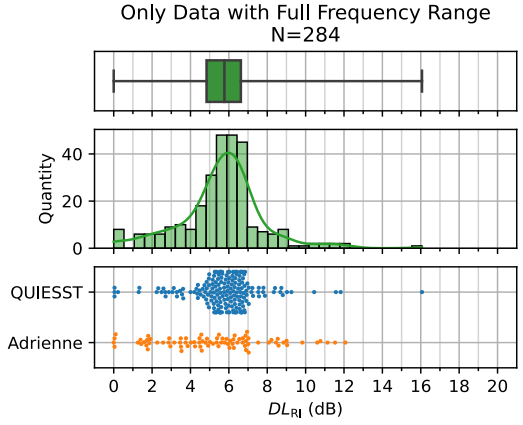
- **359** single-number ratings on sound reflection DL_{RI}
- **267** single-number ratings on airborne sound insulation for elements $DL_{SI,E}$
- **244** single-number ratings on airborne sound insulation for posts $DL_{SI,P}$
- **183** single-number ratings of global values $DL_{SI,G}$

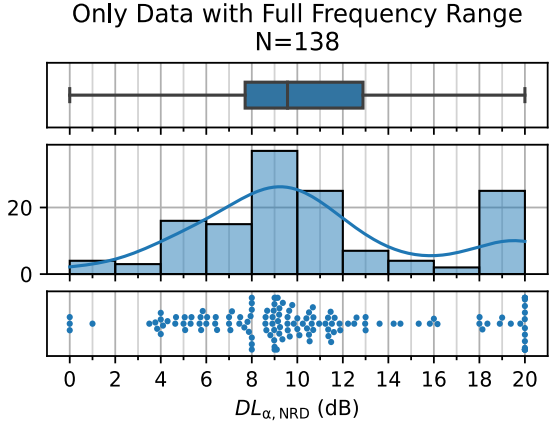
WP2 – Statistical Analysis

- **single measurement results**
- **box-plots** with minimum, median, maximum, 25% and 75% percentile
- **histograms** with statistical distribution
- **probability density function** smoothed by a **kernel density estimator**



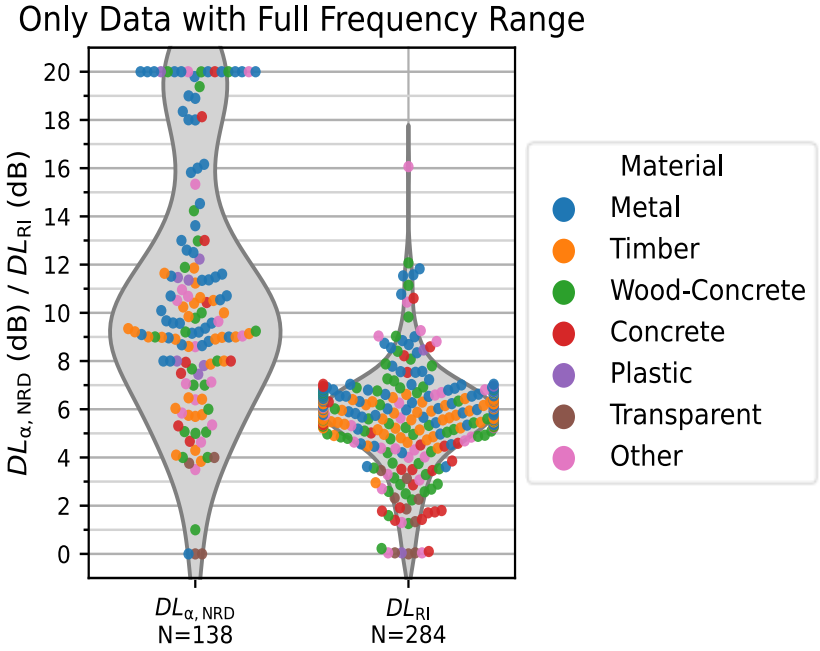






WP2 – Main Results on Sound Absorption / Reflection

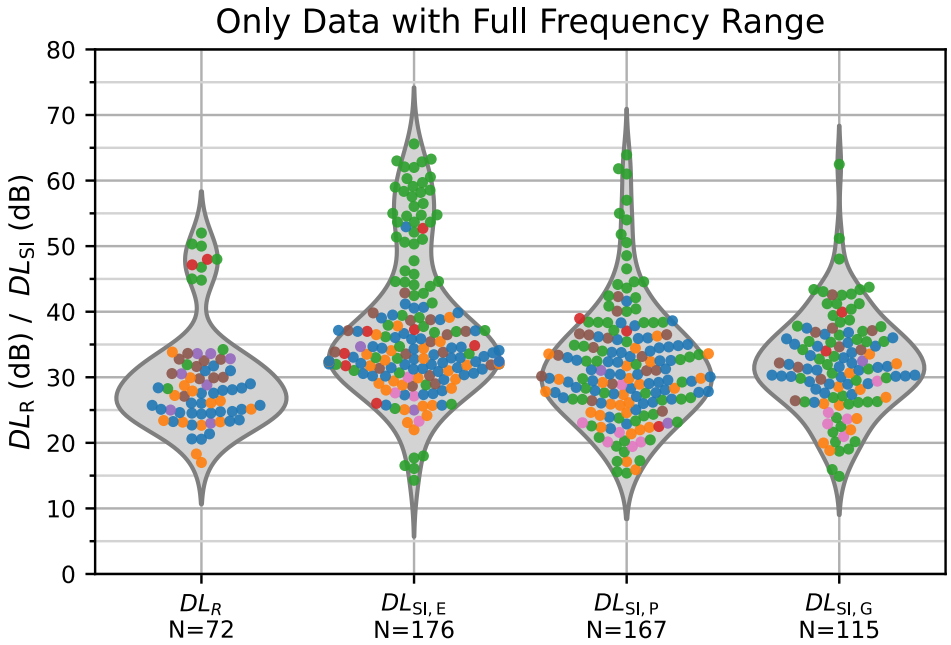
- Good **overview of the EU market**
  - Results with EN 1793-1 are considerably higher than results with EN 1793-5
  - **Median** value for EN 1793-1 $DL_{\alpha,\,NRD} \approx 9$ dB
  - **Median** Value for EN 1793-5 $DL_{RI} \approx 6$ dB
- Poor correlations between EN 1793-1 and -5: very rough estimates limited to low sound absorbing samples → **no practical use for certification or quality assurance purposes**
- NRA can set meaningful **target values for sound absorption / reflection** → see WP5



WP2 – Main Results on Airborne Sound Insulation

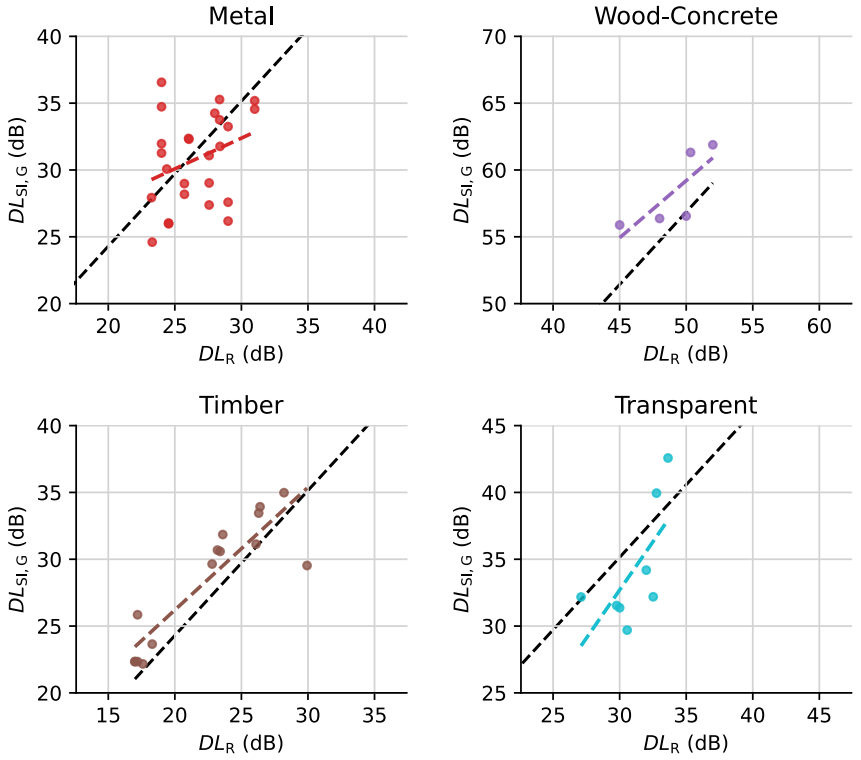
- Good **overview of the EU market**
  - Results of EN 1793-2 are in general slightly lower than results of EN 1793-6
  - Element values are in general higher than results at the post
  - **Median** value for EN 1793-2 $DL_R \approx 28$ dB
  - **Median** values for EN 1793-6:

    $DL_{SI,E} \approx 34$ dB , $DL_{SI,P} \approx 30$ dB, and $DL_{SI,G} \approx 31$ dB
- NRA can set meaningful **target values for sound insulation** → see WP5



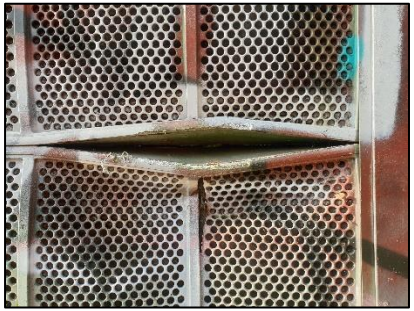
WP2 – Main Results on Airborne Sound Insulation

- Possible correlations between EN 1793-2 & -6: **promising fit between DL_R and DL_{SI}**
- **Regression model** for each material (coloured dashed lines) and for all available data (dashed black line)
- Significant uncertainties of the regression models must be considered when predictions are made
- Good information, **but no possible use of the model for certification or quality assurance purposes**



WP3: In-Situ Inspection Tools



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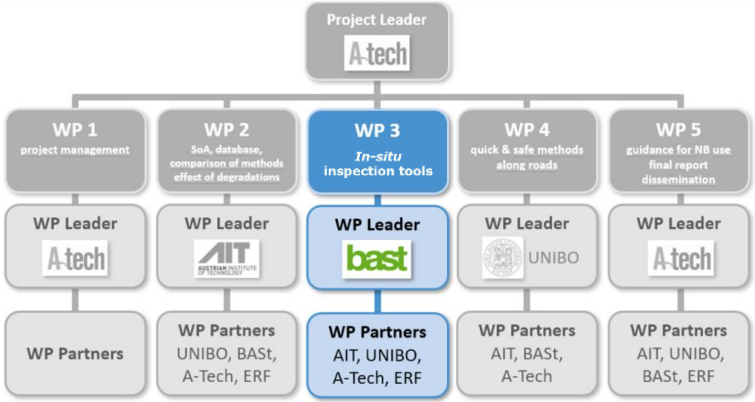


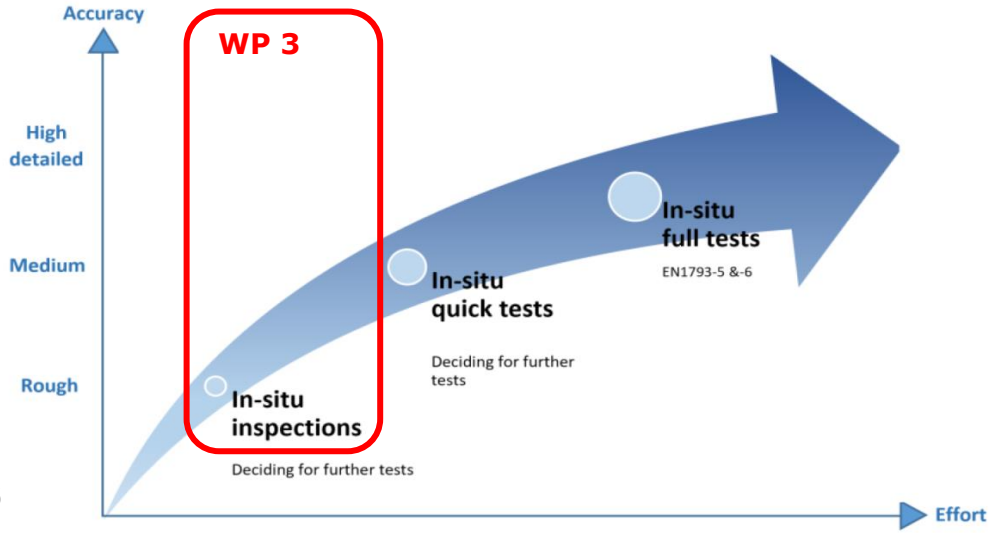
WP3: In-Situ Inspection Tools

Main question:

To what extent can in-situ inspections yield fair indications on the acoustic performances of installed noise barriers?

- **review,**
- **testing and**
- **further development of in-situ inspection methods**

➢ procedure for the **qualitative** assessment of the possible effects due to degradations in noise barriers

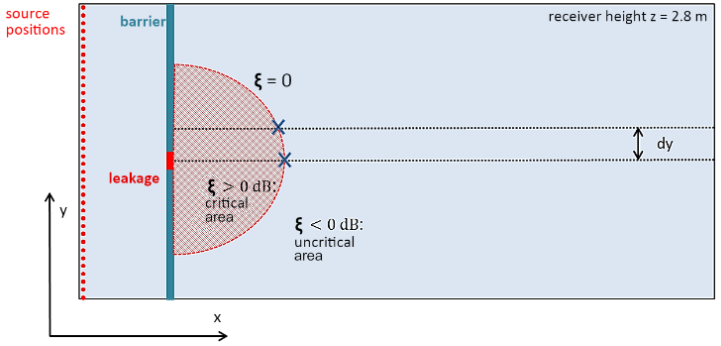


WP3: In-Situ Inspection Tools

Visual inspection procedure - only for *airborne sound insulation*

Based on theoretical framework described in WP2 > **Deliverable report D2.2**

- validated model developed in old BASt research project
- sound diffraction across the top edge is compared with sound transmission through leak
- criticality condition $\xi = L_{m,t} - L_{m,b} + 10\ dB$
- **critical radius** as a measure for **severity of leak**



WP3: In-Situ Insp

Visual inspection proce

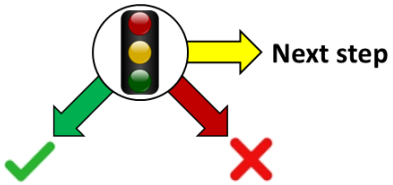
→ **Qualitative** approximation of degradation of IL

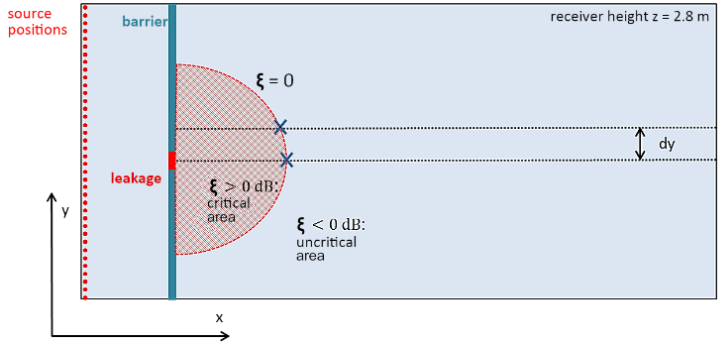
→ **No** actual acoustic **measurements**

→ **Compromise** between practical applicability and accuracy

Principles considered :

- calculation of critical area where a leak can decrease the insertion loss
- simplified geometry, e.g. fixed conventional height of 2,8 m
- consideration of size and position of the leak
- final acoustic rating as "**traffic light**" result





WP3: In-Situ Inspection Tools

Inspection protocol [Excel file]

- simple and
- input durin
- results out
- five works

Location

Manual

step instruction

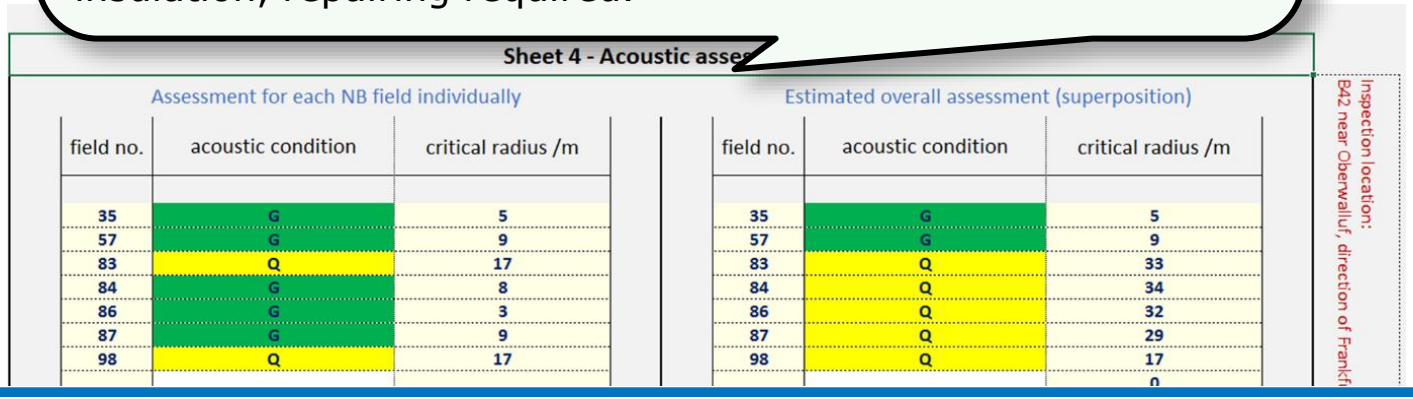
description

ity and theoretical
ackground

Green: *acceptable acoustic condition*, non-priority actions required for airborne sound insulation.

