inter·noise 2021
1–5 August | Washington, DC

Characterizing noise barriers: SOPRANOISE half-term progress report

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ABSTRACT

SOPRANOISE targets simplified assessment of the in-situ intrinsic acoustic performances of road / railway noise barriers. This paper presents its half-term progress. The research is divided in 5 Work Packages, the scientific ones being WP2 to WP5. WP2 is about establishing a State Of the Art (SoA) on the characterization of the intrinsic performances: it is now finished and presented in 2 other papers by Conter and Fuchs. WP3 is about in-situ inspection tools: based on a review / questionnaire, an inspection protocol has been developed allowing simplified assessments mainly based on visual inspections and characterization of possible defects; WP3 is now in its final testing phase. WP4 is about designing a brand new "quick and safe methods" that could take place "in between" the inspection tools and the standardized EN 1793-5 and -6; the research and development phases of WP4 are now finished, while its validation along highways is now scheduled. Finally, WP5 is about the use of noise barriers in the European market and the final report: a synthesis on the physical behavior of noise barriers and the physical significance of the test methods has been done, as well a SoA on the effective use of noise barriers; the results will be presented.

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1. INTRODUCTION

SOPRANOISE (Securing and Optimizing the Performance of Road traffic noise barriers with New methOds and In- Situ Evaluation) is a European research funded by the CEDR (Conference of European Directors of Roads) about simplified methods to characterize the in-situ intrinsic acoustic performances of (roads or railways) noise barriers: its structure and objectives have already been presented in [1]. This paper presents the “half-term” progress report on the Work Packages WP2 to WP5.

2. WP 2: SOA, DATABASE, EFFECT OF DEGRADATIONS

2.1. Task 2.1 State-Of-the-Art

In this task, a systematic research on the State-Of-the-Art regarding physical background, available comparisons, correlations and possible trends between measurement results of methods under diffuse sound field conditions [2] [3] and methods under direct sound field conditions [4] [5] was performed. The complete results of Task 2.1 have been reported in deliverable report D2.1 that will be soon available on the SOPRANOISE website [6].

2.2. Task 2.2 Database

This task was about the update and analysis of noise barrier database including new current measurements: the activities were focused on extending the relevant database of European noise barriers already developed within the QUIESST project [7]. This updated database aims to show facts and figures about acoustic performances obtained from measurements performed under diffuse sound field as well as direct sound field conditions, together with a better understanding of the respective significance, similarities and differences of these methods. The main results are summarized in a first *general* paper [8] and in a second *more specific* paper about possible empirical correlations between the methods [9]. All the analysis performed and the results of Task 2.2 are reported in deliverable report D2.2, which will be soon available on the SOPRANOISE website [6].

2.3. Task 2.3 Effect of degradations

In this task, the effect of degradations on the global acoustic performance of noise barriers was considered in detail.

First, a theoretical description has been presented to understand and model the effect of common simple sound leaks on the sound insulation of noise barriers. This has been done by applying two approaches: on the one hand, the dependence of the degree of transmission on the characteristics of the leak is derived using the model by Mechel [10]. On the other hand, extended sound field simulations are used to calculate the reduction of the sound insulation index due to the presence of a leak with a given transmission coefficient. In practice, a significant statement about the noise barrier’s condition can be obtained via the extended sound field simulations by simply assuming a worst-case transmission.

In the second part of this task, a more global model has been applied to investigate the effect of the intrinsic properties of noise barriers on the sound immission level behind and in front of the noise barrier. From the calculations with a simple sound propagation model we can conclude, that the effect of losing transmission loss of noise barriers (e.g. due to aging or caused by small holes and slits) can be regarded as minor problem far away from a noise barrier of moderate height. However, for high noise barriers, changes of the transmission loss can cause a serious problem, also far away from the noise barrier. The higher the noise barrier, the more important is a constant high transmission loss over the lifetime of the noise barrier. The consequences of degradations in the reflection loss of a noise barrier for its overall acoustical performance are also essential. The investigations show that with decreasing reflection loss, the level in front of the noise barrier is increasing. This increase can amount to a maximum value of 3 dB in the limit of infinite distance of the receiver (doubling of the noise source). For multiple traffic lanes this behavior is comparable. Further scenario calculations show that for the special case of multiple reflections between the dolly of an articulated truck and the noise barrier can also lead to significant effects under certain conditions.

The results of Task 2.3 will be presented soon in [11], while they are also included in the deliverable report D2.2,again being soon available on the SOPRANOISE website [6].

3. WP 3: IN-SITU INSPECTION TOOLS

This work package had to provide an acoustic in-situ inspection procedure that allows simplified acoustic assessments of possible degradations of airborne sound insulation mainly based on visual inspections and characterization of defects in a noise barrier. This inspection procedure is supposed to be the first step in the progressive 3-step approach pursued in the SOPRANOISE project. It is relevant to note that this inspection tool is not intended to be used for *approvals* of newly built noise barriers, what can only be done by *quantitative* measurements. The intended purpose of the inspection is to *qualitatively assess* installed noise barriers and prioritize their maintenance.

Although the calculations within the framework of the acoustic inspection protocol have a clear approximative character, they are based on a theoretical model and are able to yield a relevant first estimation of the acoustic performance of a noise barrier under inspection regarding possible degradations of the airborne sound insulation without undertaking actual measurements.

