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CEDR TRANSNATIONAL ROAD RESEARCH PROGRAMME 2018

SOPRANOISE

D5.1 WP5 Intermediate progress report including M5.1, M5.2 and M5.3

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Introduction and structure of deliverable D5.1

The present document regroups the reports of the following 3 first WP5 tasks that have been achieved since the beginning of the SOPRANOISE research:

- T5.1 website implementation;
- T5.2 physical behavior of NB / acoustic intrinsic performances; and
- T5.3 state of art on the today's NB use within the EU Market.

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SOPRANOISE

T5.1 Website implementation

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In the SOPRANOISE-team ERF is taking care of the dissemination, communication and visual identity part of the project.

In this sense ERF developed Sopranoise logo and website fulfilling the task T5.1.

Sopranoise logo:

Sopranoise website: https://www.enbf.org/sopranoise/

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SOPRANOISE

T5.2 Physical behavior of NB / acoustic intrinsic performances

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1 Introduction

Noise barriers (NB) are obstacles to *sound propagation* purposely built to shield receivers from excessive noise generated by road or railway traffic (Figure 1). Today, NB are considered the most effective noise mitigation measures available when targeting *high noise reductions*. For this reason, the more stringent the noise legislation across Europe becomes, the more NB are installed or refurbished along many road and railway corridors.

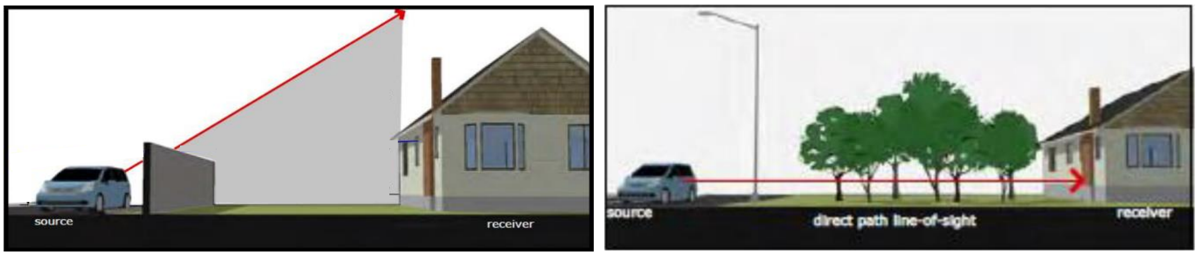


Figure 1: To reduce traffic noise, NB are placed as obstacles to the sound propagation [1]

Many factors need to be considered in the detailed design of NB: first, NB must be acoustically adequate. Acoustical design considerations include barrier materials, barrier locations, dimensions and shapes. These allow to reach a good *noise reduction* at receivers, usually expressed through the insertion loss (see further Section 2); to reach the decided effect, the designer should carefully take into account intrinsic characteristics such as *sound reflection, airborne sound insulation*, and *intrinsic sound diffraction index difference* at NB top edge. On the other hand, the non-acoustic characteristics, are equally important for NB design. These encompass mechanical resistance and stability, behavior under impact, reaction to fire, release of substances potentially harmful to the environment, etc. One must avoid barrier designs that could cause negative effects as unsafe conditions, visual blight, maintenance difficulties, lack of maintenance access, air pollution, etc. Finally, NB are true architectural objects: they should keep the landscape character and quality of their environment.

The design process of NB begins from the consideration of national regulatory requirements that specify noise limits not to be exceeded. Comparison with the actual noise levels sets the noise level abatement to be reached by the mitigation measures. Then the designer takes into account all the above-mentioned characteristics of the NB as well as of the environment, to design a NB having an insertion loss greater than the stated sound level difference, with a certain safety margin (uncertainty). Thus, the required insertion loss is set by the desired noise abatement and is determined by the characteristics of the environment combined with the NB intrinsic characteristics (airborne sound insulation, sound absorption, intrinsic sound diffraction index difference at the top edge), the last ones in turn depending on the NB materials, dimensions and shape.

All acoustic characteristics of NB are frequency-dependent: *insertion loss*, *sound absorption* and *airborne sound insulation*, are all function of the frequency of sound. According to European standards they are expressed in one-third octave bands from 100 Hz to 5 kHz, while simplified indicators (single-number rating) roughly summarise the performance on the whole spectrum following normalized road / rail traffic noise spectra. However, in complex environments with multiple sources, multiple reflections, etc. only the frequency-dependent characteristics give a real picture of the NB physical behaviour. The physics behind the NB noise reduction is explained in the following Sections 2 and 3.

NB behaviour can be measured or calculated, typically by computer simulations. The most representative measurements are taken *in situ*, i.e.: where NB are used (see Section *3*) but could also be carried out in laboratory. Simulations must take into account the five fundamental dimensions: the three spatial dimensions, for a realistic 3D reconstruction of the sound field, plus time, to understand the variation with time of some phenomena (see Section *2*), and frequency, to capture the frequency-dependent behaviour of NB in the real world.

2 *Extrinsic* performances of Noise Barriers

The noise reduction achieved by Noise Barriers (NB) in their environment is characterized by the "Insertion Loss" (IL: difference in sound level at a receiver location with and without the presence of the NB): this is an *extrinsic* characteristic that involves a lot of factors, all influencing the final NB effective performances.

To reduce excessive (road or railway) traffic[1] noise, Noise Barriers (NB) are relevant and widely used devices: before (too often) roughly concluding how NB can be effective or not, understanding how they work is fundamental [2] .

If we could sum up everything in one single sentence, it should be the following:

Whatever the situation, physics definitely rules the NB effectiveness.

Traffic noise results from 3 successive stages, namely (see Figure 2):

1. **Emission**: the sound wave is emitted by the vehicles;
2. **Propagation**: the sound wave then propagates toward the environment;
3. **Immission**: finally, the sound wave reaches the façades of the dwellings and penetrates inside those through their weakest components (e.g.: the windows).

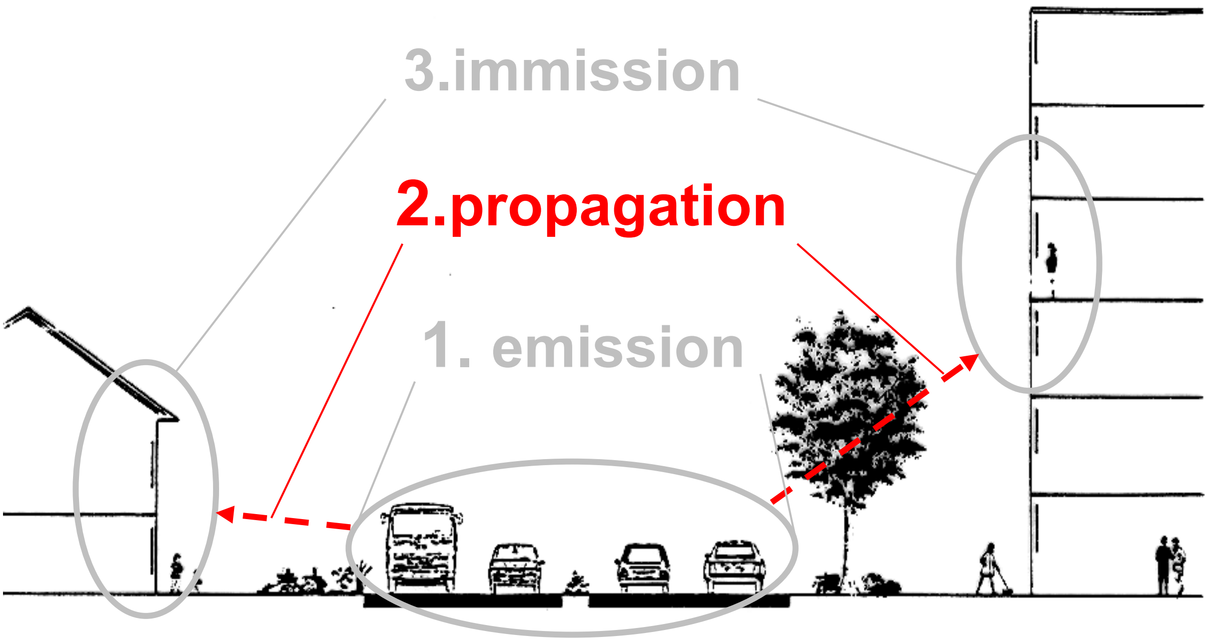


Figure 2: The 3 successive stages of traffic noise, from the vehicles up to neighbouring dwellings [2]

NB are used in the propagation part of this whole process: they act as obstacles between the noise sources (the vehicles / trains) and the environment area to be protected.

Thus, the next chapters will concentrate on stage 2, i.e.: the *sound propagation stage*.

[1] From now on, 'traffic' will be used for 'road' and / or 'railway' traffic.

2.1 Main factors influencing the NB performances

Factors influencing the final IL are much more numerous than one can usually expect; their list is detailed hereafter:

- The physical phenomena:
  - *sound emission* / *sound propagation* / *sound reflection* / *sound diffraction* and *airborne sound transmission*
- The emission characteristics:
  - strongly depending on the type of vehicles (cars, trucks, trams, trains…)
- The dimensions:
  - height, Length, Volume (whatever the concerned objects)
  - source / receiver relative positions: topography and infrastructure profile
  - frequency domain
  - time scale
- The shape of the objects:
  - vehicles (cars, trucks, trams, trains…)
  - barriers (flat vertical, flat inclined, non-flat, large NB, with added devices…)
- The sound propagation medium: the air / weather conditions
- The intrinsic characteristics:
  - *sound absorption*, *airborne sound insulation*, *intrinsic sound diffraction* at top edge

ALL those factors are influencing the final IL performance: next chapters will explain how.

2.2 The physical phenomena

When the sound wave hits a NB, three physical phenomena are involved (Figure 3):

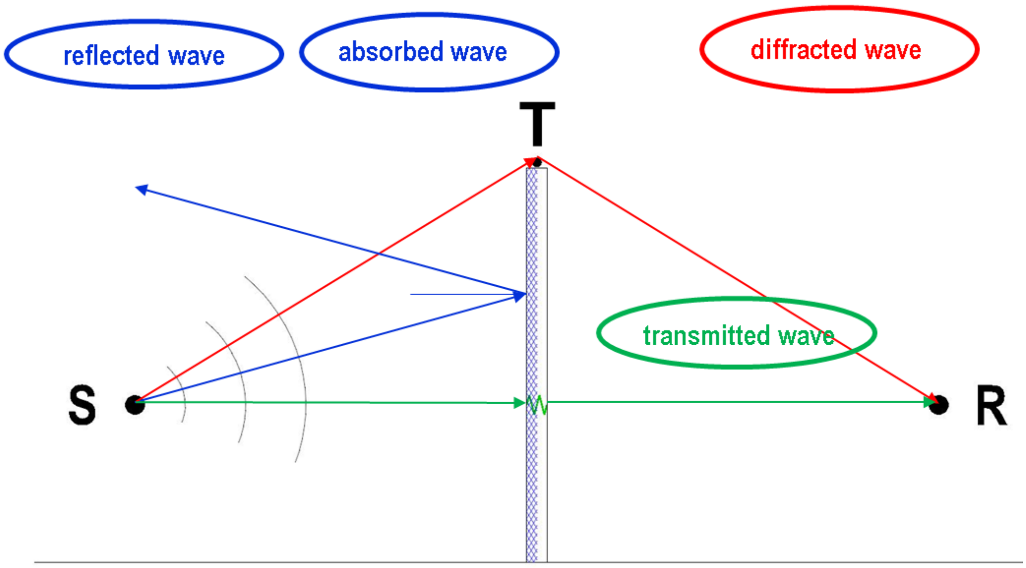


Figure 3: Sound reflection / absorption, sound transmission, sound diffraction [2]
S: *sound source* (e.g.: the vehicles); **T**: top of the NB, **R**: receiver (e.g.: a dwelling)

1. **Reflection**: the *sound wave* hitting the exposed side of the NB partly reflects on it: the reflected sound can then affect the facing areas, while the *non-reflected sound* is called the *absorbed sound*;
2. **Transmission**: the *sound wave* hitting the exposed side partly transmits through the NB itself: the aim of the NB being to play as an obstacle to the sound propagation, this transmitted energy must be negligible compared to that one diffracted at the top edge of the NB (see below) ;
3. **Diffraction**: the NB acts as an obstacle to the sound propagation: however, a part of the *sound wave* still passes over the devices: it diffracts on its top edge where it is partly attenuated, and then propagates to the protected side of the device.

Each of these waves is important: their combination conditions the noise perceived at the receiver R.

The *noise reduction* achieved by the NB, named *Insertion Loss* (IL), is the difference between the noise level arriving at the receiver without an obstacle ("free field propagation") and the noise level arriving at the receiver in the presence of that obstacle.

The following paragraphs will explain and contextualize the phenomena of *sound reflection*, *sound diffraction* and *airborne*[2] *sound transmission* in the context of the propagation of traffic noise.

[2] Chapter *2.2.3 Airborne sound transmission* will explain the meaning of using the qualificative "*airborne*", as this phenomenon has to be differentiated from the "*groundborne*" *sound transmission*

2.2.1 Sound reflection

2.2.1.1 Simple sound reflections

Figure 4 shows the effect of a wave propagating towards a surface and then reflecting on it.

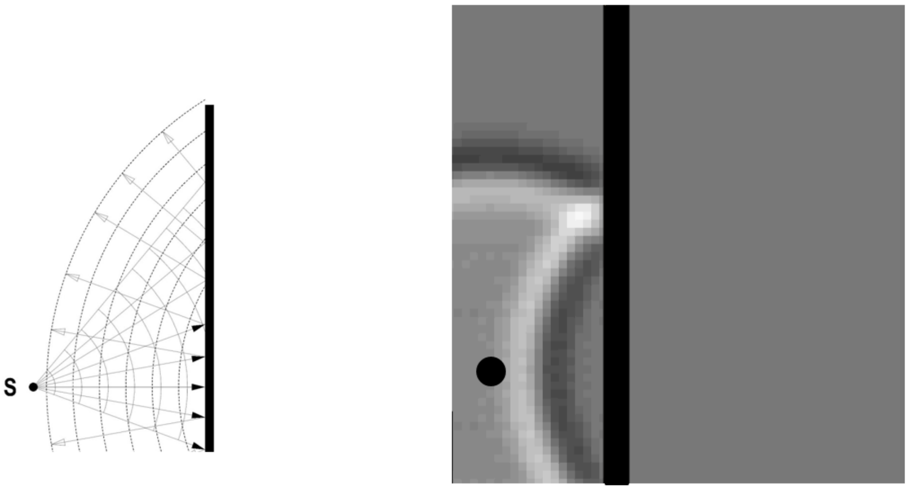


Figure 4: Simple reflection on an infinite flat surface [3]
S: *sound source*

Following the principles presented in Figure 5, when an incident sound wave emitted by a sound source **S** hits a surface with dimensions much larger than its wavelength, it is reflected in quite a similar way to visual *images in a mirror*: it is as if a virtual *image source* **S'**, symmetric to the original sound source **S** with respect to the surface, radiated behind this surface and redirected the incident sound wave. We then speak of "specular" reflections: any incident ray is reflected in a "specular" way, so that the reflected ray is redirected with an angle that is identical to the one at which it arrived on the surface.

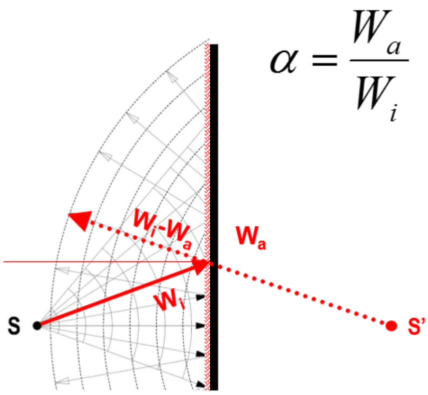


Figure 5: Law of specular reflection: angle of reflection = angle of incidence [3]

For NB, sound-absorbing materials can be used to reduce the reflected energy (or the energy coming from the virtual *image source* **S'**): depending on the sound absorption characteristics of the materials used, this reduction can be more or less effective on the total IL performance of the NB.