Yellow: *questionable acoustic condition*, further testing could be required (e.g. passing on to quick method).

Red: *defective acoustic condition* regarding airborne sound insulation, repairing required.



Sheet 4 - Acoustic asse

Assessment for each NB field individually

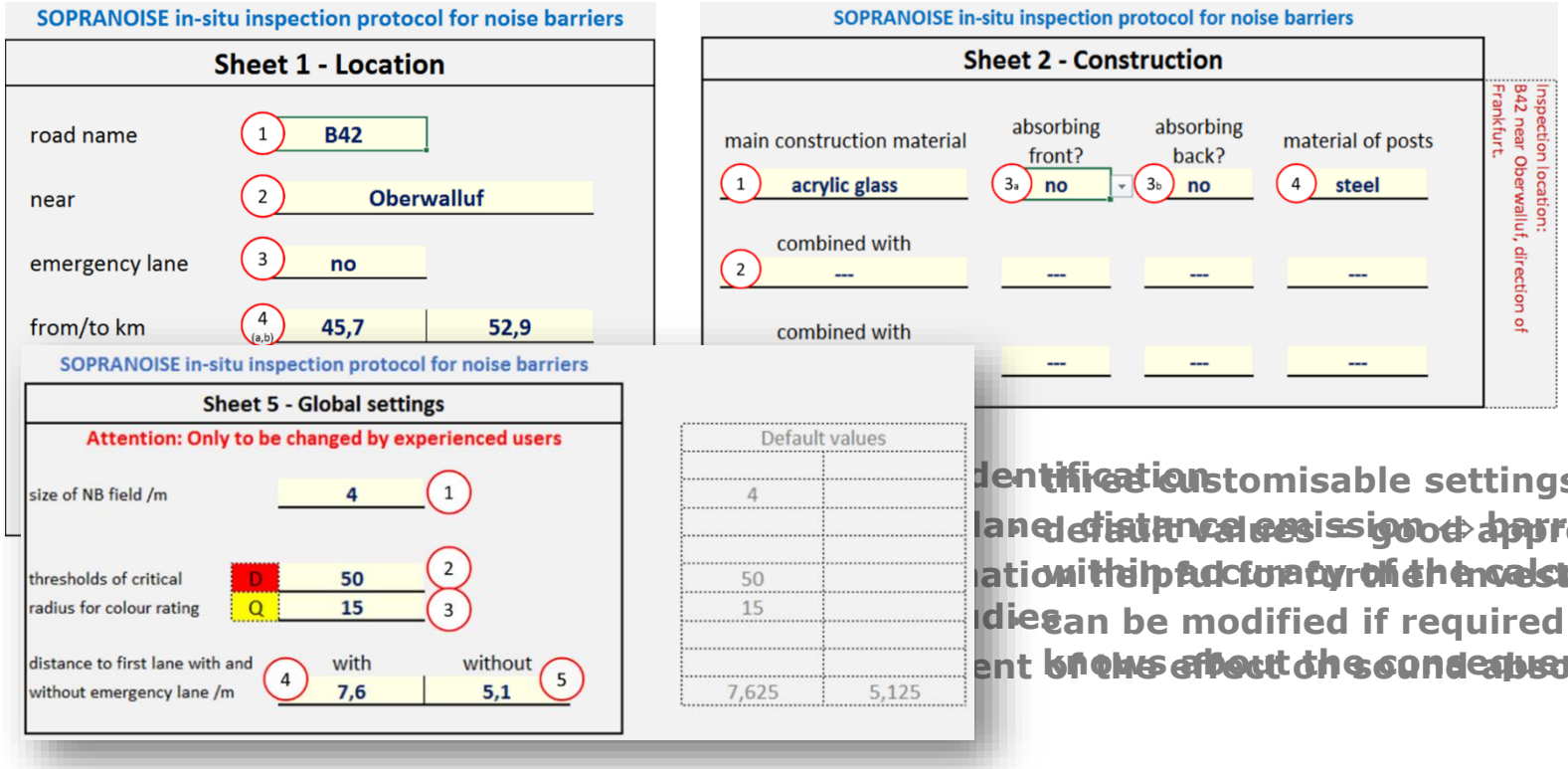
field no.	acoustic condition	critical radius /m
35	G	5
57	G	9
83	Q	17
84	G	8
86	G	3
87	G	9
98	Q	17

Estimated overall assessment (superposition)

field no.	acoustic condition	critical radius /m
35	G	5
57	G	9
83	Q	33
84	Q	34
86	Q	32
87	Q	29
98	Q	17

Inspection location: B42 near Oberwalluf, direction of Frankf

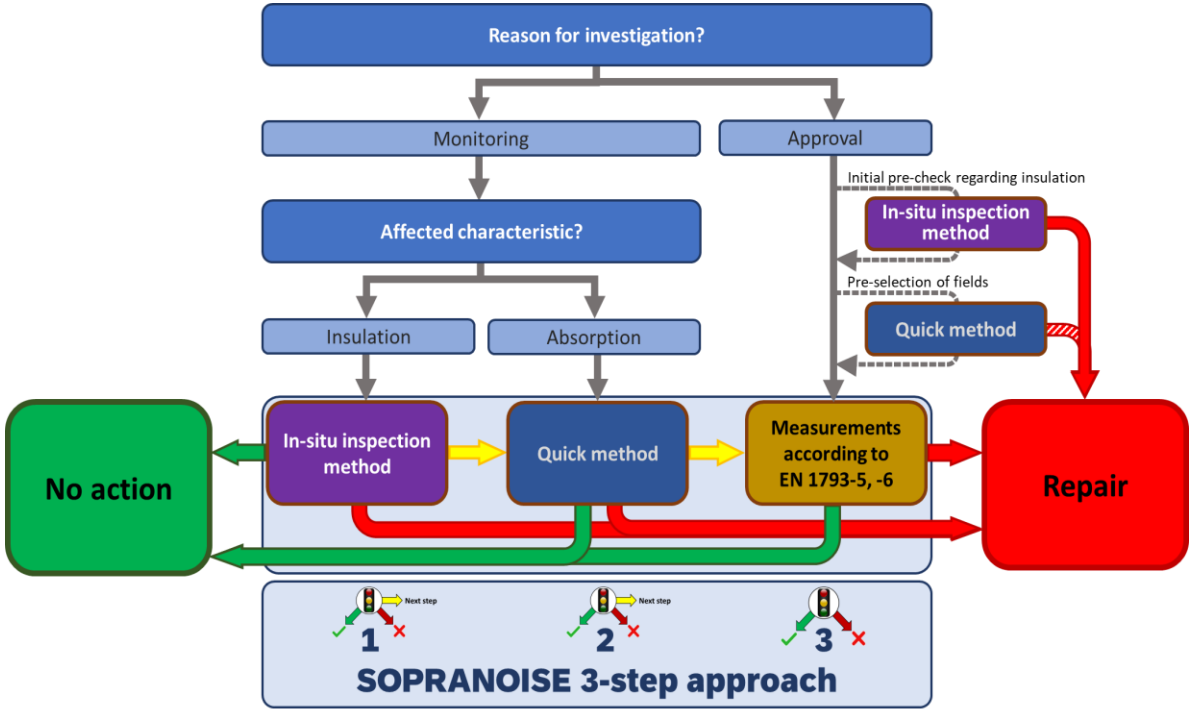
WP3: In-Situ Inspection Tools



- identification
- lane, distance emission ↔ barrier
- ation in help for further investigations
- dies
- ent on the effect on sound absorption

- three customisable settings
- default values → good approximation within accuracy of the calculation
- can be modified if required (and user knows about the consequences)

WP3: In-Situ Inspection Tools



The visual inspection now provides **a first relevant, qualitative approximation of effects on the acoustic performance of a noise barrier due to leaks!**

For quantitative statements, measurements are always required.