In the presence of a leak, an acoustical critical area behind the noise barrier is formed, in which the influence of the leak is dominant over the diffraction and the sound insulation of the barrier reduces significantly. At more distant immission points beyond this area the effect from the leak is negligible and the reduction of the sound insulation is not critical anymore.

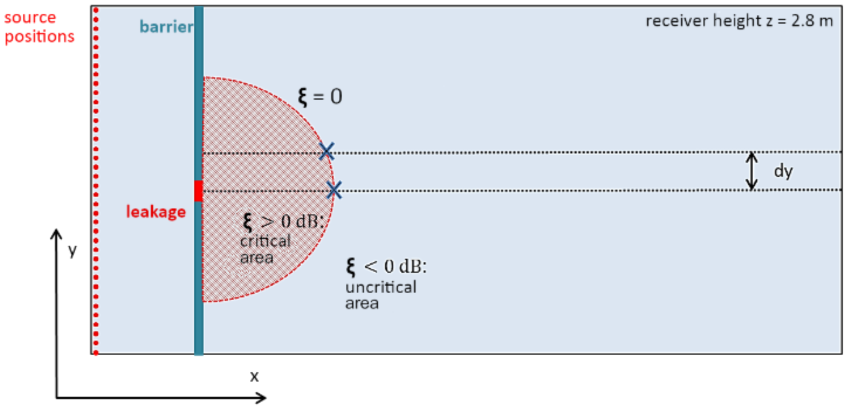

Figure 1: Illustration of the acoustical critical area behind a barrier with a leak ©BASt

Based on a review of existing inspection methods and on the results of a survey among CEDR member states, a profile of requirements for the in-situ inspection method was defined. The criteria motivated the structure and working principle of the resulting acoustic inspection protocol. The acoustic inspection protocol is set up as Excel file consisting of five different sheets. When performing a noise barrier inspection on site, the inspector can use this Excel document to obtain a first assessment of the acoustic condition of the noise barrier. This can happen interactively during the general inspection routine by using a portable device. The main features are:

- Procedure that can be implemented in a general inspection routine;
- Minimal inputs; frequent use of dropdown lists or check boxes for a fast and easy handling;
- Adjustable global settings;
- Immediate result of the acoustic *qualitative assessment* in a self-explanatory “traffic light” rating and a critical radius.

Figures 2 to 4 show example of sheets corresponding to the inspection of a degraded noise barrier.

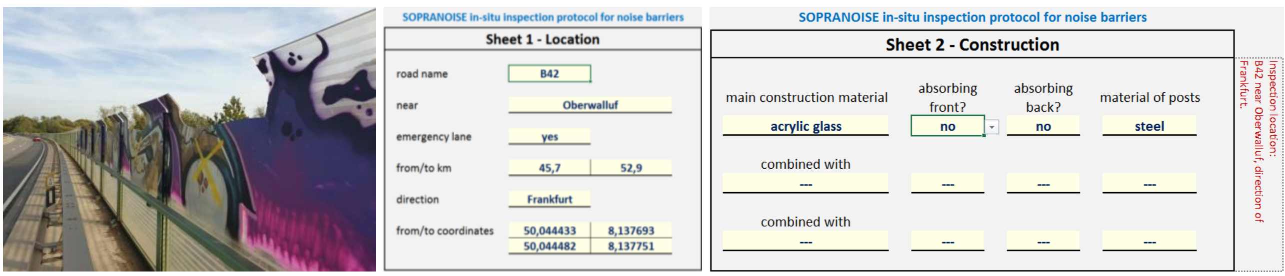

Figure 2: degraded noise barrier, ‘Location’ (middle) and ‘Construction’ (right) sheets ©*BASt*

SOPRANOISE in-situ inspection protocol for noise barriers

Sheet 3 - Defects

field no.	NB side	field height /m	defect location	type/cause of defect: impact	deformation	rust	vegetation	degradation	lacking material	view through	position /m: vertical	position /m: horizontal	size /cm: vertical	size /cm: horizontal	additional notes (e.g. on visual/aural impression, absorption material, environmental conditions, general condition, reference to photographs ...)
35	front	2	at element	☐	☐	☐	☐	☐	☑	yes	1.5 - 2.0	middle	15 - 35	65 - 125	Breakouts probably due to expansion stresses and vibrations
57	front	2	at element	☐	☐	☐	☐	☐	☑	yes	1.5 - 2.0	middle	35 - 65	65 - 125	"
83	front	2	at element	☐	☐	☐	☐	☐	☑	yes	1.5 - 2.0	middle	35 - 65	125 - 235	" (Particularly large outbreak)
84	front	2	at element	☐	☐	☐	☐	☐	☑	yes	1.5 - 2.0	middle	15 - 35	125 - 235	Breakouts probably due to expansion stresses and vibrations
86	front	2	at element	☐	☐	☐	☐	☐	☑	yes	1.5 - 2.0	middle	15 - 35	65 - 125	"
87	front	2	at element	☐	☐	☐	☐	☐	☑	yes	1.5 - 2.0	middle	35 - 65	65 - 125	"
98	front	2	at element	☐	☐	☐	☐	☐	☑	yes	1.5 - 2.0	middle	35 - 65	125 - 235	" (Particularly large outbreak)
				☐	☐	☐	☐	☐	☐						
				☐	☐	☐	☐	☐	☐						
				☐	☐	☐	☐	☐	☐						
				☐	☐	☐	☐	☐	☐						
				☐	☐	☐	☐	☐	☐						
				☐	☐	☐	☐	☐	☐						
				☐	☐	☐	☐	☐	☐						

Inspection location: B42 near Oberwalluf, direction of Frankfurt.