The *sound absorption coefficient* $\boldsymbol{\alpha}$ is defined as the ratio of *absorbed energy* W_a to the *incident energy* W_i (see formula in Figure 5): $\boldsymbol{\alpha}$ is one of the main *intrinsic* characteristics of NB (see Chapter 3).

The *sound absorption coefficient* is a function of the angle θ of incidence of sound: $\alpha = \alpha(\theta)$: often, only the average α over all angles is given, assuming that sound waves may arrive from each direction with equal probability (*diffuse sound field conditions*).

When the reflecting surface is non-flat, reflection occurs in a non-specular way: *reflected sound waves* are scattered in many directions, giving raise to the complex phenomenon of *diffuse sound reflection*, requiring the definition of an additional scattering or diffusion coefficient [4] , [5] (see also further Figure 46 and Figure 47).

Practically, reflections enhance the energy in the zone facing the surface: they can increase the noise (up to + 3 dB) in possibly noise sensitive zones that had been less impacted if those reflections did not exist.

Figure 6 shows examples of such *simple reflections*.

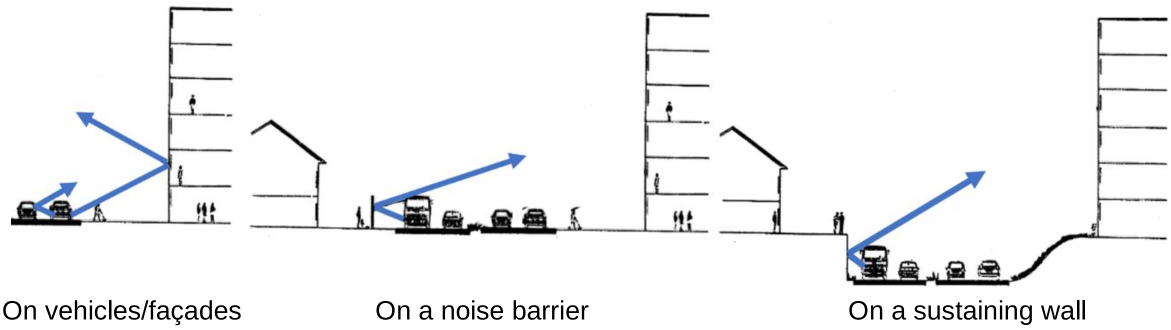


Figure 6: Examples of *simple reflections* [6]

To reduce the negative effect of *sound reflections* on NB, generally *sound-absorbing* materials are used. However, some European countries are sometimes using *inclined sound reflective* NB instead of *vertical sound-absorbing* NB, the idea being to send the reflected waves to non-sensitive zones as *to the sky*. This is forgetting that, due to weather phenomena, the energy could be diffused *everywhere* and still going toward sound sensitive zones (see Figure 7).

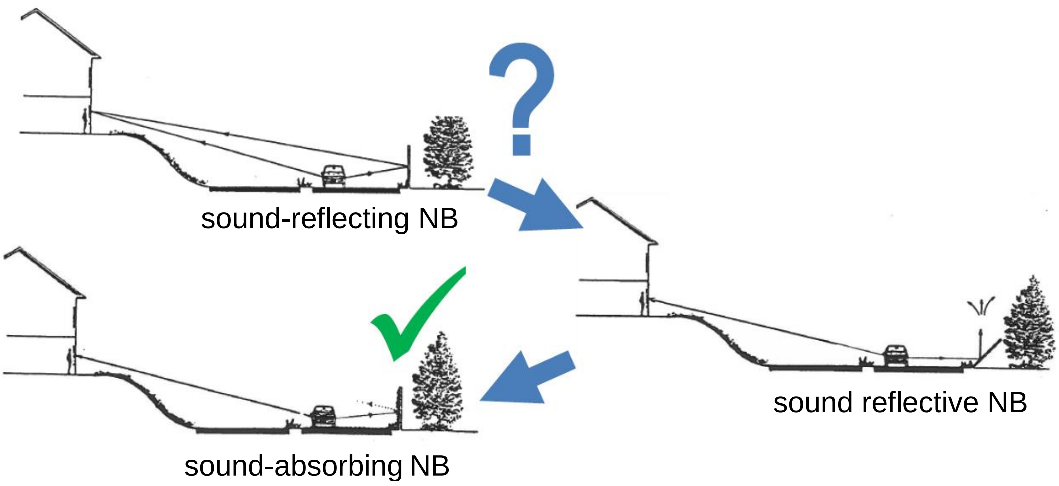


Figure 7: Sound-reflecting NB do not dissipate the energy: sound-absorbing NB do [6]

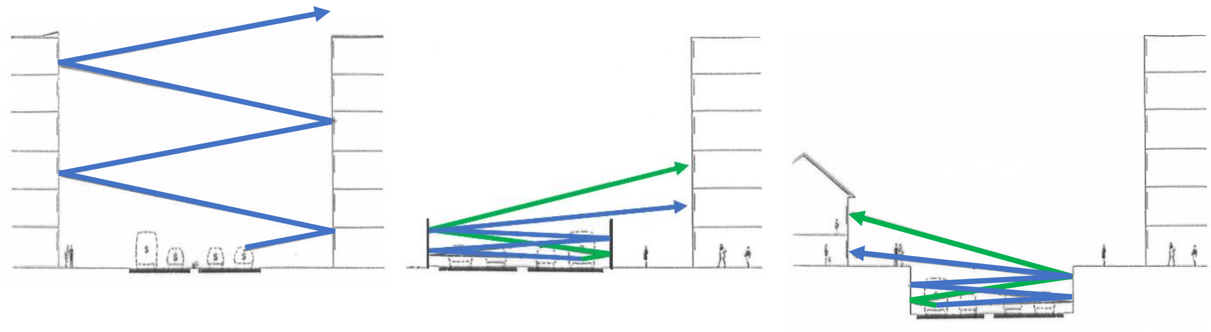
Sound-absorbing NB are definitively the best ones to dissipate the incident energy as soon as it hits the NB surface.

The effect of simple reflections is already important in the NB performance: the next chapter will show that the problem of multiple reflections can be even worse.

2.2.1.2 Multiple sound reflections

Multiple sound reflections occur when two walls are facing each other: this situation is very unfavourable because the sound waves are continuously reflected from one wall to the other, as in a "ping-pong" game: Figure 8 shows various examples in an urban environment.

Figure 9 shows the effect of multiple reflections within an open-air trench having a width of 2 x 2 lanes and a height of 6 m: this example shows that the corresponding *noise reduction* could reach more than 8 dB(A).



between façades parallel noise barriers sustaining walls

Figure 8: Examples of *multiple reflections* [6]

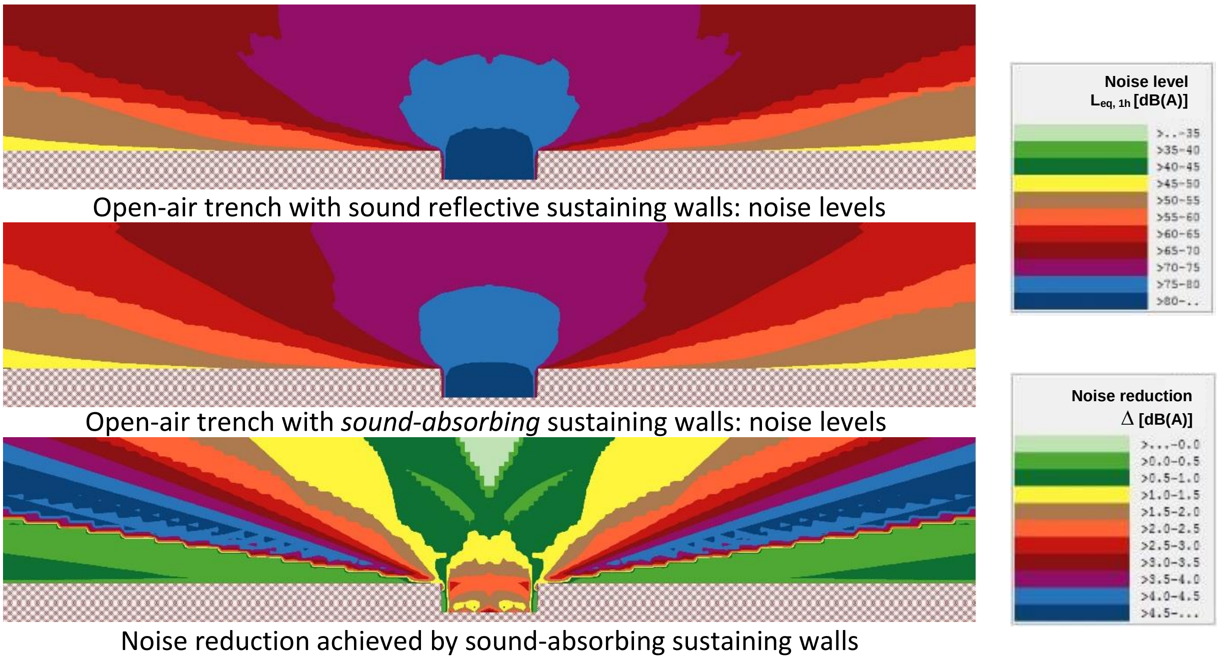


Figure 9: Vertical noise maps showing the effect of *multiple reflections* [7]

Sound-absorbing NB (as well as sound-absorbing claddings) are even more efficient to reduce noise where multiple reflections occur.

Parallel NB or parallel side walls induce multiple reflections in one direction (walls to walls), but one can also have two directional multiple reflections within tunnels (walls to walls / road to ceiling): again, sound-absorbing materials will significantly reduce reflections and the corresponding noise propagation to the environment.

2.2.1.3 Interactions with the vehicle bodies

Multiple reflections can also occur between NB or close walls and the bodies of vehicles passing in front of them: indeed, if vehicles can (in broad lines) be assimilated to *point* noise sources, at least for receivers at a certain distance from them, they are *real volumes* moving on the road, *volumes* whose sides (the vehicle bodies) are also *sound-reflecting* [8] .

In that way, interactions take place between the *sound-reflecting* NB or close walls and the vehicles when they face each other: it is therefore also a phenomenon of *multiple reflections*, but here with a very specific *temporal dimension* (the effects “follow” the vehicle as it travels in front of the NB): Figure 10 shows the interaction effect.

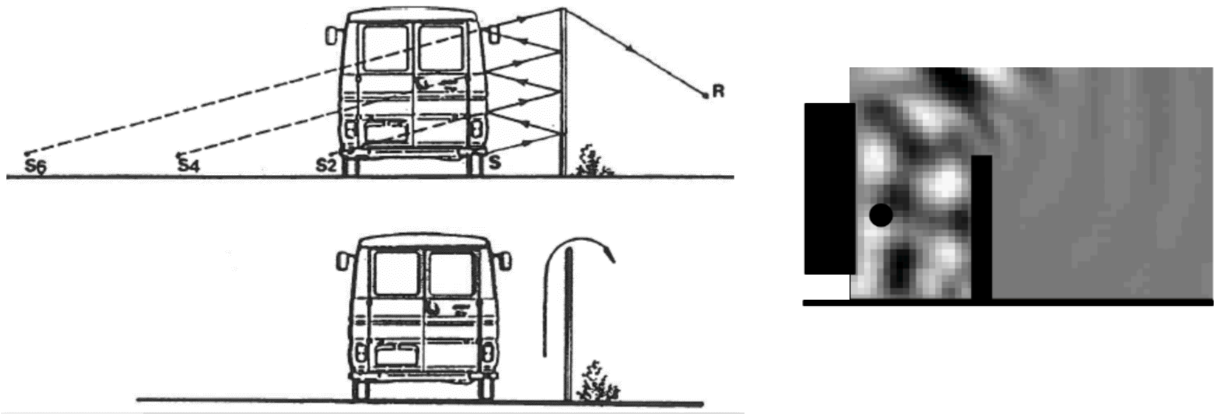


Figure 10: Interactions between a vehicle and a sound-reflecting noise barrier [3] .
In the right image the vehicle body is represented by the black rectangle.
The final effect is as if the noise source was artificially raised up to the top of the barrier.

Thus, by artificially "raising" the height of the noise source, interactions significantly reduce the protective effect of the NB. This effect is even worse if the vehicles are tall (artificial raise of the sound source) and long (increase of the effect duration): unfortunately, the tallest and longest vehicles are indeed trucks, i.e.: the noisiest vehicles on the road[3].

To reduce the effect of these multiple reflections / interactions, sound-absorbing materials are, once again, recommended: their effectiveness in reducing the *additional noise* will however vary depending on each specific vehicle pass-by.

Figure 11 presents the pass-by noise levels of a 4 m high truck in **free field**, and in front of a 2 m high NB (**sound-reflecting**, ***perfectly* sound-absorbing**[4] **and *usual* sound-absorbing**). This figure shows the *time-related effect* of the interactions, as well as the advantage of using sound-absorbing materials: even if a sound-reflecting NB could reduce noise on an entire pass-by (L_{Aeq}), it could also increase the instant noise levels (compared to the free field / without any NB) when the interactions are the strongest (the worst being on L_{Amax}).

In such difficult situations, some neighbours could even complain on some “noisier” pass-by.

<u>Important Note:</u>
Presented for the sake of the explanation, these results do correspond to pass-by of single vehicles located in the worst conditions: with a global traffic randomly moving on several traffic lanes, this effect is of course widely smoothed and situation is then much better.

With the exception of visually transparent, and therefore sound-reflecting NB, the most recommended (and most commonly used) NB are the sound-absorbing ones.

---

[3] For railways, the effect of interactions is even worse: the succession of carriages results in a *long* and *continuous sound-reflecting* body.

[4] This ideal case is for the demonstration of what happens if *no* interaction occurs.

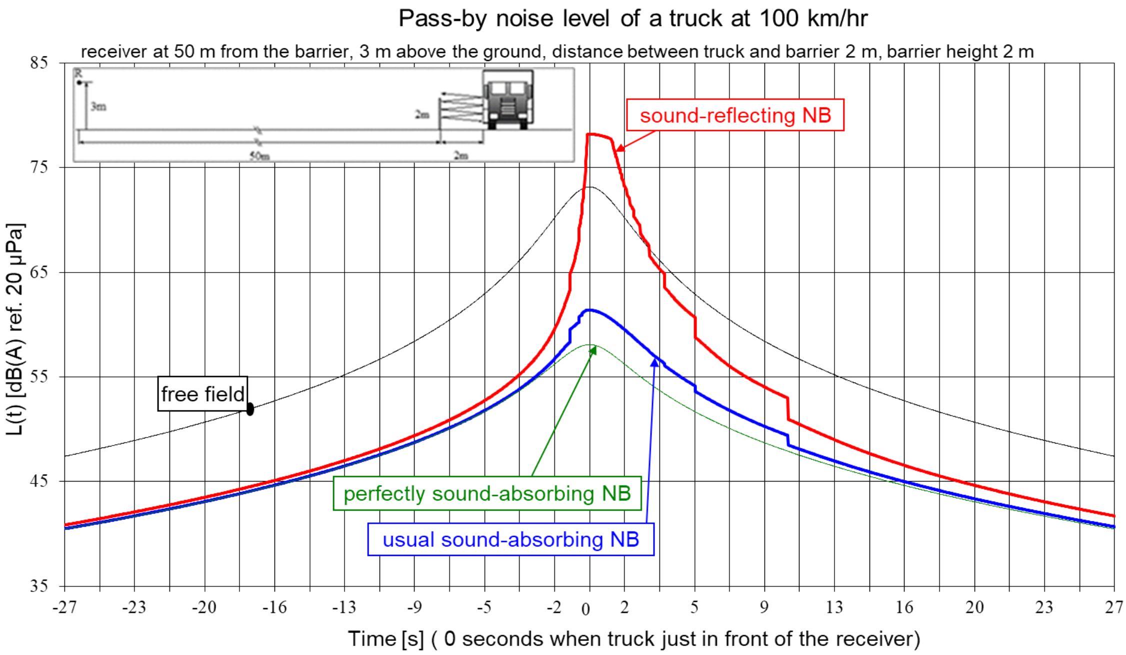


Figure 11: Pass-by noise level of a truck (*considering no interferences*) [9]
(free-field / perfectly sound-absorbing NB / usual sound-absorbing NB)

Figure 11Figure 11 presents the pass-by noise levels while considering *incoherent moving noise sources*, as it is usually considered for traffic noise. However, even if there is no coherence between the noise emitted by a moving vehicle at its successive positions, all the image sources of the same original sound source *are* coherent between them: Figure 12 presents the pass-by noise level considering those interferences: it demonstrates its complexity.