WP4 Quick Method

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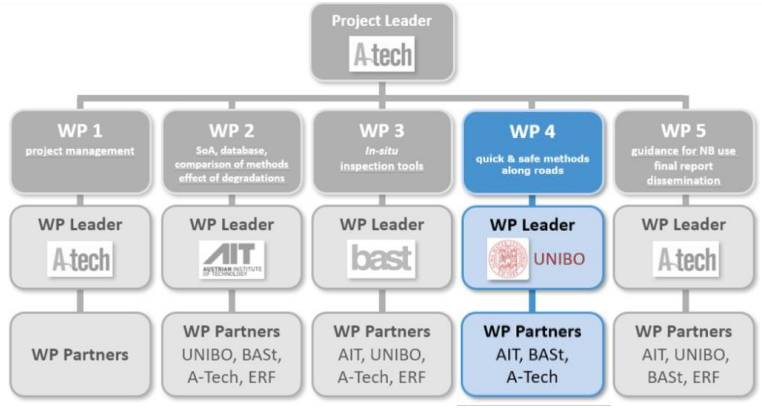
University of Bologna
(UNIBO, Italy)



WP4 – Quick Method – Step 2 of the 3-step SOPRANOISE Approach

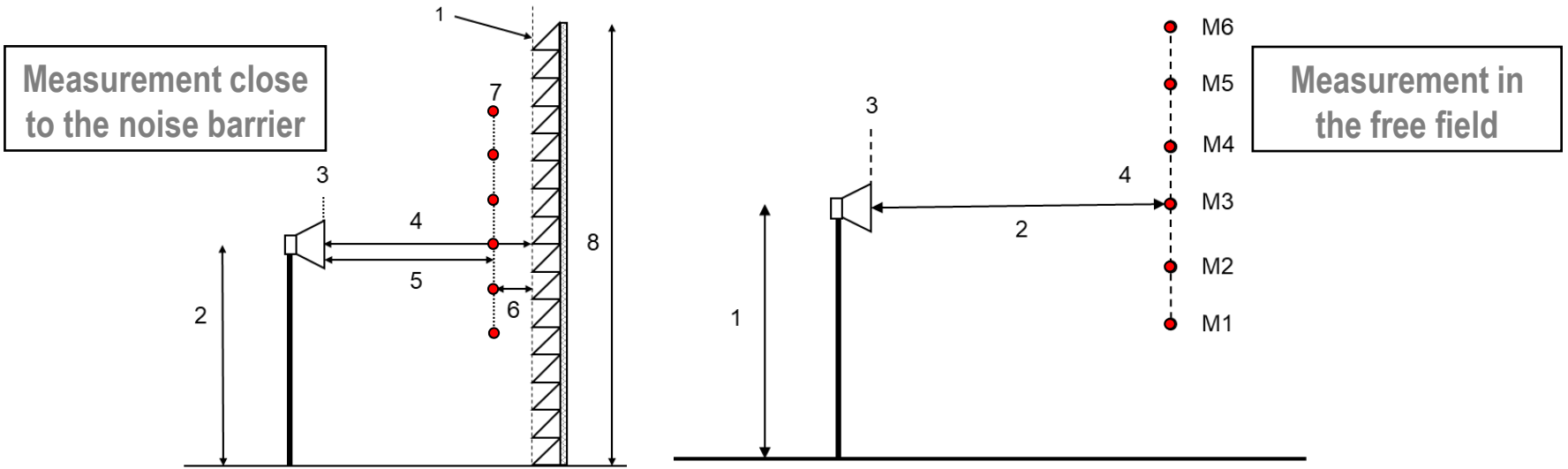
Objective: Develop a **quick measurement method** to fill the gap between in-situ visual inspections (step 1) and full testing according to EN1793-5 and EN1793-6 standards (step 3)

- skilled operators not required → **simplification of EN 1793-5, -6 procedure**
- equipment **lighter and easier to operate** than for EN 1793-5, -6 tests → **designed ad hoc**

UNIBO → **AIT**

- Lightweight loudspeaker
- Linear microphone antenna
- Battery power supply
- Operated by few buttons
- Wireless connection with loudspeaker

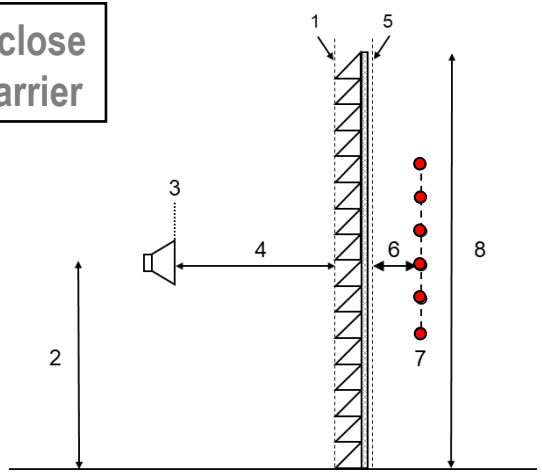
WP4 – Quick Method – General Principle - Sound Reflection



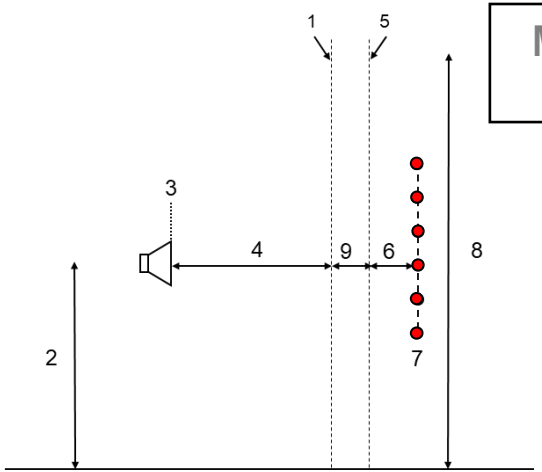
The ratio of the power spectra of the direct and the reflected components gives the basis for calculating the **"quick" sound reflection index RI_Q** as a function of frequency

WP4 – Quick Method – General Principle - Sound Insulation

Measurement close to the noise barrier



Measurement in the free field



The ratio of the power spectra of the direct and the transmitted components gives the basis for calculating the **"quick" sound insulation index SI_Q** as a function of frequency

WP4 – Design and Laboratory Tests

The new equipment has been **specifically designed** and then **tested in the laboratory** in comparison with the full EN 1793-5, -6 method on **real size samples**

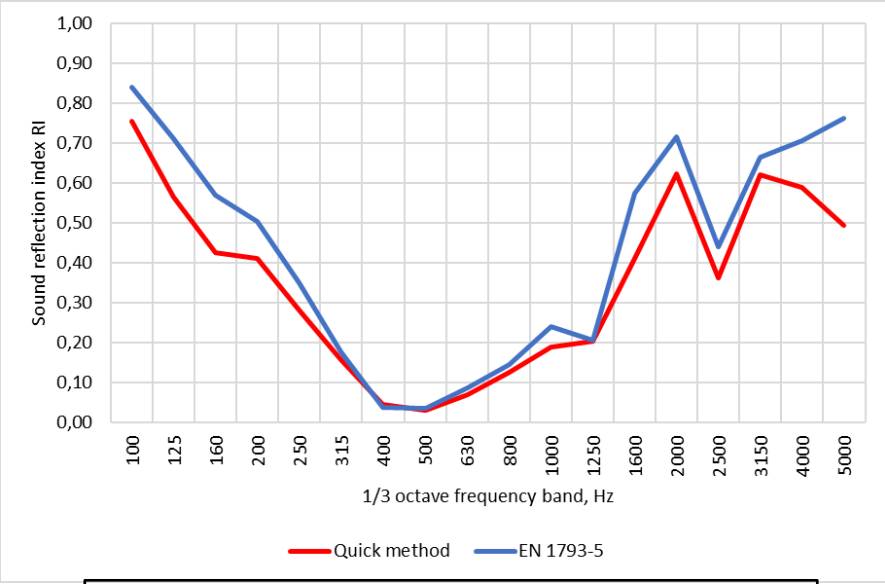
Full EN 1793-5, -6 method
Zircon loudspeaker
9-microphone grid

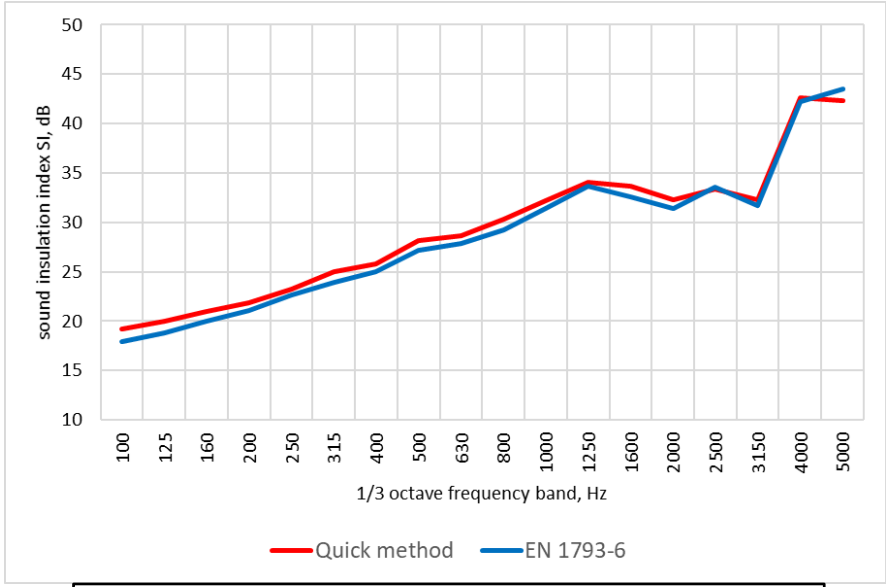
Quick SOPRA method
lightweight loudspeaker
6-mic. linear antenna