Noise barrier material: acrylic glass with --- and

Figure 3: All information on the detected defects are filled in on the 'Defects' sheet with its mainly drop-down lists and check boxes ©*BASt*

As shown in the example in Figures 2 to 4, the following data have to be entered :

- General information about the location of the noise barrier is entered on the 'Location' sheet, mainly as free text.
- All Information on the materials used in the design of the noise barrier are protocolled in the 'Construction' sheet. while the calculation itself is independent from the inputs made in this sheet, records on the noise barrier construction might be helpful for further investigations.
- The main input sheet of the inspection protocol is the 'Defects' one. All information on the detected defects are filled in there. Except for the field number and additional notes, all inputs have to be selected from a dropdown list or via check boxes. This makes the actual inspection process faster and easier to handle on site. The entry fields in the 'Defects' sheet are: field number, noise barrier side, field height, defect location, type/cause of defect, view through, position (vertical and horizontal), size (vertical and horizontal), additional notes.
- The sheet 'Acoustic assessment' (see Figure 4) presents the result of the acoustic inspection and is a pure output sheet, where each considered noise barrier field is listed with the assessed acoustic condition and a critical radius of influence. Two different types of acoustic assessment are included: on the left, the result of the calculation is given for each noise barrier field individually. From this, the severity (in the acoustic sense) of a single leak becomes evident. However, in general more than one leak can occur in the same noise barrier field or in neighbouring noise barrier fields. Thus, for a comprehensive overall acoustic assessment, the superposition of leaks close to each other has to be considered. An approximation for such an overall assessment is given on the right of the 'Acoustic assessment' sheet.
- In a last Excel sheet 'Settings', the inspector has the possibility to change few global parameters. In general, modifications are not necessary here, since the default values serve as a good approximation within the accuracy of the method.

SOPRANOISE in-situ inspection protocol for noise barriers

Sheet 4 - Acoustic assessment

Assessment for each NB field individually: field no.	acoustic condition	critical radius /m	Estimated overall assessment (superposition): field no.	acoustic condition	critical radius /m
35	G	5	35	G	5
57	G	9	57	G	9
83	Q	17	83	Q	33
84	G	8	84	Q	34
86	G	3	86	Q	32
87	G	9	87	Q	29
98	Q	17	98	Q	17
					0
					0
					0
					0

Inspection location: B42 near Oberwalluf, direction of Frankfurt.

Figure 4: Output sheet 'Acoustic assessment' with information about the acoustic condition of the inspected noise barrier ©BASt

The most important information follows directly from a “traffic light” rating: a *green* rating states that the noise barrier is in an acceptable acoustic condition and no further actions are required regarding its airborne sound insulation; a *red* rating is a clear indication of a defective acoustic condition, which has to be repaired in any case; and all cases in between with a *yellow* rating cannot be decided via inspection only. Here, additional acoustic measurements are necessary to decide for further actions – i.e. in the progressive approach pursued in the SOPRANOISE project, the quick method (as developed in WP 4) has to be applied. When degradations of the sound absorption performance are suspected, sound absorption measurements must also be carried out because the in-situ inspection tool cannot draw quantitative conclusions about it.

In a practical testing phase, German road authorities have been contacted to accompany motorway inspections and apply the acoustic in-situ inspection protocol. The tests involved noise barriers of different conditions (both structural and acoustic) and of different materials. Focus of the testing were the basic applicability and the question, how different degrees of (real) damages are assessed by the proposed acoustic rating. The tests confirmed: isolated leaks, even of larger size, supposedly have only minor effects on the acoustic performance of a noise barrier. However, the effect of several leaks – even of smaller size – lying close to each other superimposes and might lead to a significant loss of the airborne sound insulation properties of a noise barrier.

The results of WP3 will be presented soon in [11], while they are also included in the corresponding deliverable report D3.1, soon available on the SOPRANOISE website [6].

4. WP 4: QUICK AND SAFE METHODS ALONGSIDE ROADS

EN 1793-5 [4] and EN 1793-6 [5], derived from the two EU research projects ADRIENNE (1995-1997) and QUIESST (2009-2012), allow measurements on noise barriers *almost everywhere*, what is essential for approving noise barriers installed alongside roads. This is already and increasingly done by authorities in European countries. However, EN 1793-5 and -6 methods require a careful application by expert users, which may result in quite lengthy tests, and this can limit their use to few locations. Therefore, there is a need for a new “quick method” that could be easier and faster so as to be applied to a large part of an installed noise barriers in a manageable time period, even if with a broader uncertainty compared to the full EN standards [12]. From such preliminary acoustic assessments, few critical locations could then be selected to carry out final assessments according to [4] and [5].

In **Task 4.1** (ended June 30th, 2020) a comparative analysis of existing or potential quick methods has been done [1]. This assessment included the following characteristics: working frequency range, immunity to background noise (essential for in situ measurements), degree of expertise required to operators, lightness of the equipment, easiness of handling of the equipment on site, demonstrated correlation with the EN 1793-5 or EN 1793-6 results [13,14], demonstrated reproducibility of the results. The result of this comparative analysis was that a *simplified* version of the methods standardized in EN 1793-5 and EN 1793-6 would be the quickest way to achieve the intended goal while maintaining a *relatively good correlation* of the measured values with those resulting from the application of full EN 1793-5 and -6 procedures. However, this implies a considerable effort in making the hardware *lighter* and *easily portable* and in adapting the software to this new hardware. This is the task pursued by UNIBO researchers during Task 4.2.