To *never* forget: traffic noise is a complete 5 dimensions phenomenon (x, y, z, t, f)!

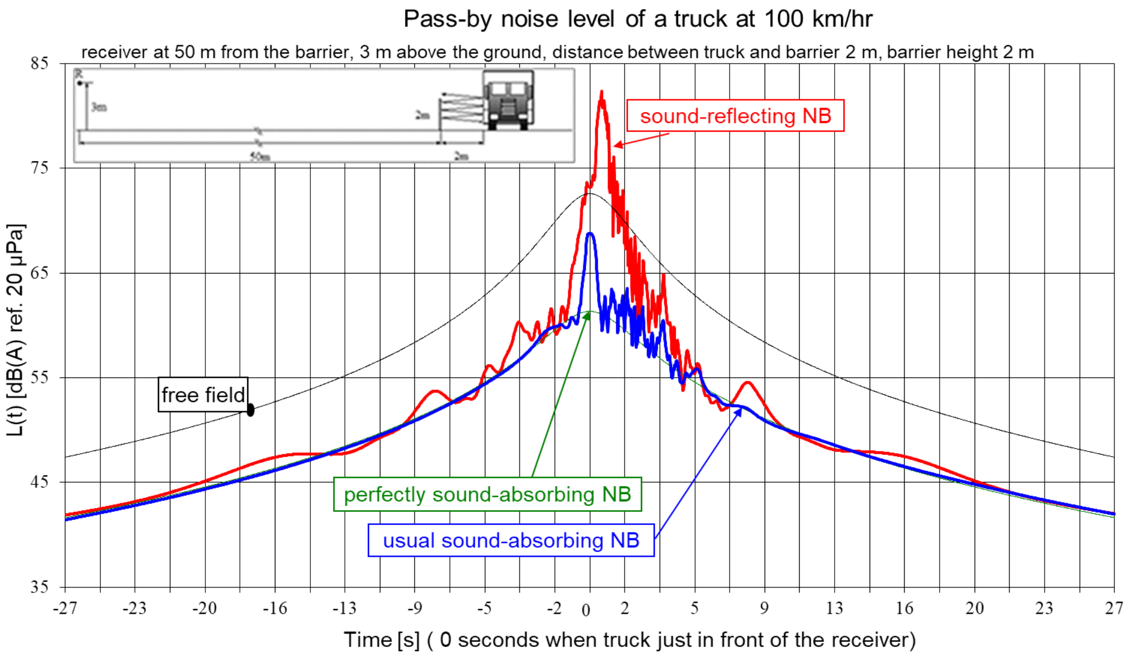


Figure 12: Pass-by noise level of a truck (*considering only the relevant interferences*) [9]

2.2.2 Sound diffraction

2.2.2.1 Physical phenomenon

In the optic domain, placing in front of a source of light an obstacle having dimensions much greater than the wavelength creates a shadow zone; a small obstacle having dimensions comparable to the wavelength would be bypassed by the light, which would enter also in the zone behind the obstacle. This physical phenomenon is called (light) *wave diffraction* [10] .

In the acoustic domain, placing an obstacle between a source of noise and our ears (except of course earing protections) does not prevent us from continuing to hear noise: the reason is that, at many frequencies, sound waves have wavelengths comparable to those of the obstacle and thus the energy *diffracts* on its edges, which re-propagates this energy in all directions, including behind it; this is called s*ound diffraction*.

This phenomenon is the same in acoustics as in optics, except that the wavelengths are significantly shorter in optics than in acoustics. In optics, visible wavelengths range from 380 to 780 nanometres (with one nanometre corresponding to one-billionth of a metre). In acoustics, wavelengths range from 17 mm (at 20,000 Hz, high frequencies) to 17 m (at 20 Hz, low frequencies): obstacles are therefore "seen" by the acoustic waves as clearly smaller obstacles and therefore easier to "bypass" than for optical waves.

The *sound diffraction* phenomenon is formalized by the *Huygens-Fresnel principle*. In order to illustrate it but avoiding complex mathematical formulations, Figure 13 puts the *Huygens-Fresnel principle* in images: *a wavefront* initiated by a wave source arriving at the diffracting top edge of the NB is decomposed into a series of new secondary sources which then radiate to recompose the next wavefront, which is their envelope. It allows to better understand how a wavefront of the same order of magnitude as a NB (few metres) "passes" over the top of the barrier to reach what is called the *shadow zone*[5].

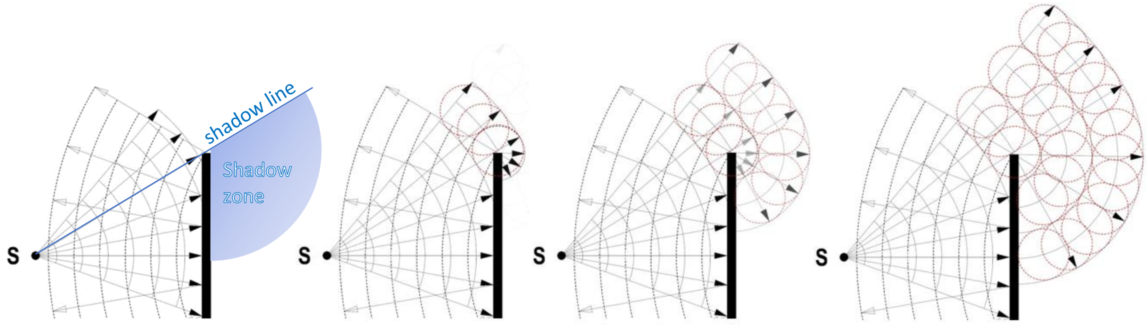


Figure 13: Propagation of a wavefront around an obstacle (Huygens-Fresnel principle) [3]

Figure 14 shows an animation of this that also includes the reflected wave from the side of the noise source: the wave "passes" to the other side of the screen, while being attenuated.

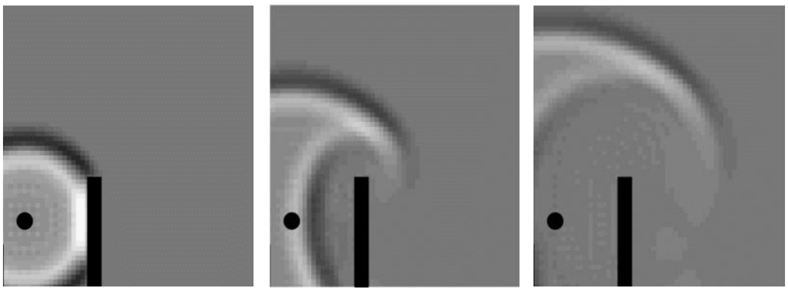


Figure 14: Propagation of a wavefront on a reflecting obstacle [3]

[5] *shadow zone*: zone located under the shadow line, joining the noise source to the top of the NB

In fact, the example of Figure 14, is simplified to illustrate the phenomenon of diffraction, considering only a single wavefront and a single reflection on the obstacle: in reality, along a road / railway, the waves are continuously maintained by vehicles ("noise") and there is also the interaction with ground on each side of the obstacle as, for example, a NB.

Figure 15 presents an animation closer to reality, but still consider a *point sound source* and neglects the possible *interactions* with the body of the vehicles.

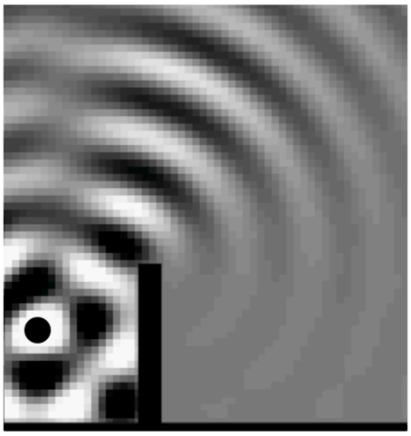


Figure 15: Propagation of continuous waves on a reflecting obstacle [3]
(considering a *point sound source* and sound reflections on the ground at both sides)

Those interactions are now integrated in Figure 16, illustrating their effects as presented in *2.2.1.3 Interactions with the vehicle bodies*.

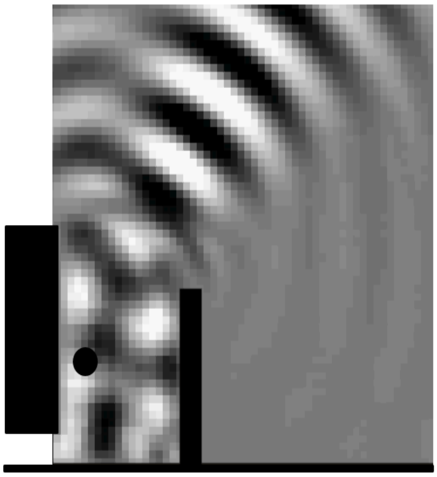


Figure 16: Propagation of continuous waves on a reflecting obstacle: interactions with a truck body (black rectangle on the left) [3]

2.2.2.2 Calculating the *sound diffraction* performance

Sound diffraction is a phenomenon strictly connected to the wave nature of sound. It is possible to make wave calculations starting from the Huygens-Fresnel principle, but they are complex and usually reserved for the research field. Geometrical approximations, like in optics, are much more affordable. With regard to the attenuation provided by NB, a geometrical approximation was experimentally studied by Z. Maekawa as early as 1968 [11] to fit the results of his experimentally studies. He established a chart (see Figure 17) through which it is possible to determine the performance (*noise reduction*) of a NB due to *sound diffraction*.

To do this, it is first necessary to determine the Fresnel number N.

$$N = \frac{2\ \delta}{\lambda}$$

δ : difference (in m) between the path of the acoustic wave with and without NB (see Figure 17)
λ : the wavelength (in m)

Then, the *attenuation* at the top edge of the NB, assumed thin (i.e. with a negligible thickness), is directly read on the Maekawa chart. It must be energetically summed with the attenuation at the virtual receiver with respect to the ground to give a first approximation of the IL of an infinitely long and thin NB placed on the ground.

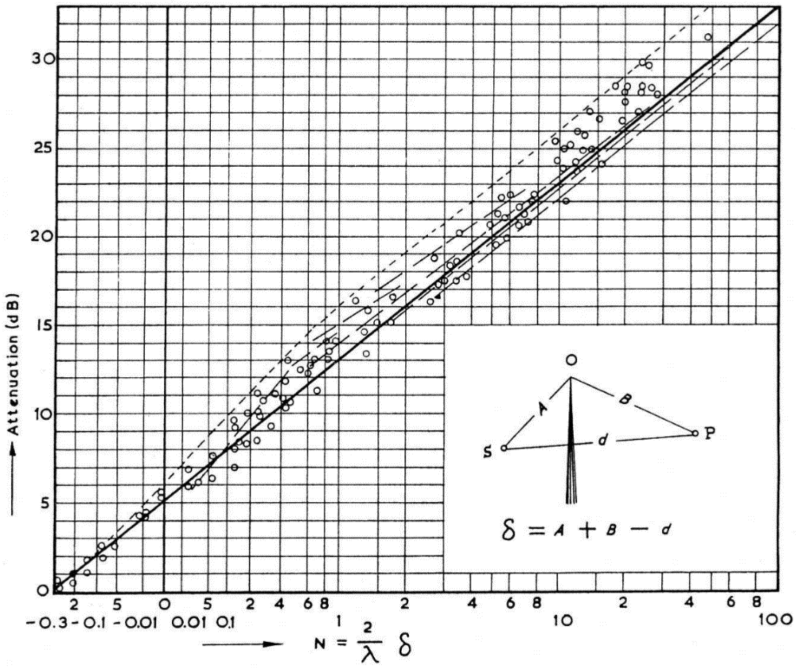


Figure 17: Maekawa's chart showing the attenuation obtained by the top edge of a NB [11]

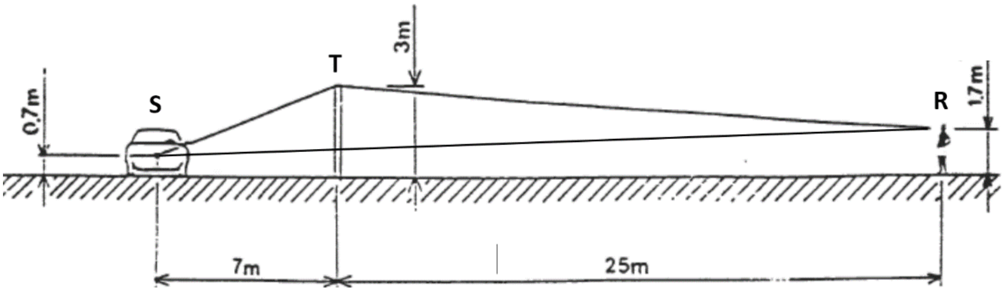


Figure 18: Example for a simplified calculation of the *sound diffraction* due to a NB

As a practical example, Figure 18 shows the conditions considered for a simplified calculation of the effectiveness (*attenuation* due to *sound diffraction*) of a noise barrier with a 3 m high NB, without any reflection (perfectly sound-absorbing), a vehicle (noise source S) located 7 m in front of the NB, the noise source being assimilated to a *point source* 0.7 m above the road, and a pedestrian, 1.7 m tall, located 25 m behind the screen.

In this example, considering a frequency of 1.000 Hz, i.e. a wavelength λ = 0.34 m, and the path difference δ = ST + TR - SR = 0.39 m, the corresponding Fresnel number is N = 2.3. With such N, Maekawa's chart (Figure 17) indicates a *sound attenuation* of 16.5 dB at 1.000 Hz.

While considering road traffic noise, according to the road traffic noise spectrum standardised in EN 1793-3, the attenuation is 14.5 dB(A).

2.2.2.3 Where to place NB?

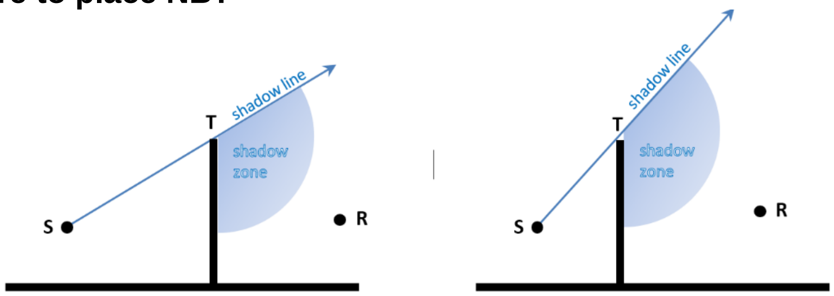


Figure 19: The closer the NB to the source, the higher the shadow line, and the more efficient the NB

Figure 19 shows that **a NB is all the more effective the higher its shadow line**: a receiver R remaining in the same position is then lower in the shadow zone and much better protected: this results in a greater difference δ = ST + TR - SR, and therefore a larger Fresnel number N.