In both cases:
microphone spacing
s = 0,40 m
as per EN 1793-5, -6

In both cases:
mic. distance to sample
d_{MB} = 0,25 m
as per EN 1793-5, -6

WP4 – Laboratory Tests: excellent agreement with EN standards





Full EN method: DL_{RI} = 5,1 dB
Quick method: DL_{RIQ} = 5,9 dB
ΔDL_{RI} = 0,8 dB

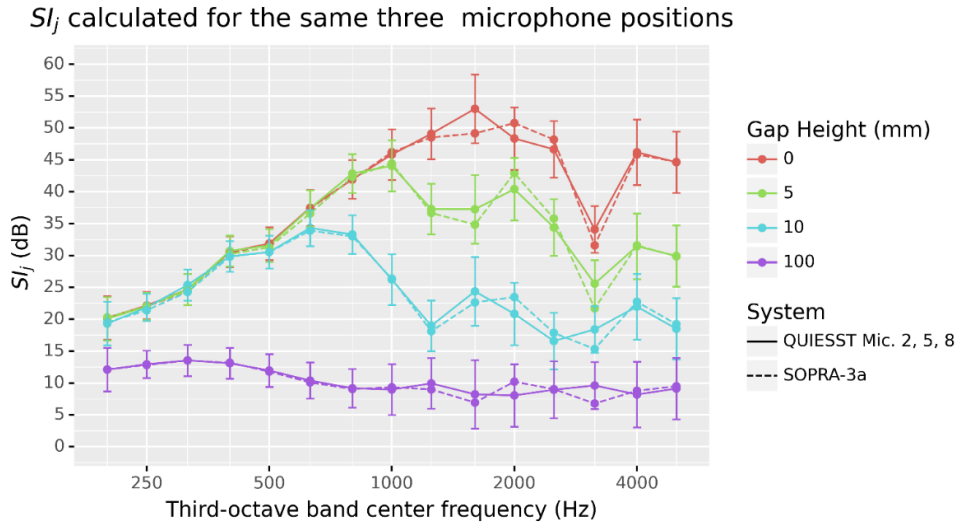
Full EN method: $DL_{SI,E}$ = 28,5 dB
Quick method: $DL_{SIQ,E}$ = 29,3 dB
$\Delta DL_{SI,E}$ = 0,8 dB

WP4 – Quick Method - Lab Tests on Artificial Defects

5 gap heights x 4 gap positions x
2 methods (quick and EN) + 2 ref. (no gap)
= 42 measurements

All microphone combinations tested:

M1 to M6, M1 to M5, M2 to M5, …



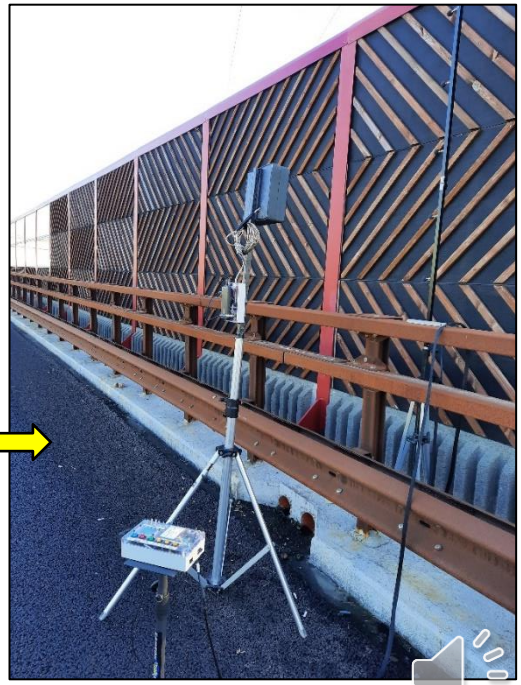
Comparison between spectral results considering the 3 center-column microphones of the

EN 1793-6 grid (M2, M5, M8) and the SOPRA-3a method (M2, M3, M4)

WP4 – Quick Method – In-Situ Validation – A22 Motorway (IT-AT)

Quick measurements done in **1 day** on a new metal barrier
- **22 Reflection index measurements**
- **11 Sound insulation index measurements**

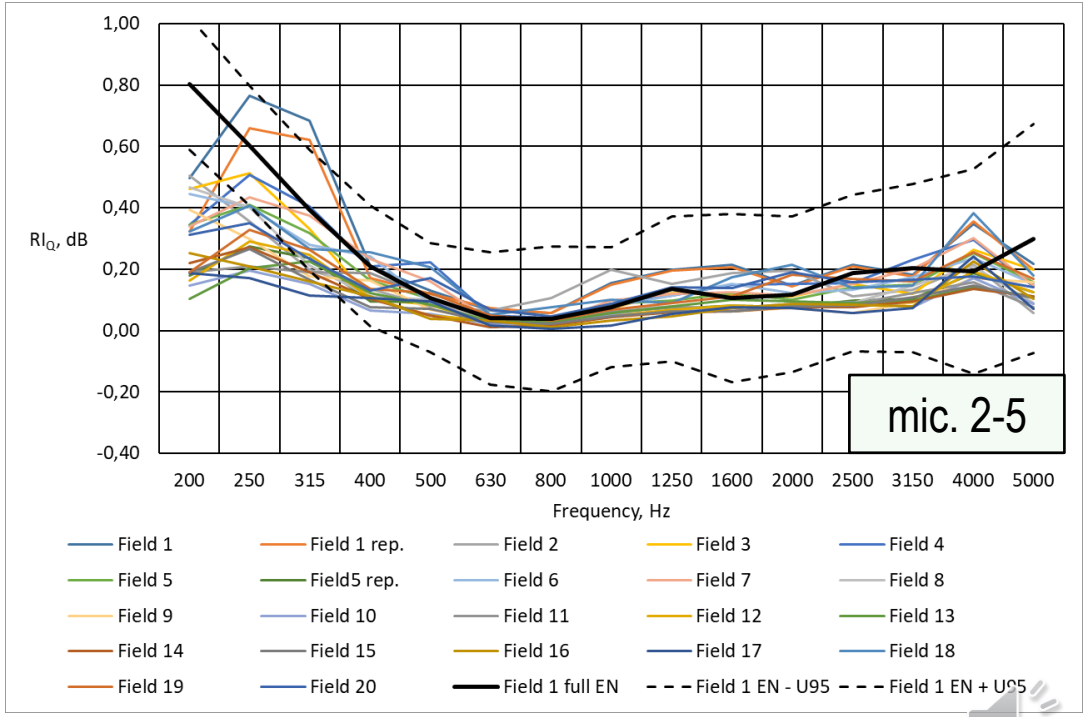
Quick measurements done in **5 hours** on a 7-year-old timber barrier
- **8 Reflection index measurements**
- **7 Sound insulation index measurements**



WP4 – Quick Method – In-Situ Validation – Sound Reflection

- In order to be quick and simple, in situ the responses from all the 6 microphones are kept
- In the post-processing stage, the subset of microphones to be considered is a function of the height of the noise barrier under test (see table in the report)