In **Task 4.2** (due by June 30th, 2021), it was necessary to design a completely new equipment, simpler and faster to be used than that one for full tests, allowing the use by *normal* operators after a short training even in critical conditions [15]. The general layout of the equipment design conceived at UNIBO is shown in Figure 5. The measuring and processing system is based on a Teensy 4.0 system, including an Arm Cortex-M7 processor, the highest performance member of the energy-efficient Cortex-M processor family. Figure 6 shows the on-board system Teensy 4.0 and its audio adaptor board during the assembling step. Figure 7 shows the assembled on-board system. It performs all acquisition and post-processing operations, writing the results on a portable memory stick.

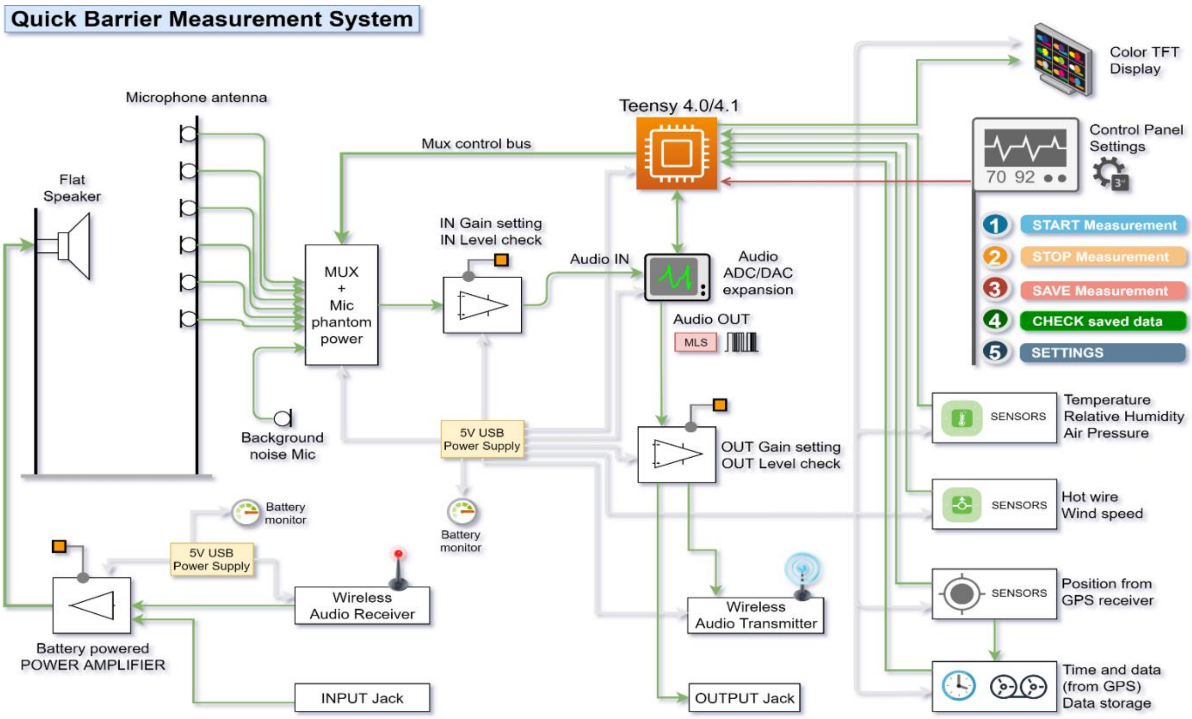

Figure 5: General layout of the equipment design conceived at UNIBO.

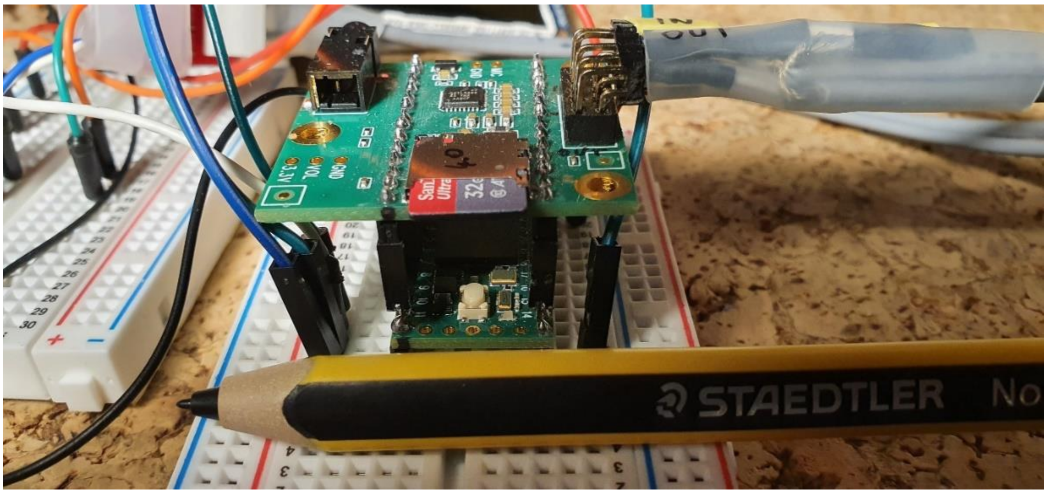

Figure 6: Assembling the on-board system Teensy 4.0 and its audio adaptor.