However, it should be remembered that a street, a road or a railway platform can have several traffic lanes or tracks: some are therefore closer to the NB while some others more distant: with more distant traffic, the shadow lines are lower and lower, and the NB becomes less and less performant to reduce noise on the protected side of the barrier (see Figure 20).

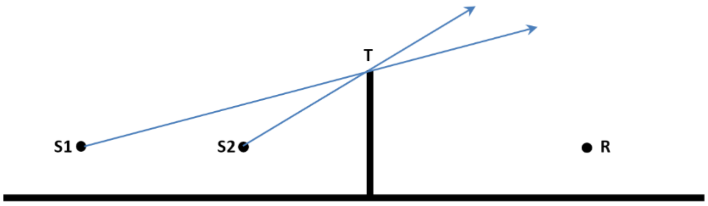


Figure 20: A NB is less effective on the most distant noise sources

2.2.2.4 Earth berms

Often naturally vegetated, earth berms can constitute obstacles to the propagation of traffic noise that are visually more appreciated than the "classic" NB. However**, earth berms require a much larger footprint than a NB of the same height** as shown in Figure 21. This lowers the shadow line as shown in Figure 22 and then the performance.

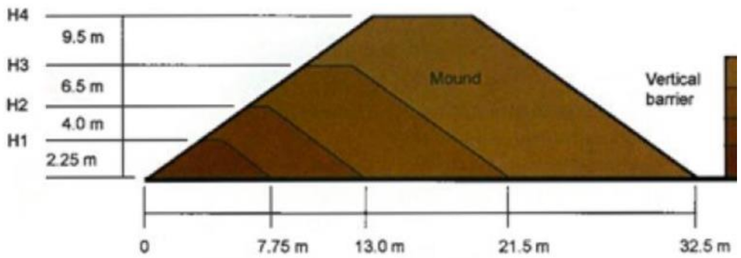


Figure 21: Earth berms require a much larger footprint than NB of the same height [1]

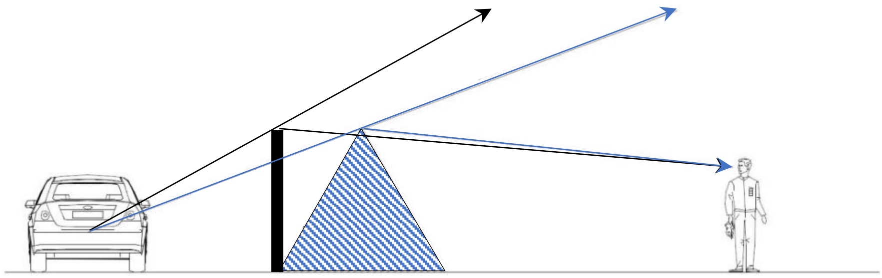
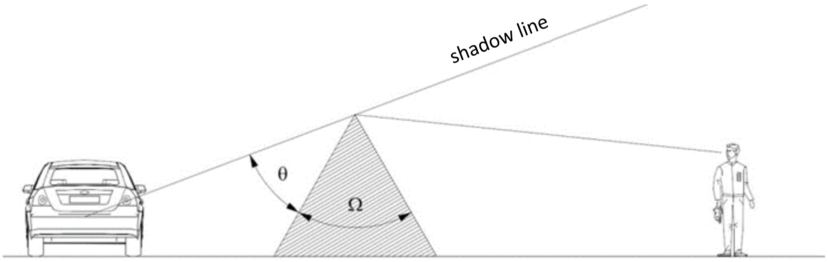


Figure 22: Earth berms: the footprint lowers the shadow line and then the noise reduction

As shown in Figure 23 , besides lowering the shadow line because of their footprint with respect to "conventional" NB of the same height, earth berms have two additional effects which reduce their performance:

- instead of hitting a vertical obstacle, the wavefront “climbs” the obstacle along a slope that is easier to "overcome" than a vertical NB;
- at the top, the energy radiates within a smaller angle than for a "thin" screen and thus the sound pressure becomes higher.

Maekawa also established a specific abacus making it possible to calculate these two effects [12] : Figure 24 presents this abacus that gives the loss of efficiency of a NB as a function of the angle of attack of the wavefront θ and of the opening of the angle Ω by characterizing the diffraction edge.



Ω = 0: perfectly ‘thin’ NB

Figure 23: Earth berms: angle of attack of the wavefront and volume of the diffracting object

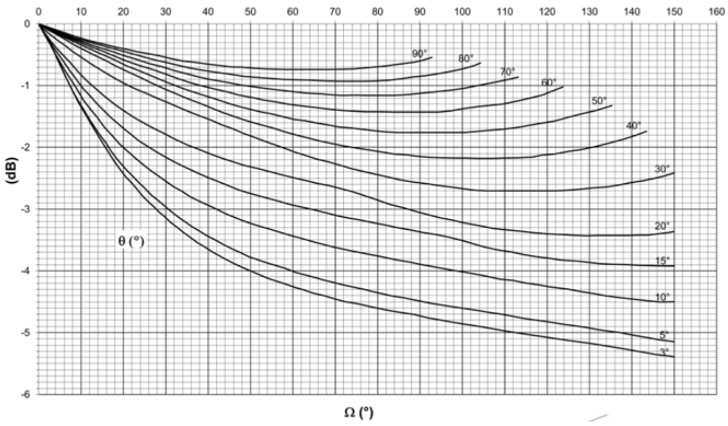


Figure 24: Earth berms: Maekawa chart for the loss of attenuation as a function of angles θ and Ω [12]

When calculating the efficiency of an earth berm, it is important to never forget this negative effect. Figure 25 shows an animation of the propagation of a wavefront over an earth berm.

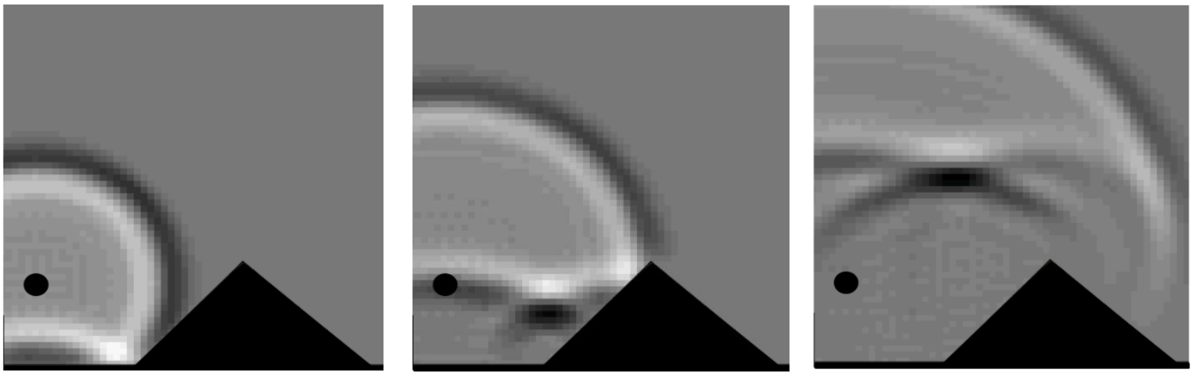


Figure 25: Propagation of a wavefront over an earth berm [3]

2.2.3 *Airborne* sound transmission

2.2.3.1 Physical phenomenon

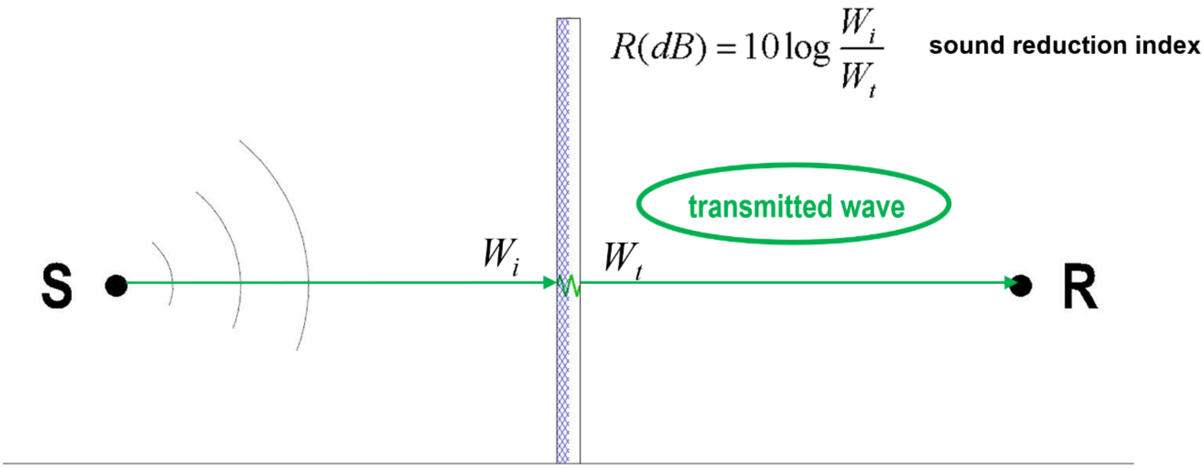


Figure 26: *Airborne* sound transmission through a NB [3]

Figure 26 explains the *airborne*[6] sound transmission through NB: from the emission by the sound source **S**, until the reception at the receiver **R**, we have the following steps:

- the sound wave is emitted from the source and then propagates to the NB;
- its wavefront reaches the surface of the NB: a certain part of the incident energy is reflected towards the *unprotected side* of the NB (see *2.2.1 Sound reflection)*, that is to say the "source side", depending on the characteristics of sound absorption of the screen; while a certain part is absorbed (see 2.2.1.1);
- the remaining part of this incident energy transmits through the NB and then propagates to its "protected side": this is referred to as *airborne* sound transmission;

  The airborne sound transmission performance is usually characterized by the airborne ***sound reduction index R*** *that expresses, in dB, the ratio of the transmitted energy* W_t *to the incident energy* W_i.
- the wavefront reaches the top of the NB, diffracts on it (see *2.2.2 Sound diffraction*) and then propagates to the "protected" side.

As shown in Figure 27, **the noise perceived within the protected side of the NB corresponds to the sum of the energy transmitted through it AND the energy diffracted at its top**.

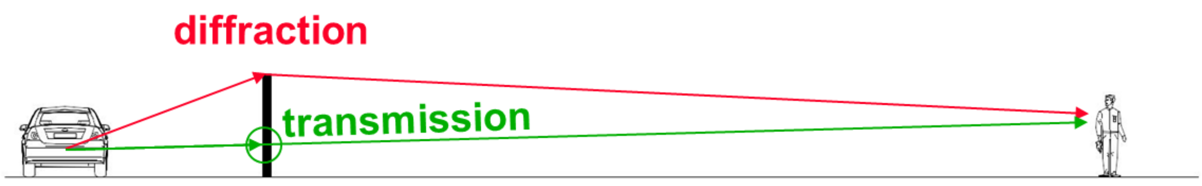


Figure 27: *Noise behind the NB = transmitted noise + diffracted noise*

[6] "*airborne*" (transmission via the air) is used to differentiate it from the so-called *"ground borne"* (transmission via the ground) transmission that could happen between the vehicles and the surroundings through the ground and finally radiates inside the buildings as another possible noise.

2.2.3.2 Relevant performance

It is quite easy to understand the advantage of limiting the transmitted energy, in order to obtain the best possible performance from NB: as a common rule, when two noise levels A and B add up, the result of this *energetic* addition is almost equivalent to noise level A, as long as noise level B is about 15 dB lower than noise level A.

So, in order for the noise transmitted through the NB to be negligible compared to that one diffracting at its top, the following rule of thumb is generally applied:

"The effect of transmission is negligible as long as the single-number rating of airborne sound insulation performance DL_R (dB) is 15 dB higher than the performance ΔL_{Aeq} (the one which would theoretically be obtained by the NB only by diffraction)":

$$DL_R > \Delta L_{Aeq} + 15 \text{ dB}$$

As an example, for a “classic” NB providing a theoretical overall noise reduction of about 8 dB on L_{Aeq} noise levels, DL_R should be greater than 23 dB.

Figure 28 shows what becomes the effective *practical performance* of a NB with a *theoretical performance* of 8 dB by *sound diffraction* only when sound transmission occurs as a function of its airborne sound insulation performance. It also shows that it is not necessary to require more than 23 dB because, beyond this level of performance, the transmitted energy becomes sufficiently negligible: a NB with DL_R = 23 dB will perform as well as a NB with DL_R = 50 dB.

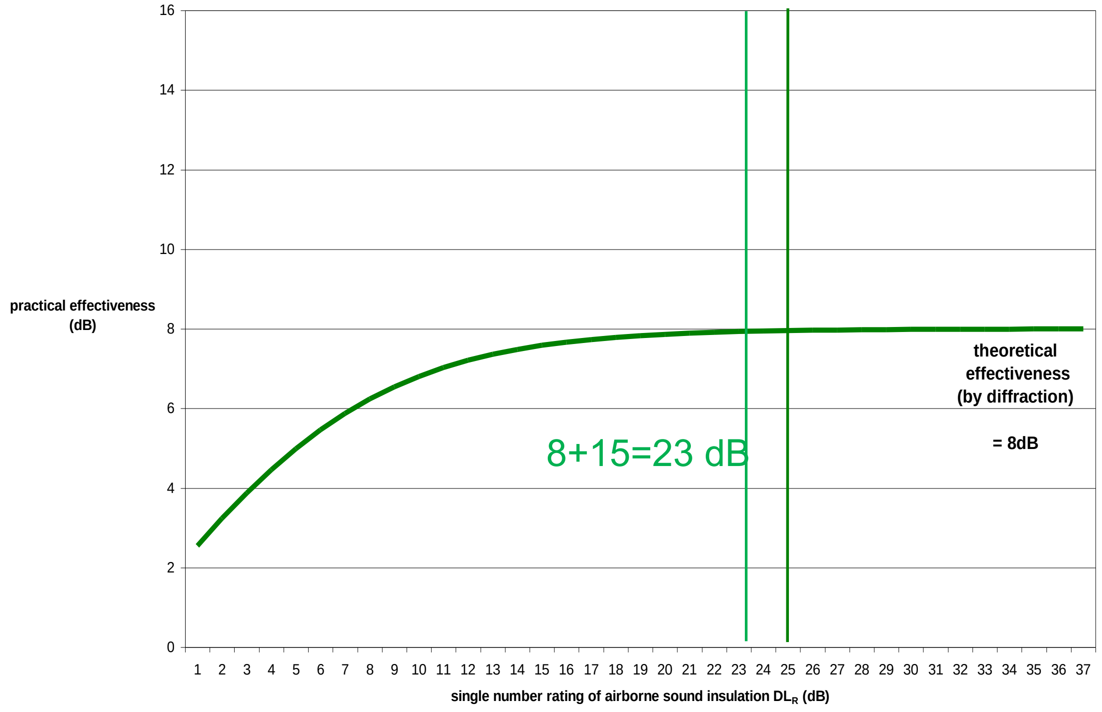


Figure 28: Effect of the airborne sound transmission on NB total performance (8 dB by *diffraction* only)

Figure 29 summarizes the effect of *airborne sound transmission* on the *effective performance* for NB *theoretical performances* ranging from 1 to 15 dB (typical values).

Figure 28 and Figure 29 clearly show that **the greater the attenuation by *sound diffraction*, the greater the performance to reduce *airborne sound transmission* must be**.