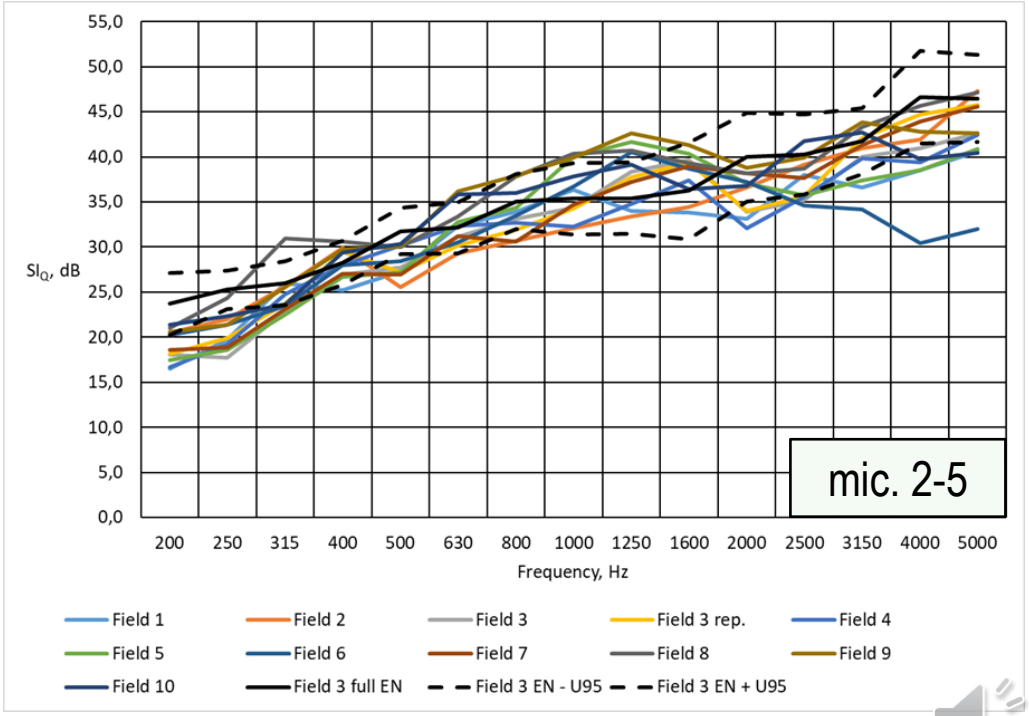
Metal noise barrier
Dotted lines: tolerance interval according to EN 1793-5 (U_{95})



WP4 – Quick Method – In-Situ Validation – Sound Insulation

- In order to be quick and simple, in situ the responses from all the 6 microphones are kept
- In the post-processing stage, the subset of microphones to be considered is a function of the height of the noise barrier under test (see table in the report)

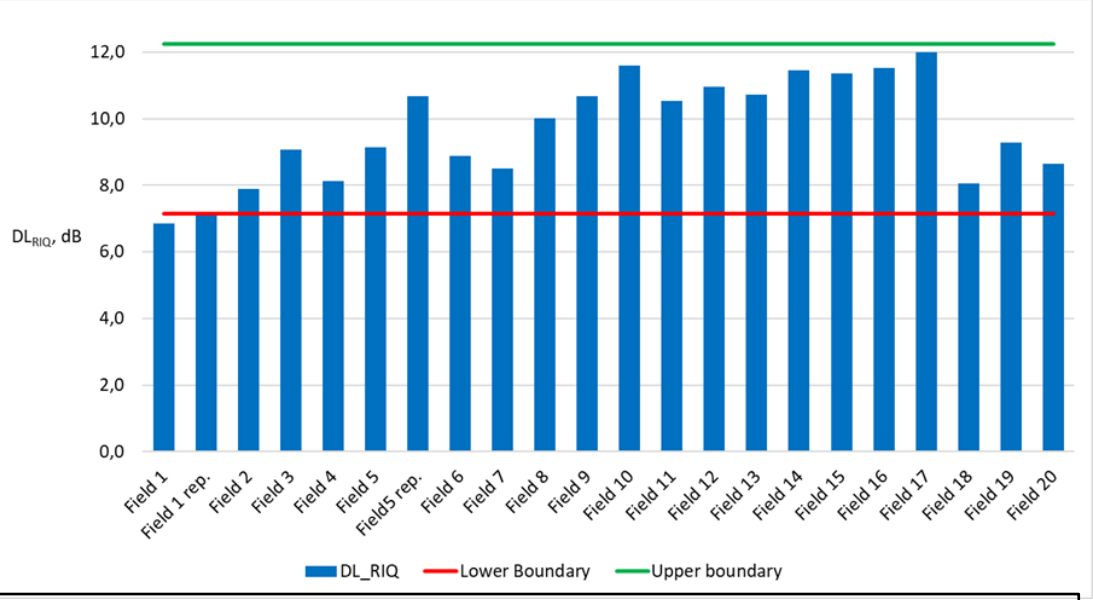
Metal noise barrier
Dotted lines: tolerance interval according to EN 1793-5 (U_{95})



WP4 – Quick Method – In-Situ Validation – Added Value

Sound **reflection** index single-number rating DL_{RIQ}

Green line: DL_{RIQ} + 1,96*std dev.
Red line: DL_{RIQ} - 1,96*std dev.

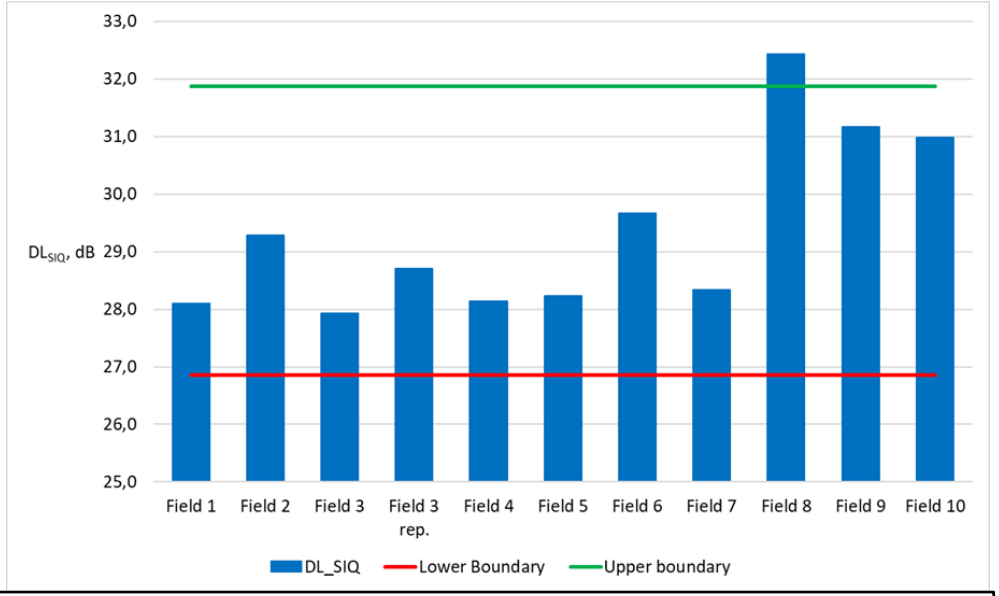


- Due to the combined variance of manufacturing, quality of installation workmanship, etc., the **single-number rating values range from 6,9 dB to 12,0 dB**.
- Only a quick method, allowing to do multiple measurements in a short time, can give this information.
- A visual inspection cannot appreciate this variance: it would conclude that all barrier fields are very similar and in good order and thus should get the same single-number rating.

WP4 – Quick Method – In-Situ Validation – Added Value

Sound **insulation** index single-number rating DL_{SIQ}

Green line: DL_{SIQ} + 1,96*std dev.
Red line: DL_{SIQ} - 1,96*std dev.



- Due to the combined variance of manufacturing, quality of installation workmanship, etc., the **single-number rating values range from 27,9 dB to 31,2 dB**.
- Only a quick method, allowing to do multiple measurements in a short time, can give this information.
- A visual inspection cannot appreciate this variance: it would conclude that all barrier fields are very similar and in good order and thus should get the same single-number rating.

WP4 – Quick Method – Conclusions

- Quick method, easier and faster than EN 1793-5, -6 developed? **Yes**
- Quick method and new equipment working in lab? **Yes**
- Reasonable correlation with EN 1793-5 and EN 1793-6? **Yes**
- Quick method validated in real conditions alongside roads ? **Yes** (A22 IT-AT)
- Quick method tested on controlled defects in lab? **Yes**
- Description of procedure? **Yes**, see Report D4.2
- *Additional information on the variance of the performance along the whole noise barrier? Yes, see Report D4.2 → basis of a sampling procedure*
  (… research to be continued with Italian and Austrian NRAs)

WP5 : Guidance for Noise Barriers Use

Task 5.1 website: **https://www.enbf.org/sopranoise/**

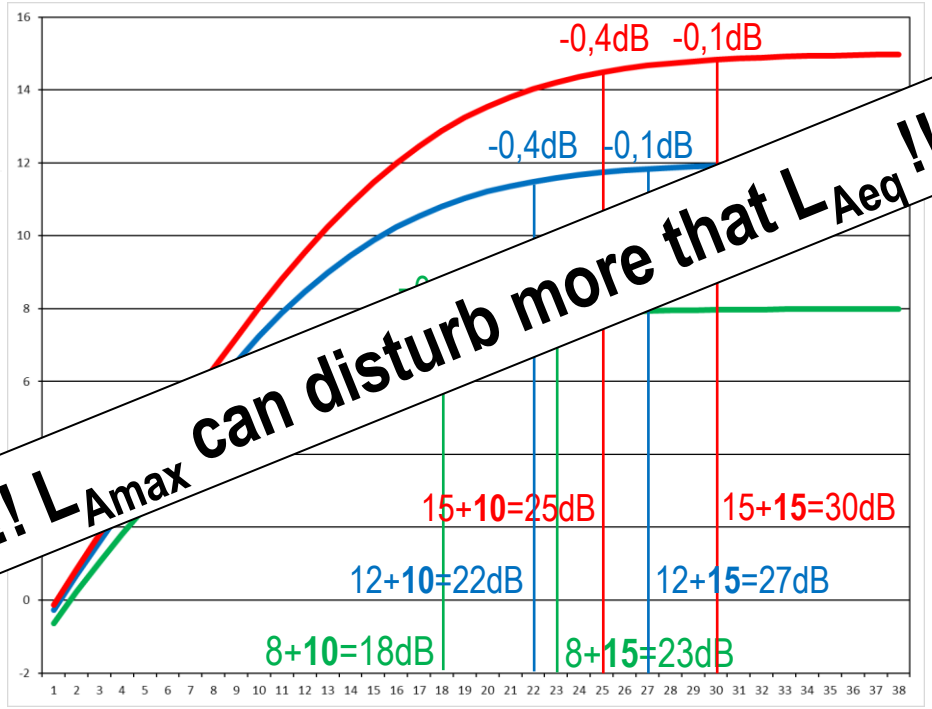
Task 5.2 Physical behavior of NB / acoustic intrinsic performances