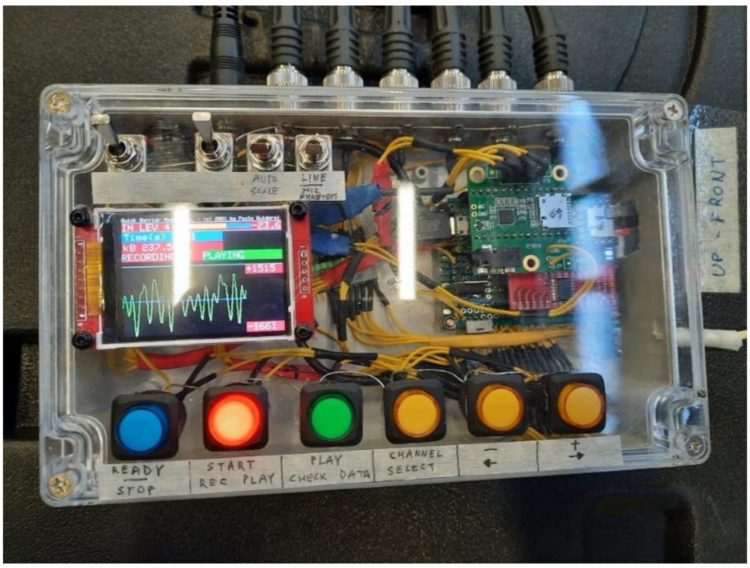

Figure 7: The assembled control and processing hardware developed at UNIBO.

The microphone array, which in the EN standards is a 0,80 x 0,80 m square grid of 9 microphones is replaced with a linear array of 6 microphones, regularly spaced by 0,40 m from an height of 1,20 m above ground to 3,20 m. It permits to check the full span between two posts of a 4 m high noise barrier, detecting all possible defects, even those close to the top of the barrier. The linear antenna should be kept vertical and manually displaced in short steps, say 1 m wide, to scan the full extension of the noise barrier. Using the standard square 9-microphones array this would require many careful adjustments of the array, i.e. a very long measurement time. The measuring procedure is borrowed with few changes from EN 1793-5 and EN 1793-6:

- Loudspeaker and microphone are placed at the same distance to the noise barrier under test as in EN 1793-5 and EN 1793-6.
- The test signal is generated and 6 impulse responses are acquired.
- For each microphone position in front of the device under test, a free-field impulse response with the measurement set-up oriented toward the free space is acquired.
- Each set of impulse responses – in front of the device under test and in the free-field – are processed as in EN standards to get the final sound reflection index, *RI*, or sound insulation index, *SI*.

The laboratory tests currently on going (May 2021) have the main goal of verifying to which extent the values of the sound reflection index and sound insulation index values obtained with the new equipment are close to those obtained with the standard equipment for full EN tests. As an example, a timber noise barrier sample, available at UNIBO laboratory, has been tested for sound reflection. The noise barrier under test is made up of wooden panels with a sound-absorbing face (street side) and a face in wooden matchboard (external side). The barrier is built by overlapping two wooden panels of the same length, 3,00 m, and the same height, 2,00 m. The panels are inserted into HEA 160 posts spaced 3,00 m apart. The overall height of the barrier is 4,00 m. A sound-absorbing layer, 120 mm thick, made of recycled polyester fibres with a density of 30 kg / m^3 is placed in the interspace between the rear matchboard and the front HDPE sheet. The joints are sealed with an EPDM gasket.

Figure 8 reports the comparison of the sound reflection indices obtained with the two different equipment and procedures.

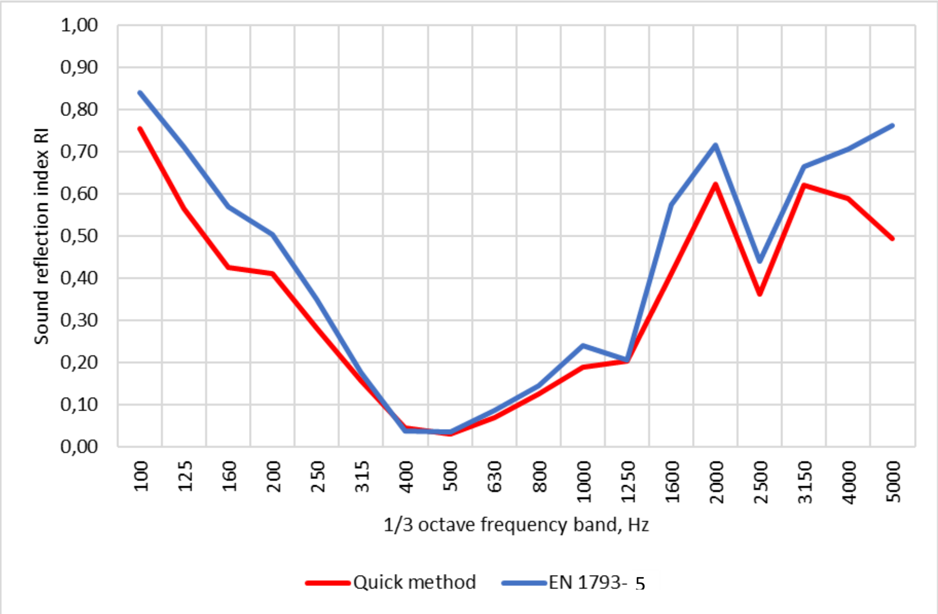

Figure 8: comparison of the RI values obtained with the quick method and the EN 1793-5 standard.