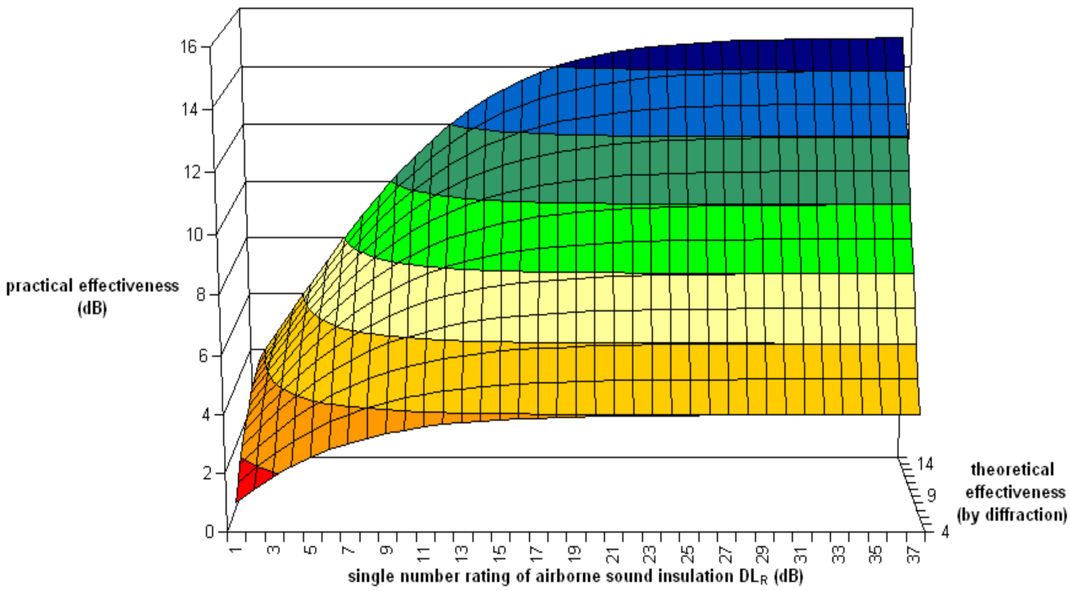


Figure 29: Effect of the airborne sound transmission on NB total performance (1 to 15 dB diffraction)

Keeping that in mind, it is now important to remember that traffic noise remains definitely a *time related phenomenon* that occurs at any single passage of vehicles. So: even if the most common unit used to characterise traffic noise is the *equivalent sound level* $L_{Aeq,T}$, to establish relevant values for the *airborne sound transmission*, it is necessary to consider the *diffraction effect on the instantaneous noise levels* $\Delta L_A(t)$ or even directly on ΔL_{Amax} instead of $\Delta L_{Aeq,T}$.

In the same way as for Figure 11, the only way to explain *time related effects* is to look at the *pass-by noise levels*: Figure 30 and Figure 31, as presented at next page, show those noise levels when a 4 m high truck passes respectively in front of a 2 m high, and a 7 m high NB.

- **Black curves present the pass-by noise levels in free field, i.e.: without any NB**.
- **Green curves present the pass-by noise levels due to *pure sound diffraction***.

The difference between the black curves and the green ones represents the noise reduction effect due to *pure sound diffraction* in function of the position of the vehicle: for a 2 m high NB, it goes from 7 dB (vehicle far away) up to 15 dB (vehicle just behind the NB). For the sake of the demonstration (to better differentiate the curves) we purposely consider a NB with an *airborne sound insulation performance* DL_R of 20 dB (i.e.: a bit lower than [7 + 15 =] 22 dB).

- **Violet curves present the pass-by noise levels due to *pure sound transmission***.
- **Yellow curves present the total effect of [*pure sound diffraction + pure sound transmission*]**.

On Figure 30, even with a 2 m high NB, we see that airborne sound transmission can already degrade the targeted noise reduction: it also shows that *sound transmission* has negligible effect when vehicle is far away and becomes significant when the vehicle passes in front.

On Figure 31, with a 7 m high NB, we now see that *airborne sound transmission* can degrade by more than 6 dB the targeted noise reduction on the highest noise levels when using a NB with DL_R of 20 dB: in that case, a DL_R of about 35 dB is appropriate.

To conclude, it can be said that:

***Sound transmission* has to be considered in the NB specifications: the performance to achieve is a function of the targeted performance on the highest pass-by noise levels. However, higher values are useless as they will give no further total performance.**

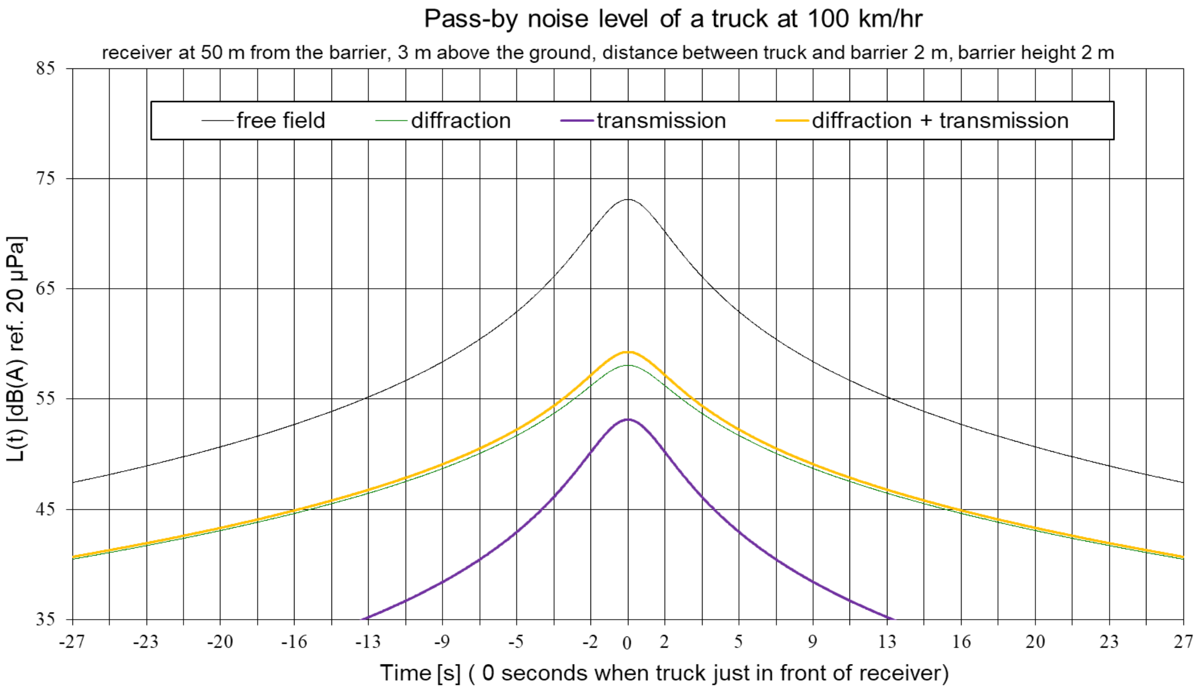


Figure 30: Effect of airborne sound transmission (DL_R = 20 dB) on the NB total performance

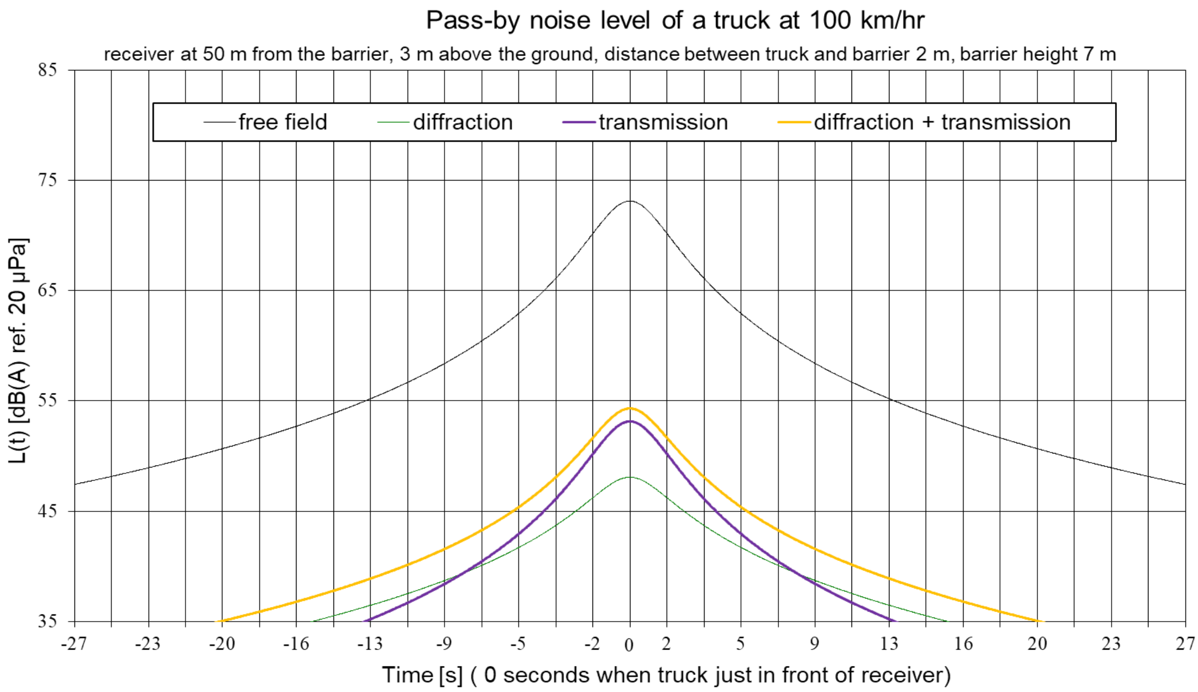


Figure 31: Effect of airborne sound transmission (DL_R = 20 dB) on the NB total performance

2.3 The emission characteristics

Previous Chapter *2.2* presented the three main physical phenomena that rule the acoustic performance of NB during the *noise propagation*, i.e.: *sound absorption* when the wavefront hits the NB, *sound diffraction* when the wavefront *passes over* the top of the NB, and *airborne sound transmission* when the wave passes through the NB. However, before approaching the NB, the wave has first to be emitted: as well as *sound propagation*, *sound emission* plays an important role in the NB performance to reduce noise.

At the early stages of *traffic noise control engineering*, it was usual to model vehicles as *point sound sources* for road vehicles and *finite length line sound sources* for trains: Figure 32 shows the propagation of a sound wave emitted by a *point sound source*: the wave propagates as concentric spheres centred on the point source itself (see also previous figures in Chapter 2.2 and Figure 13 presenting how a wavefront can be decomposed into a multitude of new point sources creating the next position of the wave front, following the Huygens-Fresnel principle).

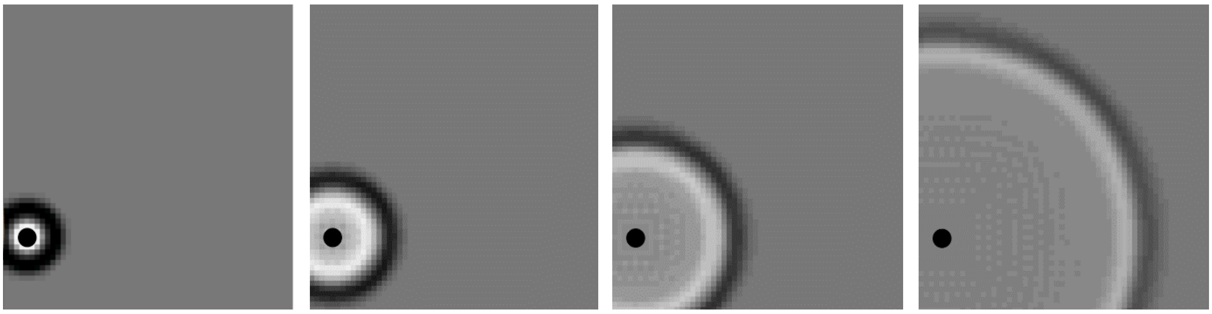


Figure 32: Propagation of a wavefront from a *point sound source*

However, road vehicles are not *point sound sources*, nor the trains are *finite length line sound sources*: they do have some *sound directivity*. This *directivity* will affect how the energy is reduced by NB: Figure 33 shows examples of such directivity for passenger cars, light trucks and heavy trucks, while Figure 34 shows examples for trains. This directivity partly explains why NB could better reduce railway traffic noise than road traffic noise: being placed where the trains / trams radiate their maximum energy, low-height NB make full use of this effect.

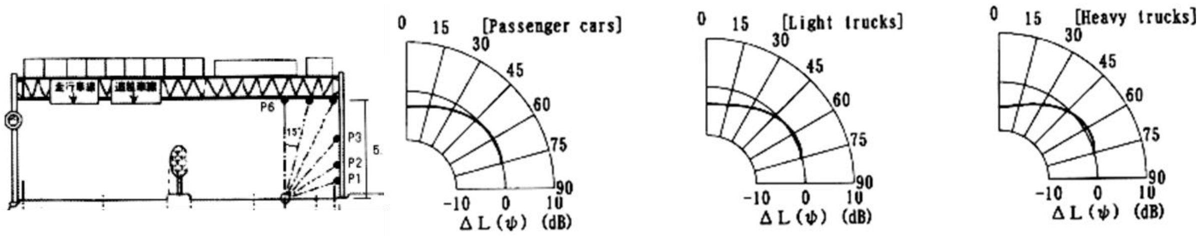


Figure 33: Examples of *sound source directivity patterns* of road vehicles [13]

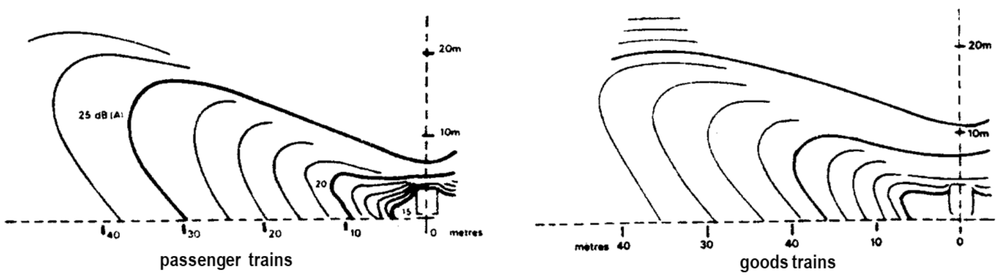


Figure 34: Examples of *sound source directivity* patterns of trains [14]

Thus, *sound emission* also plays significant role in the NB noise capability to reduce noise.

2.4 *The dimensions*

Although obvious, dimensions are too often underestimated in the *noise reduction process* of NB: Chapter *2.2.1.3 Interactions with the vehicle bodies* already presented some time related effects as *multiple interactions* and pointed out the following very important fact:

Traffic noise is a complete 5D (five dimensions) phenomenon (x, y, z, t, f).

2.4.1 *Geometric* dimensions of the objects

All the objects involved in the traffic noise, from the noise emission up to the its perception, do have geometric dimensions that influence the performance of NB noise reduction.

Vehicles dimensions

As presented in previous chapters, road vehicles are not *point sound sources*, nor the trains are *finite length line sound sources*: every vehicle is a *moving volume* with *sound reflecting* surfaces delimiting its body, some vehicles being possibly quite long as trucks and trains. All those dimensions influence considerably the noise reduction performance of NB and should be taken into consideration when evaluating it.

Obstacles dimensions

Chapter *2.2.2 Sound diffraction* detailed the logic effect of NB **height** in their *noise reduction* performance, while Chapter *2.3 The emission characteristics* mentions that a limited height NB could still be efficient if placed in the area where the greater part of the sound energy is radiated, as *low-height NB* for trams or trains. Apart its height, the NB **length** is important too, not only because a *finite length* NB might not hide some parts of the traffic, but also because even on the hidden parts of the traffic, the lateral edges of the NB also diffract the *sound energy* in the same way the top edge does (see Chapter *2.2.2 Sound diffraction*).

Figure 35 shows *noise maps* around a 4 lanes / tracks traffic at 4 m height above a full flat environment protected by a *perfectly sound-absorbing* 3 m high NB: the 1st *noise map* with an infinite length NB, the 2nd one with a hole / gap of 50 m, the 3rd with a 500 m long NB, and the last one with 2 successive NB sections of 225 m in length, distant by a hole / gap of 50 m.