Attempt to be as exhaustive as possible about every key factor affecting the NB performance : Difficult to list all … nor to present a common, simple, **“rule of thumb”**

WP5 : Guidance for Noise Barriers Use – Sound Insulation

IL (dB)

(diffraction + transmission)



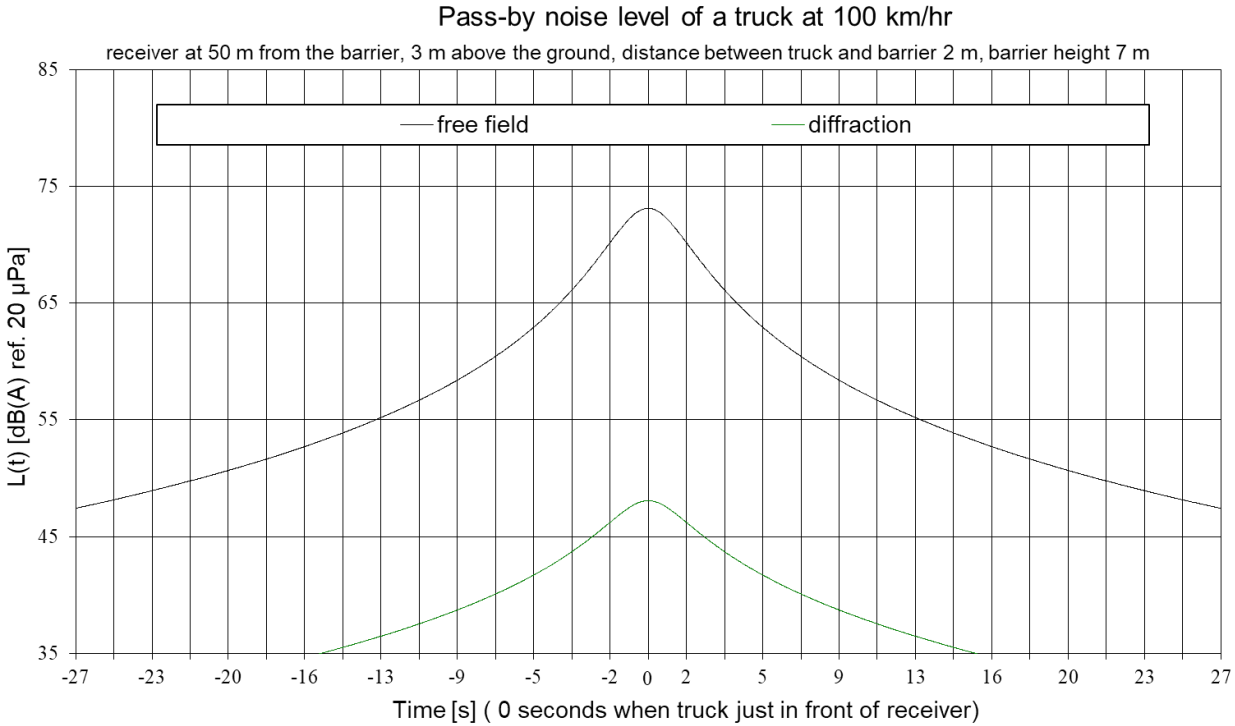
NB airborne sound insulation (dB)

!!! L_{Amax} can disturb more that L_{Aeq} !!!

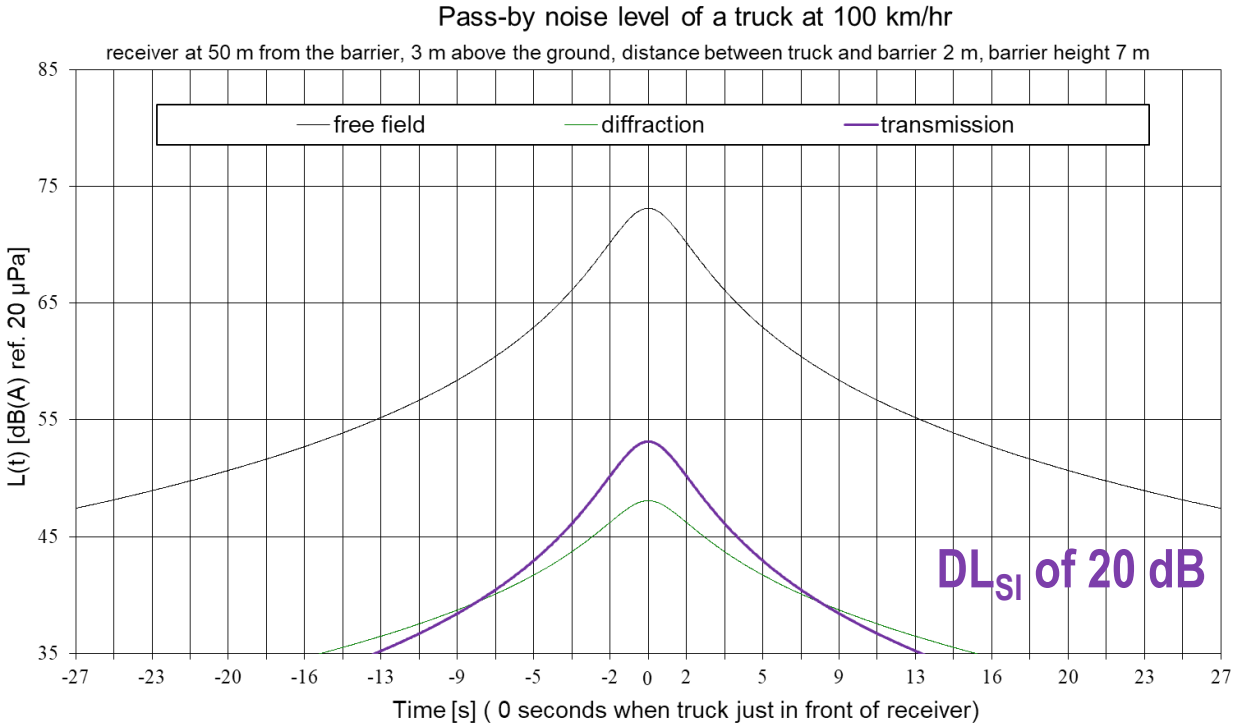
8 dB

(diffraction only)