The overall trend is similar; the RI curve obtained with the quick method is slightly underestimated (i.e.: absorption is overestimated) compared to the full method curve. The single-number ratings are:

- Full EN method: DL_{RI} = 5,1 dB (200-5000 Hz)
- Quick method: DL_{RI} = 5,9 dB (200-5000 Hz)

Figure 9 reports the comparison of the sound insulation indices obtained for the acoustic elements.

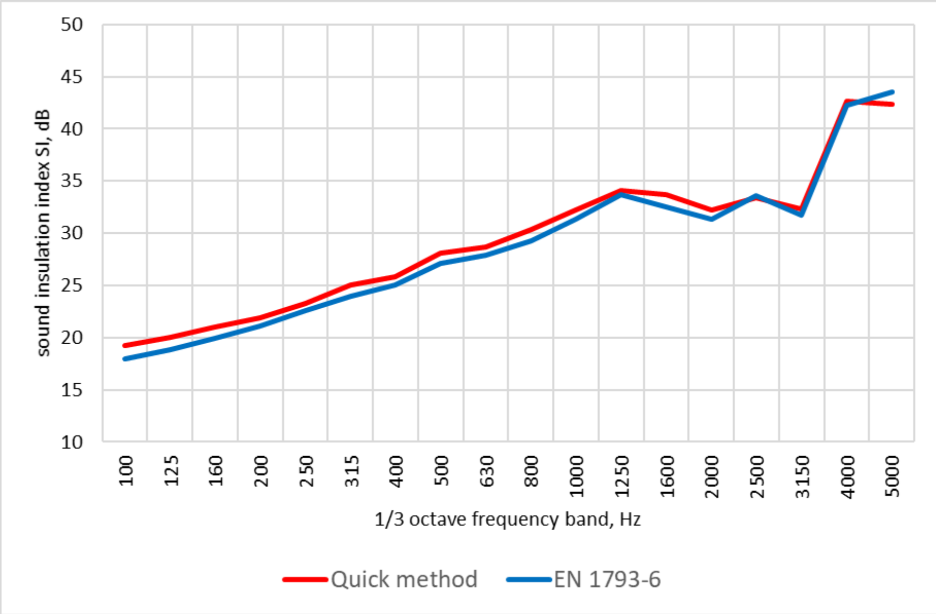

Figure 9: comparison of the SI values for the acoustic elements obtained with the quick method and the EN 1793-6 standard.

The overall trend is very similar; the quick method seems to slightly overestimate the SI value according to the full standard (0.8 dB for the single-number-rating). The single-number ratings are:

- Full EN method: DL_{SI} = 28,5 dB (200-5000 Hz)
- Quick method: DL_{SI} = 29,3 dB (200-5000 Hz)

After completion of **Task 4.2** (June 30th, 2021) the new quick method will be ready for validation in real on-site conditions. This will be done in **Task 4.3**, applying bot the new quick method and the full EN method on real noise barriers installed along the A22 motorway, which connects Northern - Italy to Austria (by November 30th, 2021). In **Task 4.4** (due by January 31st, 2022) the final, comprehensive report on the new quick method will be written, including design, laboratory testing, validation along a real motorway and comparison with full EN methods. It will also include recommendations for proper use of the quick methods.

5. WP 5: GUIDELINES FOR NB USE AND SCIENTIFIC REPORT

At this stage of the research, the final scientific report is obviously not yet available, but the WP5 three first tasks have been already done.

5.1. Task 5.1 Website

The SOPRANOISE specific website is available: https://www.enbf.org/sopranoise/. This site is a channel of communication that will soon let the first public deliverables being available to download.

5.2. Task 5.2 Physical behavior of NB / acoustic intrinsic performances

The aim of this task is to provide a comprehensive review of all the phenomena that rule the performance of noise barriers (NB), insisting on the importance of every key factor as the *extrinsic* performances and the *intrinsic* ones.

Although this is obvious to skilled acousticians, it is worth remembering that the road / rail traffic noise is a very complex phenomenon: in its path from the sound emission to its final perception by individuals, every key factor rules the final NB performance (i.e.: reducing the noise perception). This phenomenon has at least 5 dimensions: the geometric ones (X,Y,Z), the frequency and the time: vehicles are volumic reflecting / diffracting elements, each one emitting as a group of sound sources randomly moving in the space / complex environment: the noise barriers could be very effective on some parts of the whole process, while being less effective, or even useless, to some others. Thus, the specific (*extrinsic* and *intrinsic*) characteristics of a noise barrier may, or may not, be important.

The corresponding T5.2 report is included in the deliverable D5.1 that will be soon available on the SOPRANOISE website [6].

5.3. Task 5.3 State-Of-the-Art on the today's NB use within the EU Market

Task 5.3 aims to summarize the SOA on the current use of NB within the EU market: this survey is based on a questionnaire that has been distributed to the relevant EU road and railway authorities, as well as to the relevant stakeholders involved in the NB implementation and their maintenance.

The questionnaire had the following 7 questions about: (a) NB types used, (b) specifications / requirements, (c) contract awarding process, (d) control at the installation, (e and f) maintenance and (g) end-of life. The representativeness of the responses is quite good as we got 32 replies from 18 EU countries (BE, BG, CZ, DK, DE, IE, ES, FR, IT, HU, NL, AT, PL, FI, SE, IS, NO and UK), 21 road and 6 railway authorities, 3 national / international associations of NB manufacturers and 2 individual NB manufacturers. The replies to the questionnaires lead to a huge amount of interesting data: we only present here the answers to the questions (a) and (b), the other ones being stated in the full Task 5.3 report, included in deliverable D5.1 that will be soon available on the SOPRANOISE website [6].