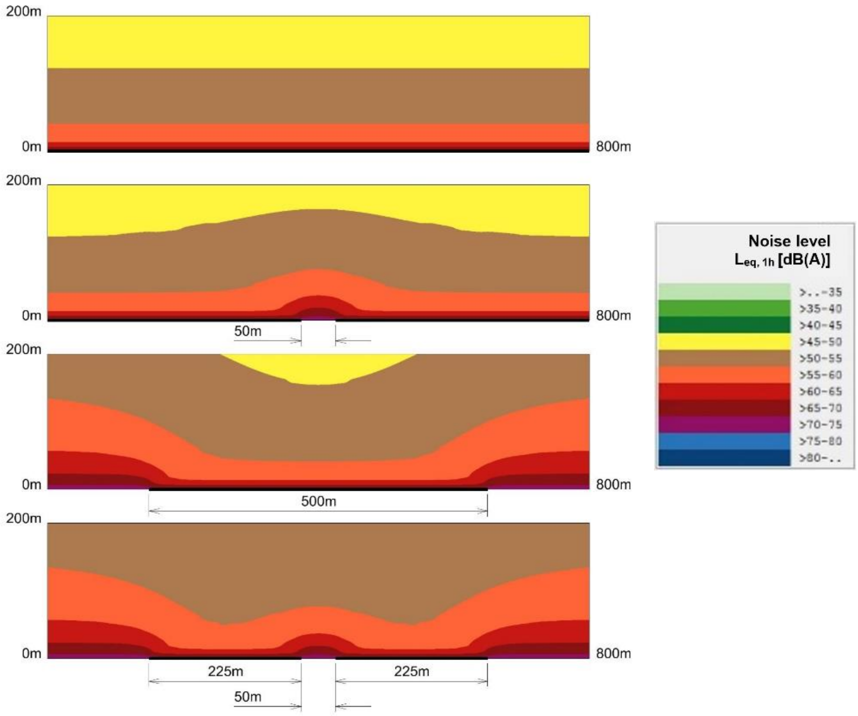


Figure 35: Noise maps showing the effect of NB length

While Figure 35 shows the effect of NB length by $L_{Aeq,\ 1h}$ *noise maps*, it is worth remembering that traffic noise is a time related effect: for a single vehicle pass-by, one can easily understand how such pass-by noise can be negatively perceived when the vehicle passes in front of holes / gaps in NB, or arrives in unprotected sections (finite length NB).

Finally, NB are most often considered as "*thin*" obstacles: this is the case with the majority of NB. However, some NB might be *quite big*, and their **volume** can also influence the *noise reduction* performance. *Earth berms* are evident examples of such *volumetric obstacles*: Chapter *2.2.2.3 Earth berms*, explained the effect that such *volumetric obstacles* could have (which could even be negative). On the EU market, NB are not always *thin*, *flat* and *vertical*: more and more products are *volumetric* and / or *non flat* and / or *non vertical* (e.g.: *vegetated* NB, *gabions* NB, particular *shaped* NB...: their effects on noise reduction could be rather complex and difficult to calculate, what explains why it is too often neglected, but this omission is unfortunately a mistake!

2.4.2 S / NB / R relative positions: topography and infrastructure profile

As already presented in Chapter *2.2.2 Sound diffraction*, the relative position of the *sound sources* (the vehicles), the obstacles (the NB) and the receivers (pedestrians, dwellings) conditions the *sound attenuation* due to *sound diffraction* at the top edge of a NB (Figure 17).

In fact, it is exactly the same as for the height of the obstacles to *sound propagation*: the more inclined the shadow line, the greater the *sound attenuation* (see Figure 19).

Thus, by playing on the inclination of the shadow line and the protected area in the shadow zone, the topography surrounding the traffic infrastructure (road / rail platform), as well as the longitudinal profile of the infrastructure will also strongly influence the *sound propagation*: they can even create natural obstacles to *sound propagation*.

Excavated roads / platforms - Surface roads / platforms - Elevated roads / platforms

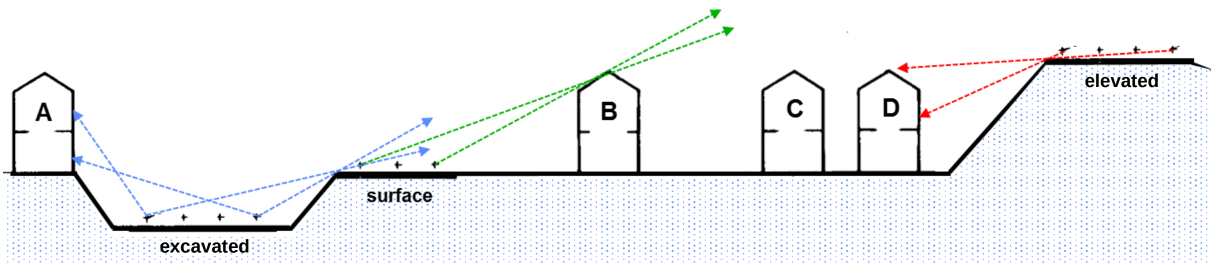


Figure 36: How longitudinal profile and topography influence *sound propagation*

In Figure 36, 4 rows of houses are present, for the sake of simplicity houses with one floor:

- the *excavated road / platform* does not offer any protection towards row A, but the excavation edge can slightly protect row B (blue *shadow lines*): depending on the location of the houses in relation to the top edge of the excavation, it may therefore provide little or no protective effect; similar situation occurs with *road / platform* in *trench*, but then reflections could occur on their *lateral sustaining walls* if they were not *sound-absorbing*;
- the *surface road / platform* directly exposes rows A and B, but row B, known as the *front row* of houses, obstructs the propagation of noise from this road towards the other rows of houses, as the 2nd and 3rd rows (C and D) (green *shadow lines*): in town, houses are often juxtaposed and thus create rather *long obstacles* to *sound propagation*, which can effectively protect their back side, as well as the 2nd and 3rd rows of houses;
- the *elevated road / platform*, although its edge can also offer a slight protection to the receivers located *just under* the *shadow zone* (red *shadow lines*), generally *sprinkles* many

more houses because the noise overpasses rows D and C to also disturb rows B and A; similar situation occurs with *road / platform* on *viaducts*.

Effectiveness of NB according to the longitudinal profile and topography

When placing NB of equal heights, obviously, their *sound attenuation* by *sound diffraction* strongly depends on where they are placed, and especially on the *longitudinal profile* of the infrastructure: Figure 37 explains how the shadow lines are higher (and consequently the *sound attenuation*) when the infrastructure profile is higher compared to the houses to protect (similar situation occurs with *road / platform* in *trench* or on *viaducts*).

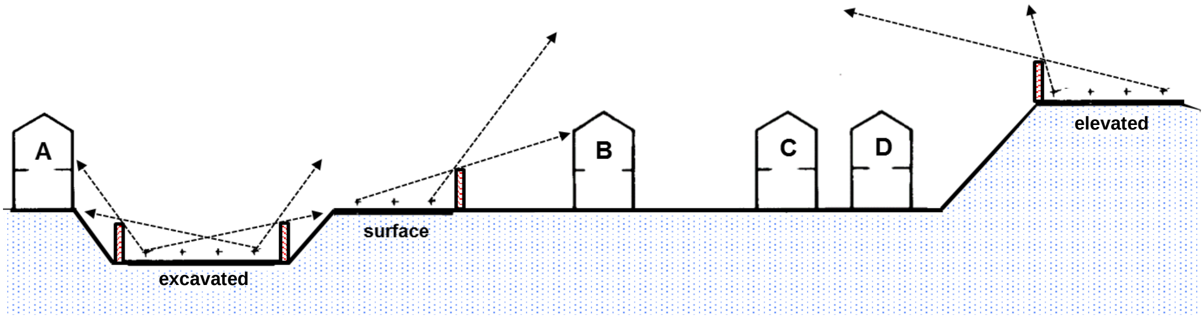


Figure 37: How longitudinal profile and topography influence NB *sound attenuation*

Without NB, the higher the road / platform, the larger the noise impacted area:

- Excavated or trench roads / platforms of medium depth (i.e.: approximately 5 to 7 m) provide some little protection on buildings which do not have a direct view on traffic;
- Buildings on the front row of houses are very exposed: if the houses are juxtaposed, they protect their own back façades as well as the following rows of houses behind them.
- Unprotected elevated roads / platforms or viaducts have the worst impact in urban areas.

With NB, the higher the road, the greater the NB noise reduction:

- Placing NB at the bottom edge of excavated roads is inefficient;
- Placing NB at the top edge of trenches or at the top of excavated roads, when possible, can be effective, except for floors with direct view of the road (even a partial view of some of the traffic lanes is sufficient to make ineffective the NB);
- In urban surface situations, it is almost impossible to place NB, except to protect urban spaces (parks, footpaths), or if the houses to be protected are set sufficiently back from the road / train platform;
- NB on elevated roads / platforms or viaducts are the most effective because they clearly raise up the shadow line.

To summarise: in urban situations, ***unprotected*** **elevated roads / platforms or viaducts are the worst cases** of *noise pollution*, while **(NB) protected elevated roads / platforms or viaducts** are situations which **have the best *noise reduction* performance** the NB can have.

2.4.3 Frequency domain

The lengths of the sound waves (the wavelengths) plays also a major role in the whole process of traffic *noise reduction*: they condition all the physical phenomena as well as the NB *intrinsic* characteristics (see Figure 38). All the phenomena are negatively affected by the importance of the wavelength: the larger the wavelength, the worse the effect on the *noise reduction*.

On the other hand, *road traffic noise* has a different content (spectrum) than railway noise: EN 1793-3 [15] defines the normalized road traffic noise spectrum, while EN 16272-3-1 [16] and EN 16272-3-2 [17] define the normalized railway noise spectrum; both are shown in Table 1 and Figure 39.

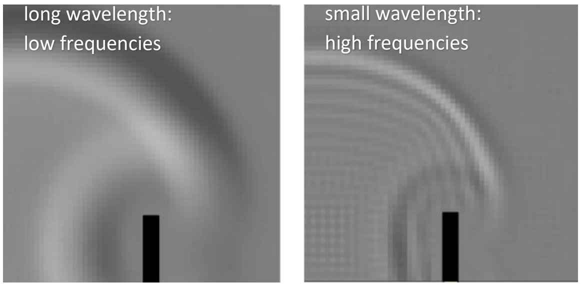


Figure 38: *Wavelengths* influence the NB *sound attenuation* by *sound diffraction*

Table 1: Normalised road traffic (EN1793-3) and railway traffic noise (EN16272-3) spectra [15]

f_i [Hz]	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
L_i roads [dB]	-20	-20	-18	-16	-15	-14	-13	-12	-11	-9	-8	-9	-10	-11	-13	-15	-16	-18
L_i railways [dB]	-27	-25	-23	-21	-19	-17	-15	-13	-12	-11	-10	-9	-9	-9	-9	-10	-13	-17

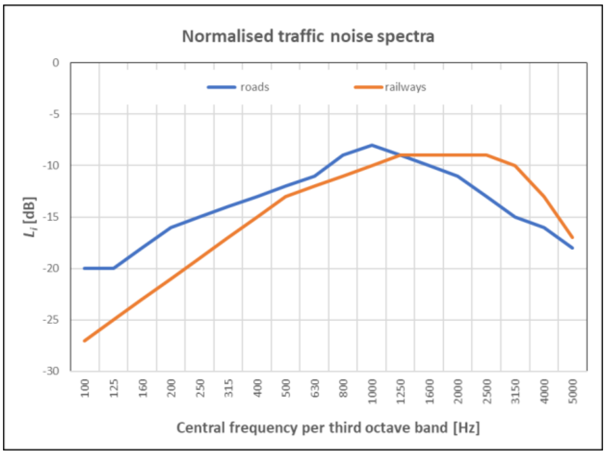


Figure 39: Normalised road traffic (EN1793-3) and railway traffic noise (EN16272-3) spectra [15]

Finally, merging both the time domain (see below) and the frequency domain, sound waves can, to some extent, interfere between themselves when their sound sources are coherent: this can lead to very complex situations. This should be considered while designing NB (e.g.: with multiple interactions, the *image sources* are all coherent between themselves and with their original sound source - see Figure 12).

2.4.4 Time domain

The *overall noise* perceived in the environment is nothing else than the sum of the respective contributions of every single vehicle moving at its own speed in the middle of the traffic: the NB *noise reduction* performance is different for every single vehicle, depending on its kind, its position at a given time, not forgetting its relative importance in an evolving *background noise*.

It is the *time dimension* that explains the particular discomfort with isolated vehicles pass by, e.g.: trucks perceived during quieter periods of the night due to weak airborne sound insulation (Figure 29), or *noise increase* due to multiple interactions with sound-reflecting NB (Figure 11).

2.5 *The shape of the objects*

Chapter *2.2.1 Sound reflection* explained how reflections can influence *wave propagation*, and Chapter *2.2.2 Sound diffraction* explained how diffraction allows waves to partly pass to the other side of an obstacle by diffraction at the top edge of the obstacle.

It is obvious that the *shape of the objects* will strongly influence the way in which the waves will be reflected on them, just as this shape will influence the way in which these objects will diffract the *incident wave*.

Furthermore, since several objects can face each other, resulting effects of *multiple reflections* will be able to accumulate, as for example between two facing walls, whether they are both fix (two parallel sustaining walls or two parallel NB) or mobile (two vehicles) or although one of the two is fix (a sustaining wall / a NB) and the other mobile (a vehicle).

2.5.1 Vehicles

Several types of vehicles make up the traffic: bikes, cars, vans, light trucks, heavy trucks (semi-trailers and trailers), single length, double length or even triple length buses, trams, passenger trains, good trains...

Each of those vehicles has a more or less *continuous body* of *different lengths*: the *sound waves* will therefore be reflected in a different way depending on the vehicle shape and length. In addition, when a single vehicle passes in front of a fixed receiver point, the pass-by duration depends not only on its speed, but also on its length.

2.5.2 NB

The NB market is very large; however, it is usual to subdivide it into categories (remembering that they all can be *sound-absorbing* or *sound-reflecting*):

- *thin flat* NB: vertical or inclined (towards the vehicles or towards the environment);
- *thin non-flat* NB: curved or of a particular shape (see Figure 40 and Figure 41);
- *volumetric* NB: vegetated NB, “stepped” retaining walls;
- while they can also be capped with some *additional devices* (so-called *added devices*) intended to improve the *sound attenuation* obtained by *sound diffraction* on the NB top edge (see *2.5.3 Added devices*).

In the early years of NB, (*sound-reflecting*) ***thin flat inclined* NB** were used to send *sound reflections* away from inhabited areas: Figure 7 shows why vertical *sound-absorbing* NB are better choices.

***Thin non-flat* NB** are often designed to avoid problems of *sound reflections* / *multiple reflections*: their design must thus also be adapted to the shape of the vehicles whose noise they have to reduce: Figure 40 shows a NB *specially optimised* to enhance its *noise reduction* when protecting the noise propagation from a high-speed train line.

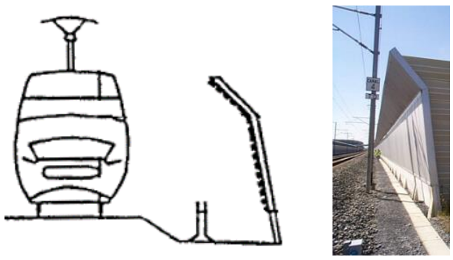


Figure 40: High-speed train with *special shaped body* facing an *optimised shaped* NB (© A-Tech)

Often on viaducts, *visually transparent* NB are preferred because they reduce their visual impact. However, *visually transparent* materials are unfortunately *sound-reflecting* and, if they were placed vertically, they would also provide *multiple reflections* degrading their IL. Therefore, in order to better control these *multiple reflections*, curved shapes are often used: Figure 41 shows a visually transparent NB that has been *curved* designed to reduce the negative effect of *sound reflections*.