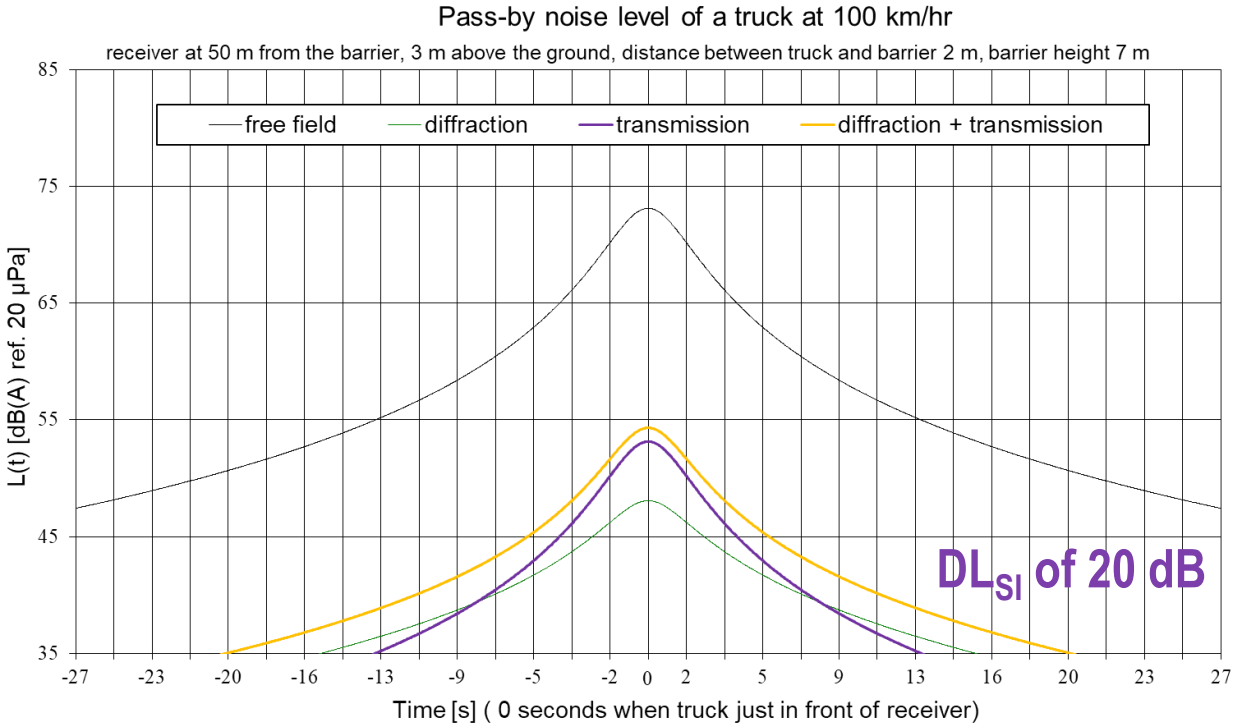
WP5 : Guidance for Noise Barriers Use – Sound Insulation



WP5 : Guidance for Noise Barriers Use – Sound Insulation



WP5 : Guidance for Noise Barriers Use – Sound Insulation



WP5 : G…

Problem is complex:

There is no perfect noise barrier that could be the best everywhere …

No simple "rule of thumb"

Task 5.1 w…

Task 5.2 (report on) Physical behavior of NB / acoustic int… …nances

Attempt to be as exhaustive as possible about every key factor affecting the NB performance : **see T5.2 report in Deliverable D5.1 on website**

Task 5.3 State-Of-the-Art on the today's NB use within the EU Market (**7 questions survey on :**)

NB **types** used, **specifications** / **requirements**, **contract awarding process**, **control at the installation**, **maintenance** and **end-of life**

32 replies from 18 EU countries (road / rail authorities, NB associations and manufacturers)

WP5 SOA on the Today's NB Use within the EU Market : Types

Table 1: summarized replies on the installed *sound absorbing NB*

Sound absorbing (m²)								
Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Total
8.895.562	3.169.045	761.892	3.204.830	15.000	169.249	813.846	1.812.473	18.841.897
47%	17%	4%	17%	0%	1%	4%	10%	100%
18.841.897								

Table 2: summarized replies on the installed *sound reflecting NB*

Sound reflecting (m²)								
Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Total
842.985	655.303	59.655	9.707	2.393.937	77.921	30.906	150.859	4.221.274
20%	16%	1%	0%	57%	2%	1%	4%	100%
4.221.274								
17%								

Table 3: summarized replies on the *"other?" (undefined) NB*

Other? (m²)								
Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Total
16.762	1.085.242	294.300		10.687	3.509	18.772	294.682	1.723.954
1%	63%	17%		1%	0%	1%	17%	100%
1.723.954								

Table 4: statistics on the whole replies about NB types

absorbing (m²)	reflecting (m²)	other (m²)
18.841.897	4.221.274	1.723.954
76%	17%	7%
24.787.124		

WP5 SOA on the Today's NB Use within the EU Market : Requirements

However, it should always be the acoustic design study that fixes the relevant DL_{RI} values

Figure 31: Single-number values DL_{RI} for all the test reports within the SOPRANOISE database [11]

$$most\ common\ DL_{RI}\ requirement \approx 5\ \ to\ 6\ dB$$

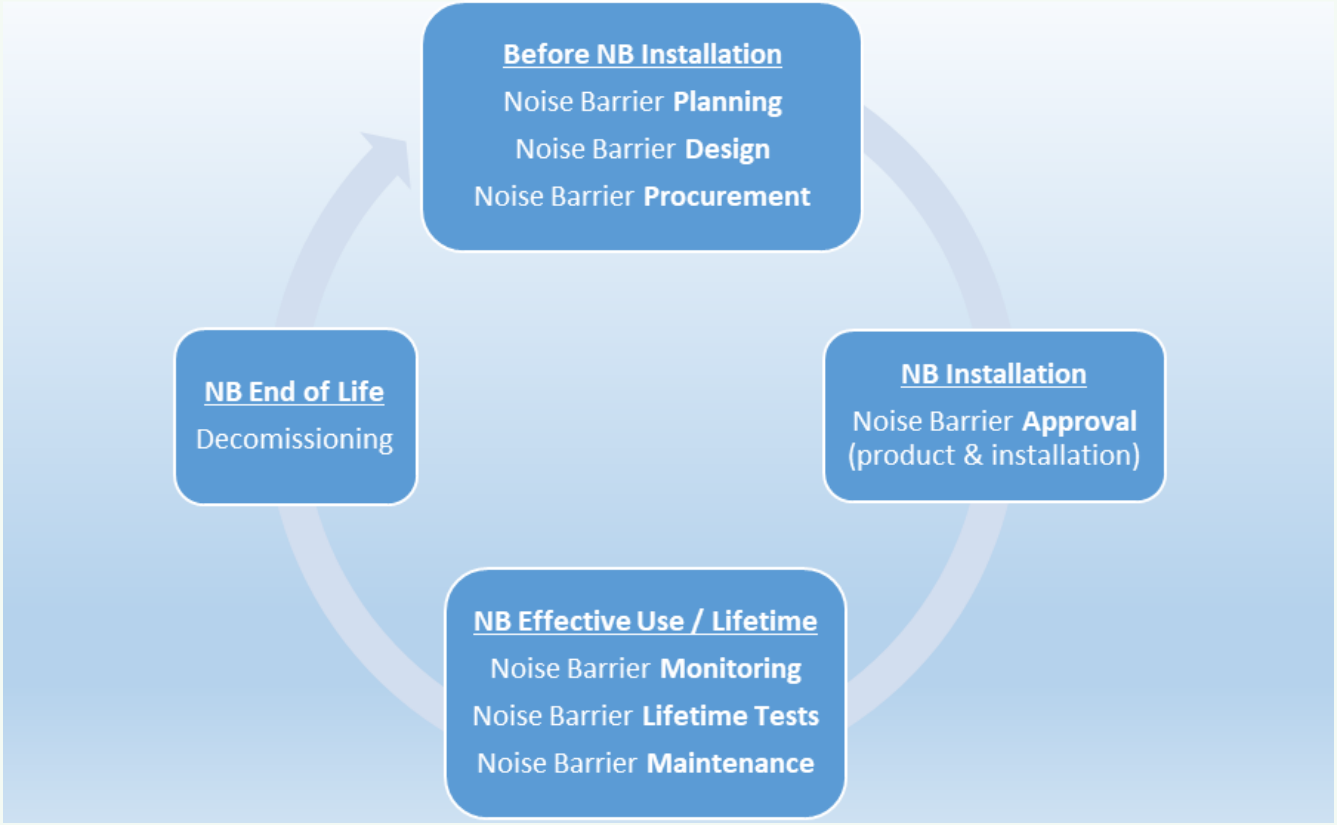
WP5 SOA on the Today's NB Use within the EU Market : Requirements

(60% of the repliers are still using 1793-2 for free standing NB)

However, it should always be the acoustic design study that fixes the relevant DL_{SI} values

Figure 32: Single-number values DL_{SI} for all the test reports within the SOPRANOISE database [11]

$most\ common\ DL_{SI}\ minimal\ requirement \approx 25\ dB$


Before NB Installation
Noise Barrier Planning
Noise Barrier Design
Noise Barrier Procurement
NB Installation
Noise Barrier Approval
(product & installation)
NB Effective Use / Lifetime
Noise Barrier Monitoring
Noise Barrier Lifetime Tests
Noise Barrier Maintenance
NB End of Life
Decomissioning

Conclusions

Noise barriers can provide very high and effective noise reduction but **only if they are correctly designed, built, monitored and maintained during their whole lifetime**.

Taking advantage of all the outcomes of the research, SOPRANOISE provides a **better knowledge and relevant information at every stage of a new noise barrier project**:

- **before its installation** (planning, design, procurement),
- **at the installation** (approval),
- during its **whole use/lifetime** (monitoring, lifetime tests, maintenance),
- up to the decision about its **end of life**.

It is highly recommended that the NRAs consider noise projects in a *holistic way* in order to keep their value as long as possible.

SOPRANOISE 3-step approach provides now appropriate quick methods for assessing the noise barriers acoustic performances, whenever and wherever.

SOPRANOISE Final Results and Outcomes

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