Question a: types of NB used

Tables 1 to 3 show the summarized replies to question (a), with the surfaces relative to each specific NB type, while Table 4 presents the global statistics: *sound absorbing NB* effectively represent 76% *of the data here compiled*, the *sound reflecting ones* represent 17%, while the *"others"* represent 7%: this is a very interesting finding. Looking at more detailed Tables 1 to 3 allows to understand the different kinds of NB following their *main product material*: concrete NB are predominant, then metallic NB (steel + aluminum), then wood NB.

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		

Question b: tender specifications / requirements

Even this question concerned the application of EN 1793-5 and -6 [4, 5], many replies came referring to EN 1793-1 and -2 [2,3] that normally refer to noise reducing devices for which the intended use is under diffuse sound field conditions (thus not corresponding to NB). This important finding shows that many countries are still referring to EN 1793-1 and -2 characteristics because of the historical characterization when only those (ISO based) methods were standardized.

The replies to all 1793-1, -2 have then been considered too within the Task 5.3 report, but only the replies to then DL_{RI} (EN1793-5) and DL_{SI} (EN1793-6) are presented here in Tables 5 and 6.

Table 5: sound absorption requirements, replies considering DL_{RI} (EN 1793-5)

		replier type	replier name	usage	DL_{RI} (dB)	usage	DL_{RI} (dB)	usage	DL_{RI} (dB)
Belgium	(BE)	ROA	VL	all	5				
	(BE)	ROA	W	all	5				
Germany	(DE)	ROA	NRA	reflecting	0,5	reducing reflections	3,0	highly reducing reflections	5,0
Spain	(ES)	MAA	ANIPAR	Metallic panels (Timber) panels	≥ 7	Concrete panels	≥ 4	Transparent panels	-
France	(FR)	ROA	NRA	all	5				
	(FR)	MAA	SER	all	5-6				
	(FR)	RAI	SNCF	all	8-11				
Italy	(IT)	ROA	AUTOSTRADE	traditional NB	> 8	integrated NB	> 6	double sided integrated NB	> 6
	(IT)			mix (**) traditional NB transparent < 30%	> 5	mix (***) traditional NB transparent > 30%	-		
	(IT)	ROA	A. BRENNERO	concrete	4	metal	7	metal double-sided absorbent	5
	(IT)			transparent absorbent	2 (*)	transparent	-	wood	4
	(IT)	ROA	ATIVA	Metallic panels		concrete, wood, plastic		transparent	
	(IT)	MAA	UNICMI	Metallic panels (Timber) panels	7 (6)	Concrete panels	4	Transparent panels	-
Austria	(AT)	ROA	ASFINAG	all	5				
	(AT)	MAN	FORSTER	all	5-6				

Some repliers are using a single requirement: for those, the most common requirement for DL_{RI} is 5 dB (highlighted in blue), this value is generally considered as a minimum value, SNCF being the only replier requiring values from 8 up to 11 dB, what is very difficult to reach by existing EU NB. About the DL_{α} (EN1793-1) requirements, the common minimal value is 8 dB, what is quit logic as DL_{α} values are higher that the DL_{RI} ones.

Table 6: airborne sound insulation requirements, replies considering DL_{SI} (EN 1793-6)

		replier		usage	DL_{SI} (dB)			usage	DL_{SI} (dB)			usage	DL_{SI} (dB)		
		type	name		element $DL_{SI,E}$	post $DL_{SI,P}$	both global		element $DL_{SI,E}$	post $DL_{SI,P}$	both global		element $DL_{SI,E}$	post $DL_{SI,P}$	both global
Belgium	(BE)	ROA	VL	all	28	26	-								
	(BE)	ROA	W	all	28	26									
Bulgaria	(BG)	ROA	NRA	1			24-30	2			30-36	3			34-45
Spain	(ES)	MAA	ANIPAR	Metallic panels (Timber) panels	≥ 34	≥ 30	≥ 32	Concrete panels	≥ 34	≥ 30	≥ 32	Transparent panels	≥ 34	≥ 30	≥ 32
France	(FR)	ROA	NRA	all			28								
	(FR)	MAA	SER	all			28								
	(FR)	RAI	SNCF	all			> 24								
Italy	(IT)	ROA	AUTOSTRADE	traditional NB	> 27	> 24		integrated NB	> 23	> 20		double sided integrated NB	> 22	> 19	
	(IT)			mix (**) traditional NB transparent < 30%	> 27 (*)	> 24		mix (***) traditional NB transparent > 30%	> 27 (*)	> 24					
	(IT)	ROA	A. BRENNERO	concrete	34	32		metal	27	25		metal double-sided absorbent	27	25	
	(IT)			transparent absorbent	27	25		transparent	27	25		wood	27	25	
	(IT)	MAA	UNICMI	Metallic panels (Timber) panels		> $DL_{SI,E}$ - 2	27	Concrete panels		> $DL_{SI,E}$ - 2	34	Transparent panels		> $DL_{SI,E}$ - 2	27
Austria	(AT)	ROA	ASFINAG	all			25								
	(AT)	MAN	FORSTER	all			24-25								
Sweden	(SE)	RAI	TRV	all	25	25									

Most common requirements for DL_{SI} are in the range from 24 to 28 dB (highlighted in blue), some countries requiring different values in function of the product materials. For information, the DL_R (EN1793-2) requirements are very similar, what is also logic; here DL_R values are very similar to the DL_{RI} ones .