Figure 41: *Sound reflecting* NB curved to reduce the negative effect of *sound reflections*

***Volumetric* NB** such as vegetated NB, or *staircase sustaining walls* must be used very carefully: in fact, their *sound absorption* characteristics are often limited and due to a healthy vegetation; however, the vegetation weakly resists to the proximity of the traffic and its pollution (e.g.: de-icing salts).

2.5.3 Added devices

As already stated hereabove, *added devices* (e.g.: Figure 42) are specific components that are designed to cap NB. NB product standard EN14388 defines an *added device* as follows:

"*additional component that influences the acoustic performance of the original noise-reducing device, acting primarily on the diffracted energy*".

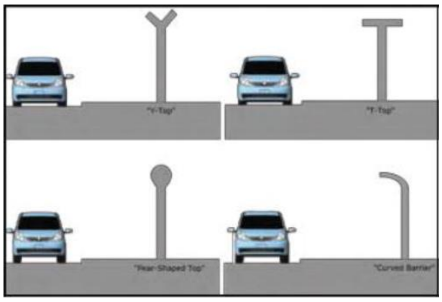


Figure 42: Different examples of added devices [1]

However, it is highly recommended to remain cautious about the alleged *increase of sound attenuation* of such devices, which are only effective under the shadow line, but which can in no way justify an equivalent reduction in height when dwellings are found above the line after such a decrease of height (see Figure 43).

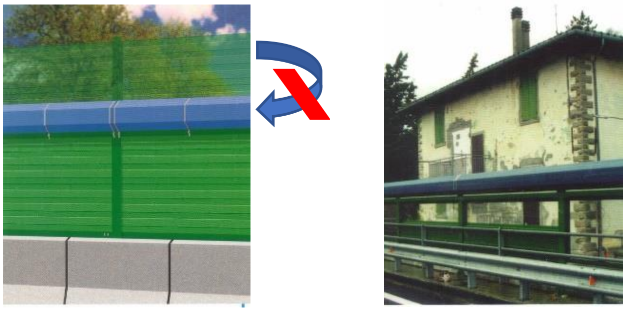


Figure 43: Use *added devices* carefully as they may not protect above the *shadow line*

Section *3.4 Intrinsic sound diffraction* will introduce the standardised EN method that has to be used to characterise the acoustic performance of *added devices*.

2.6 The sound propagation medium: the air / weather conditions

Sound waves cannot propagate without a *medium*: the air. The physical content / conditions of the air influence the *sound propagation* and, thus, can affect the *noise reduction* performance of NB.

The major weather factors influencing *sound propagation* are the wind, and the temperature: they play on the *sound speed* and mainly influence the *long-range sound propagation*.

Without wind and temperature effects, we speak about *homogeneous sound propagation conditions*: IL of NB is generally established under those conditions. However, in presence of wind and / or temperature gradients, *sound waves* do not propagate along *straight trajectories* anymore, but as *bended trajectories* instead: those *bended trajectories* could then drastically affect the (theoretical) *sound reduction performance* of NB.

The following description is extracted from the *SETRA manual on NMPB 2008* [18] : it describes both the so-called *downwind* and *upwind* conditions / effects.

2.6.1 *Downwind* conditions / effects

Thermal origin: at night, when the sky is clear, the ground radiates and cools more easily than the air. The low atmospheric layers become colder than the upper layers and the air temperature rises with the height above the ground. This situation is called *temperature inversion*. It corresponds to a situation of *positive vertical sound speed gradient*.

Aerodynamic origin: if the *wind direction* corresponds to the direction of the *sound wave* propagation, the algebraic sum of the sound speed in *homogeneous* atmosphere and of the wind speed will provide a *sound speed profile* which increases with the height.

The acoustic effect of these conditions is represented in Figure 44.

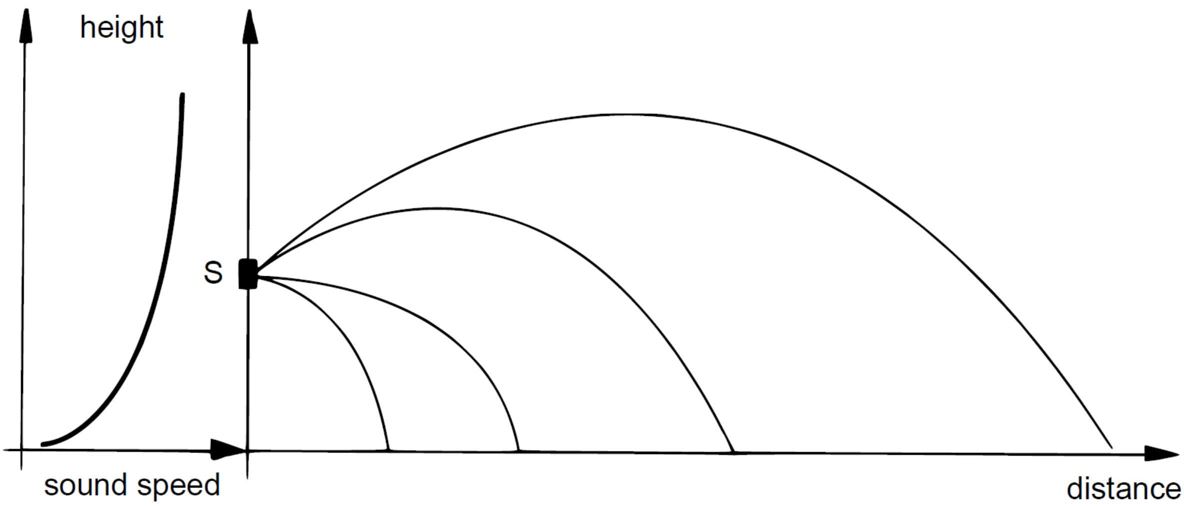


Figure 44: Acoustic propagation in downward-refraction conditions [18]

The sound waves travel *downwards*: in these conditions, the *far field sound level* is stronger than without meteorological effects. This meteorological situation therefore favours *sound propagation*, but can also reduce the *sound attenuation* by *sound diffraction* on NB tops, as the corresponding *bended waves* can *overpass* the NB.

2.6.2 Upwind conditions / effects

Thermal origin: in this case, the temperature drops with the height above the ground. This phenomenon is produced during the day: the sun heats the ground which transfers its heat to the lower atmospheric layers. The result is that the air temperature near the ground is higher than at a height. The *sound speed* decreases with the height in relation to the ground.

Aerodynamic origin: when the wind blows in the opposite direction to the sound propagation direction, the *wind speed* is subtracted from the *sound speed* in an immobile atmosphere. The *sound speed*, in the direction of propagation, therefore, drops with the height above the ground.

The acoustic effect of these conditions is represented in Figure 45.

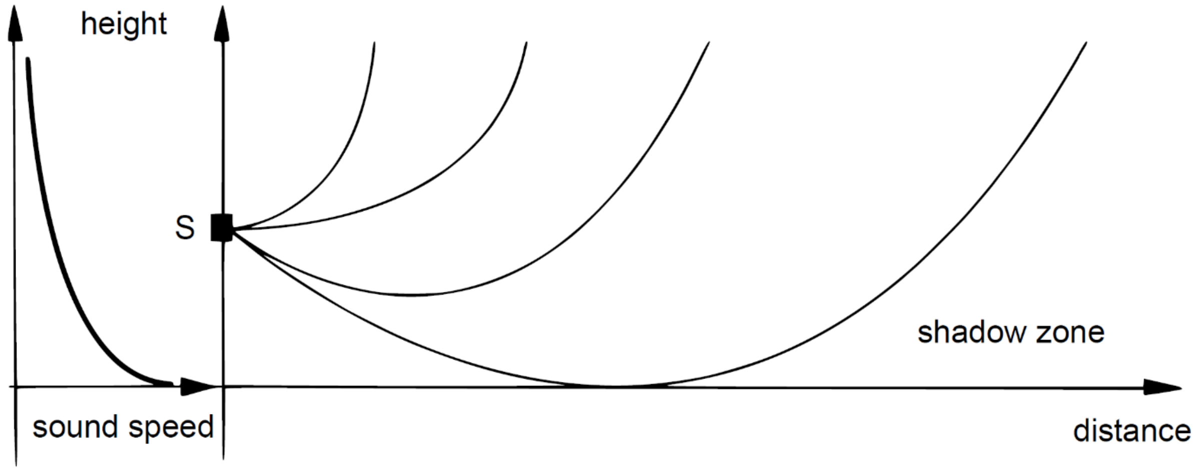


Figure 45: Acoustic propagation in upward-refraction conditions [18]

The acoustic rays travel *upwards*: in these conditions, the *far field sound level* is weaker than without meteorological effects. In theory, there is even a ‘shadow zone’ where no direct acoustic wave can penetrate; actually, there are sound levels weaker than in a homogeneous atmosphere, due to waves coming from scattering and turbulence phenomena. This type of conditions does not therefore favor sound propagation and a NB placed in the corresponding shadow zone would have then no effect when those conditions occur (while those conditions already decrease noise in the shadow zone).

2.7 The intrinsic characteristics

Intrinsic characteristics are the ones inherent to the NB elements / products themselves: the whole Chapter 3 is dedicated to those characteristics.

3 *Intrinsic* performances of Noise Barriers

As already presented in the previous chapters, within the entire process of *traffic noise propagation* from the noise emitted by traffic up to its reception in the environment, NB are important devices that could provide relevant *noise reduction*.

As already stated in Section 2, NB *noise reduction* is characterized by the "Insertion Loss" (IL), i.e.: the difference in traffic noise perceived at a specific location with and without the presence of the NB. IL is an *extrinsic* characteristic that involves a lot of factors pertaining both to the NB and the environment. On the other hand, *intrinsic* characteristics are those characteristics *inherent to the products* used to build up NB: they are very important because they condition the IL as far as *sound reflection*, *airborne sound transmission* and *sound diffraction* are concerned.

3.1 Importance of the intrinsic characteristics of NB

The *intrinsic characteristics* of NB are *sound absorption*, *airborne sound insulation*, and *intrinsic sound diffraction at the NB top edge.* To summarize what is presented in *Chapter 2:*

1. *Sound absorption* on the traffic side of a NB should be high enough so that sound reflected by the NB in the far field is low enough not to increase noise pollution on the other side of the road/railway (*2.2.1.1 Simple sound reflections*). Another adverse effect that can be reduced by a good sound-absorbing NB is the multiple reflection effect, between two parallel NB (*2.2.1.2 Multiple sound reflections*), or between a NB and vehicles passing close to it (*2.2.1.3 Interactions with the vehicle bodies*).
2. *Airborne sound insulation* should be high enough so that the sound transmitted through the NB is negligible compared with the sound diffracted over the top, but higher values becomes useless (*2.2.3 Airborne sound transmission,* and *2.2.3.2Relevant performance*)
3. Additionally, *intrinsic sound diffraction at the NB top edge* should contribute to the overall sound attenuation acting primarily on the diffracted sound field. Products added on the top edge of a NB for enhancing the *intrinsic sound diffraction* are the so-called "added devices".

Intrinsic characteristics are determinant to establish the overall sound level in the *near field*, i.e. close to the NB, say at distances of smaller than 30 m from the NB, and thus they are essential to determine the overall sound level for the most exposed people. However, they can also have an important impact in the *far field*, for example when poorly absorbing NB reflect most of the incident sound on the other side of the road where many inhabitants live.
It is common to divide the sound field in the area shielded by the NB into a *near field* and a *far field*. However, it should be kept in mind that the transition from the near field to the far field is gradual and cannot be simply reconducted to a single distance from the NB. Moreover, at present, different criteria are in use to define the extension of the near field, depending also on the NB intrinsic characteristic considered.

For ***sound absorption*** the *near field* extends just 1-2 m for a flat, strongly-absorbing NB, but it can extend much more for a non-flat, non-absorbing NB (Figure 46 shows the sound pressure field, at 1 kHz, that is reflected by a sound-reflecting 'zigzag' NB having a surface depth of 0,29 m, while Figure 47 shows an animation of this kind of effect).
Far-field effects of the *intrinsic sound absorption characteristics* (those one being measured in the *near field*) has been investigated in the frame of the EU project QUIESST [2] . Considering that the effect of sound reflections from the NB in the far field is related to the NB shape, the NB materials, the location of the receiver position in the far field, the characteristics of the sound propagation path and the background noise, it has been decided to assess the *far-field* effect by comparison with a *reference noise barrier*, which is a flat, rigid, vertical barrier of the same height as the real NB.

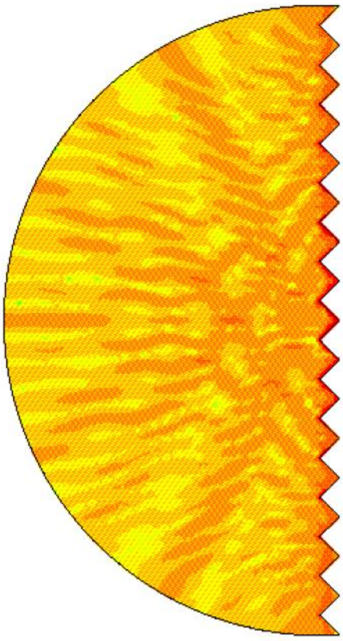


Figure 46: Sound pressure field, at the frequency of 1 kHz, reflected by a reflecting 'zigzag' barrier having a surface depth of 0,29 m [19] .

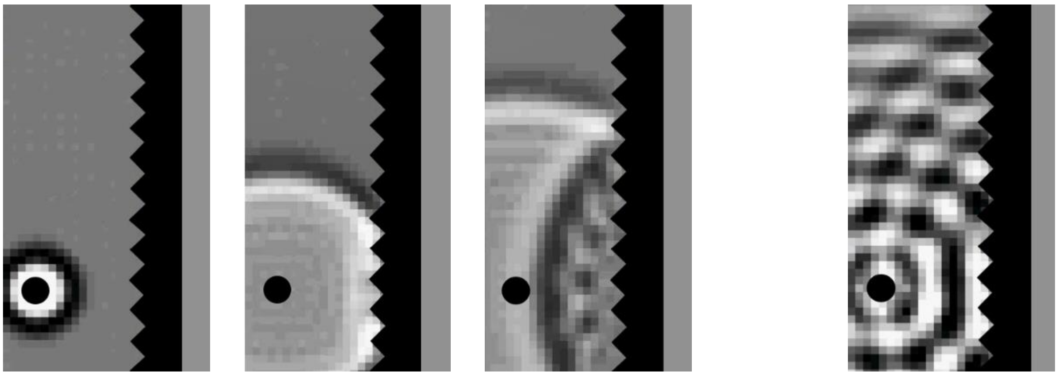


Figure 47: Propagation of a single wavefront on a reflecting 'zigzag' barrier (3 pictures at left) and effect with sustained waves (4th picture at right)

The *far-field reflection index* RI_{ff} has been defined as the ratio between the amount of energy which is reflected by the device and the energy that would be reflected by the reference barrier. Then, an engineering extrapolation method has been developed, using the *RI* values measured in the near field according to EN 1793-5 [20] to calculate an estimated contribution of the reflected sound to the sound level in the far field, expressed as the *single-number rating* for the far field reflection index: $DL_{RI,ff}$.

This *single-number rating*, expressed in dB(A), is computed at five different receiver positions (see Figure 48): at a distance of 100 m from the NB, and at heights of 1.5, 5, 10, 20 and 40 m above the ground.

In order to obtain a compact description of the reflection effects in the far field, the *single-number ratings* at the five positions are then clustered and averaged in two groups: the average of the *single-number ratings* of the three lowest positions $DL_{RI,ff,LR}$ is considered to be representative for low-rise buildings and the average of the *single-number ratings* of the highest two $DL_{RI,ff,HR}$ is considered representative for high-rise buildings.