The **WP5 pending tasks** are: **Task 5.4** "How to asses the NB acoustic performances" (due date: December 2021), **Task 5.5** "Guidelines and scientific report" and **Task 5.6** "finale event" (due date: February 2022).

The final deliverable will be then available on the SOPRANOISE website [6] and the developed method will be submitted to CEN TC226 WG6 as candidates for future standardization.

6. CONCLUSIONS

SOPRANOISE improves the understanding of the NB acoustic performance (i.e.: reducing the noise perception); at this stage of the research, one can state the following.

The data assembled in WP2 database are representative and useful: they will be public [6].

WP3 developed an acoustic in-situ inspection protocol that yield a clear and realistic approximation of the degradation effect in the airborne sound insulation of a noise barrier: Deliverable D3.1 includes the relevant reports detailing this protocol and will be public [6].

At the present stage of the research within WP4, it can be said that all the objectives have been reached: a hardware device has been built using components available on the market (overall cost below 4000 €). Some preliminary tests have been done; more tests in the laboratory are planned. Full tests according to EN 1793-5 and EN 1793-6 are also planned in order to have an idea of the reliability of the new quick method versus the full EN standards. Moreover, the post-processing software already developed at UNIBO is being simplified and transferred to the new portable device. The actual easiness of use in situ will be tested in Task 4.3 along the A22 motorway, but the preliminary results already obtained in laboratory are very encouraging.

Finally, WP5 is continuing, Tasks 5.1, 5.2 and 5.3 are now finished and their outcomes (as well as for WP2 and WP3) will be soon available on the SOPRANOISE website [6].

7. ACKNOWLEDGEMENTS

We gratefully acknowledge the CEDR (Conference of European Directors of Roads) that supports this research as part of their own “Transnational Road Research Programme”.

8. REFERENCES

1. Clairbois, J-P., Garai, M., Bartolomaeus, W., Chudalla, M., Strigari, F., Conter, M., Fuchs, A. & Nicodeme, C., SOPRANOISE: EU Research on new techniques to characterize Noise Barriers acoustic performances. *Proceedings of INTER-NOISE 2020*, paper 16_4_468. Seoul, South Korea, August 2020.
2. CEN, “EN 1793-1: Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 1: Intrinsic characteristics of sound absorption under diffuse sound field conditions,” *CEN. Brussels, Belgium,* 2017.
3. CEN, “EN 1793-2: Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 2: Intrinsic characteristics of airborne sound insulation under diffuse sound field conditions,” *CEN. Brussels, Belgium,* 2018.
4. CEN, “EN 1793-5: Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 5: Intrinsic characteristics – In-situ values of sound reflection under direct sound field conditions,” *CEN. Brussels, Belgium,* 2016 /AC:2018.
5. CEN, “EN 1793-6: Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics – In-situ values of airborne sound insulation under direct sound field conditions,” *CEN. Brussels, Belgium,* 2018 +A1:2021.
6. https://www.enbf.org/sopranoise/.
7. Conter, M., Czuka. M. & Breuss. S., *“D4.3 & MS 4.2 - Final procedural report on WP4 activities, including public database of European NRD, data analysis and definition of NRD families”*, QUIESST project, 2012.
8. Conter, M., Fuchs, A. & Reiter, P. “SOPRANOISE – update and analysis of noise barrier database including new current results” *Proceedings of the INTER-NOISE 21, 50th International Congress and Exposition on Noise Control Engineering, 1-5 August 2021*

9. Fuchs, A., Wehr R. & Conter, M. “Empirical study on the correlation between measurement methods under diffuse and direct sound field conditions for determining sound absorption and airborne sound insulation properties of noise barriers” *Proceedings of the INTER-NOISE 21, 50th International Congress and Exposition on Noise Control Engineering, 1-5 August 2021*
10. Mechel, F. P., The acoustic sealing of holes and slits in walls, *Journal of Sound and Vibration*, **111(2)**, 297-336 (1986).
11. Strigari, F., Chudalla, M. et al., SOPRANOISE – In-Situ Inspection Procedure for Airborne Sound Insulation Properties of Existing Noise Barriers (original title: “SOPRANOISE - Inspektionsverfahren zur Bewertung der Luftschalldämmung”). *Proceedings of DAGA 2021*, to be published (2021).
12. Garai M., Schoen E., Behler G., Bragado B., Chudalla M., Conter M., Defrance J., Demizieux P., Glorieux C., Guidorzi P., Repeatability and reproducibility of in situ measurements of sound reflection and airborne sound insulation index of noise barriers, *Acta Acustica united with Acustica*, **100**, 1186-1201 (2014).
13. Fuchs A., Wehr R. & Conter M., Proposal for an in-situ approval testing and quality assurance procedure for assessing sound reflection properties of noise barriers. *Proceedings of 24th ICSV*, London, UK, July 2017.
14. Guidorzi P. & Garai M., Sound insulation measurements on noise barriers across their entire extension: a preliminary study. *Proceedings of INTER-NOISE 2020*, paper_5_4_994. Seoul, South Korea, August 2020.
15. Garai M., Guidorzi P., Sound reflection measurements on noise barriers in critical conditions, *Building and Environment*, **94(2)**, 752-763 (2015).