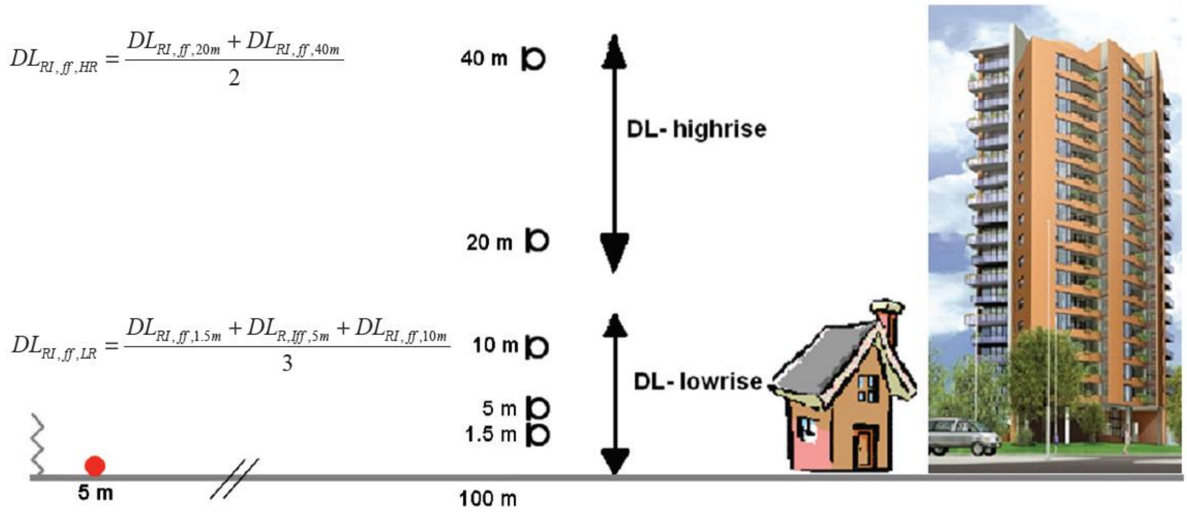


Figure 48: Locations that are considered for the sound source, the NRD and the receivers definitions of $DL_{RI,ff,HR}$ and $DL_{RI,ff,LR}$ [2]

For ***airborne sound insulation***, the *far-field* effects have been investigated in Task 2.3 of this SOPRANOISE research [21] .

It assumes that, in most cases, a leak can be characterized by a *vertical slit,* a *horizontal slit*, or a *hole*:

- *horizontal slits* are a model for missing or poor sealing between vertically stacked acoustic elements or between those elements and the bottom of the NB,
- *vertical slits* are a model for leaks between vertical elements, or at the panel-post joint,
- *holes* are a model for localized damages. For example, approximately round leaks are produced in wooden barriers by mechanical impacts or animals, as well as in transparent barriers by stones thrown up from the road surface by passing vehicles.

All these leaks can be represented with the Mechel's model [22] .

Comparing the overall sound field obtained at several receivers behind a perfectly insulating NB with the one behind an identical NB with leaks, a *critical area* can be considered behind the noise barrier: within this area, the influence of the leak is dominant over the diffraction and the *sound reduction* of the barrier significantly decreases. At more distant receivers, i.e.: beyond this *critical area*, the effect of the leaks becomes negligible.

The *critical area* is defined by the *criticality condition*

$$\xi = L_{m,t} - L_{m,b} + 10 \text{ dB}$$

Where $L_{m,b}$ is the total sound level at the receiver point due to the diffraction on the top edge of the NB and $L_{m,t}$ is the total sound level due to the sound transmission through the leak.

- For $\xi > 0$, the corresponding receivers lies within the *critical area*, where the negative effect of the leak is relevant.
- For $\xi < 0$, the leak has no further influence on the NB performance.

Thus, the *critical area* is delimited by the curve $\xi = 0$ (see Figure 49).

Calculations show that the *critical area* increases with the importance of the leak, as well as with the NB height (similar effect as described in 2.2.3.2): see Figure 50.

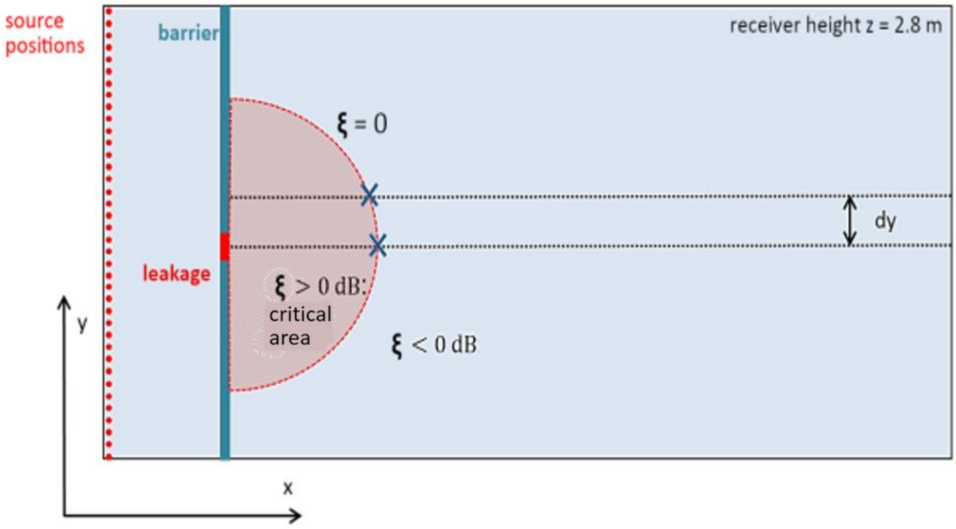


Figure 49: Illustration of the acoustical *critical area* behind a NB with a leak [21]

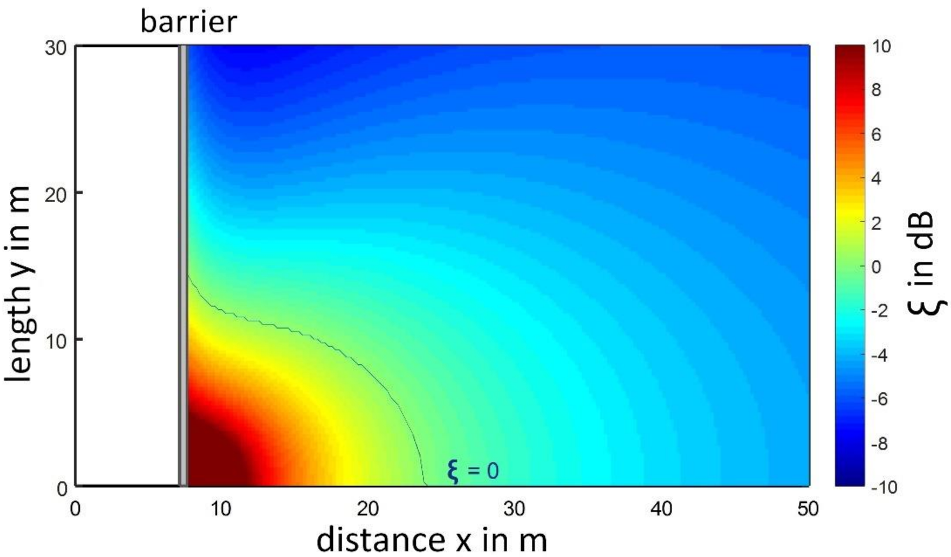


Figure 50: Top view of the calculation of the criticality condition ξ at an immission height of 2,8 m for a leak size of 0,5 m² with the following parameters; barrier height = 9 m, transmission coefficient of the leak τ = 0,4 leak [21]

3.2 *Intrinsic sound absorption*

The usual characteristic used for describing *sound absorption* of a surface is its *sound absorption coefficient* α: it is defined as the ratio of the *sound power* absorbed at the surface of the test object to the *sound power* arriving on it, given on a linear scale (see also Figure 5 in *2.2.1.1 Simple sound reflections*). However, this apparently simple definition implies some subtleties giving rise to practical consequences when assessing the *sound absorption* of NB.

First of all, the amount of sound that is not absorbed is reflected back from the surface according to a complex and frequency-dependent scheme, which never reduces to the limiting cases of a *pure specular reflection*, nor to a completely *diffuse* one: the *scattering* profile of the surface can drastically influence the measured *sound absorption*, especially for non-flat surfaces [4] , [5] .

Then, the sound absorption coefficient is a function of the angle θ of incidence of sound: $\alpha = \alpha(\theta)$. In *building acoustics*, there exist two complementary methods for measuring the sound absorption coefficient α: one at normal incidence ($\theta = 0$), and the other one assuming a *diffuse sound field*. The first method is standardized in ISO 10534 [23] and applies for small test samples (typically 40-100 mm diameter): the resulting quantity characterises the *normal-incidence sound absorption coefficient* α_0. The second method is standardized in ISO 354 [24] and applies for samples of about 10 m^2 placed in a (laboratory) reverberation room. It holds under a diffuse sound field assumption and thus the resulting quantity characterises the *diffuse sound field absorption coefficient*, or *Sabine's absorption coefficient* α_S.

For NB, a laboratory test method has been standardized in **EN 1793-1** adapting the ISO 354 procedure; therefore, it **holds only under the assumption of using the tested NB under *diffuse sound field conditions***, i.e.: it is only valid for NB to be installed in deep trenches, tunnels and other situations where a nearly reverberant sound field exists [25] . It also considers the volume of the sample under test; the result is given as α_{NRD}. ISO 354 assumes the realization of a *diffuse sound field* and relies on the measurement of reverberation times with and without the sample to be tested, and on the subsequent calculation of the *sound absorption*. Thus, being an indirect measure, the accuracy of the method is strongly dependent on the accuracy of the model used to relate *sound absorption* with the *reverberation time*, which normally implies that the room must be "ergodic, mixing and weakly absorbing" to ensure the *sound field* to be sufficiently *diffuse* [26] . In simpler words, the reverberation room must be so that: i) an average made at random points at the same time is equal to the average along a random path in stationary conditions, ii) all normal modes can perfectly mix each other at every point, and iii) the sound absorption of the empty room is extremely low. Despite the fact that standards propose several guidelines and checks to be satisfied in order to ensure that the test room complies with the *diffuse sound field* model, and that several studies also proposed measures to quantify the *degree of diffuseness* (e.g. [27] , [28] , [29]), experience confirms that obtaining a *diffuse sound field* is much harder than one would desire. The outcomes of these difficulties and the choice of using the outdated Sabine's formula for the reverberation time cause a systematic overestimation of the sound absorption coefficient. This causes unphysical values of the sound absorption coefficient and of its complement to one, the sound reflection factor.

Figure 51 shows the results of two measurements done on the same kind of NB made of perforated metallic cassettes filled with polyester fibre matts. As can be seen the *reverberation room* values of the sound absorption coefficient go over one in some *one-third octave bands*; hence the *sound reflection* values, calculated as the complement to one of these values, assume negative values!

A different test method has been standardized in **EN 1793-5** [20] for assessing the *intrinsic sound absorption performance* of NB to be installed not under *diffuse sound field conditions*, but under ***direct sound field conditions*, i.e.: the one corresponding to the normal *intended use* of NB in *open environments***. The test method indirectly assesses *sound absorption* by measuring the *sound reflection* (its complementary characteristics). Even for flat strongly absorbing NB, the *RI* values are always positive (Figure 51). Those tests can be carried out anyway, whatever indoors or outdoors, as soon as the *direct sound field conditions* are met. Indoors, it can be applied in purposely built test facilities (of course respecting *direct sound field conditions*). Outdoors, it can be applied in purposely built test facilities, e.g.: near a factory or a laboratory, but also *in situ*, i.e.: where the NB are installed.

Even if some research studies suggest that some correlation exists between the two methods [30] the **measurements results of the EN 1793-5 method for *sound absorption* are not comparable with the results of the EN 1793-1 method, mainly because of completely different sound field used**.

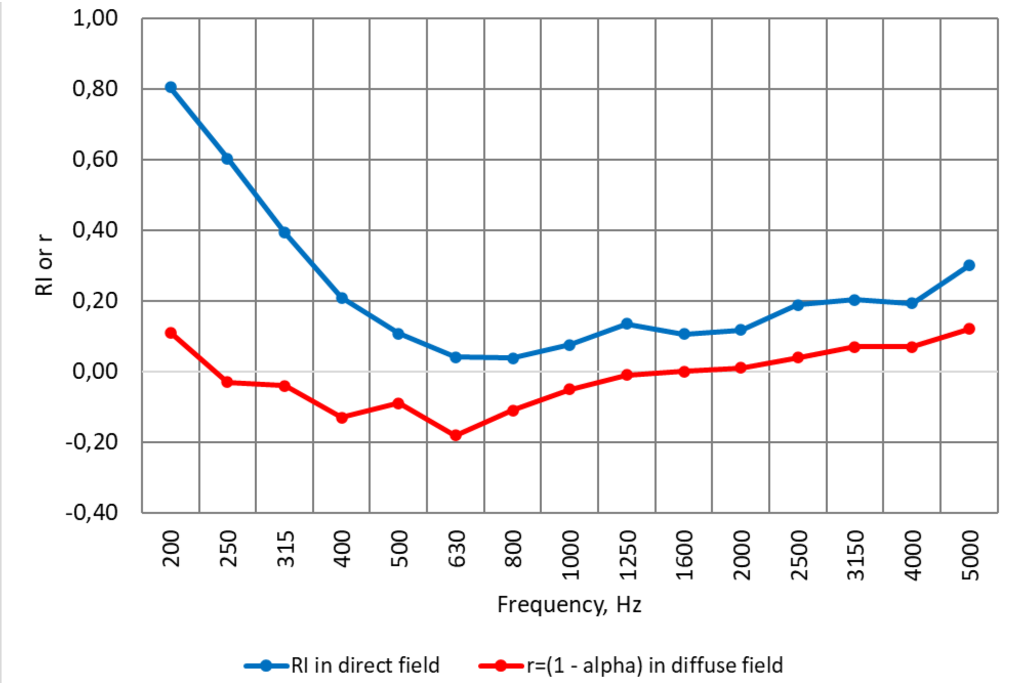


Figure 51: *Sound reflection index RI* measured in *direct sound field* and *sound reflection coefficient r* = (1 - α_S) calculated from *sound absorption coefficient* α_S measured in *diffuse sound field* for a NB made with perforated metallic cassettes filled with polyester fibre matts

3.3 Intrinsic airborne sound insulation

In principle the *airborne sound insulation* performance is expressed by the ratio τ of the sound power passing through the test object (*transmitted* W_t) to the sound power arriving on it (*incident* W_i), given on a logarithmic scale and expressed in dB (see also Figure 26 in *2.2.3 Airborne sound transmission*, *2.2.3.1 Physical phenomenon*).

In building acoustics this yields the *sound reduction index R*:

$$R = -10\log(\tau) = -10log\left(\frac{W_t}{W_i}\right) = 10log\left(\frac{W_i}{W_t}\right)\ \text{dB}$$

where τ is the *sound transmission coefficient* for the sound power *W*.

However, it should be recalled that, in practice, the measurement of this quantity is realized assuming ***diffuse sound field conditions***, as the one approximately realized inside the coupled reverberation rooms used to qualify building components according to the ISO 10140 package of standards [31] . So the measured results are derived from the expression:

$$R = L_1 - L_2 + 10log\left(\frac{S}{A}\right)\ \text{dB}$$

where L_1 is the sound pressure level in the source room, L_2 is the sound pressure level in the receiving room, *S* is the surface area of the sample under test and *A* is the equivalent sound absorption of the receiving room.

Moreover, when going *in situ* to test inside real building interfaces according to the ISO 16283 package [32] , flanking transmission comes into play and then an *apparent sound reduction index R'* < *R* is measured:

$$R' = -10\log(\tau') = 10log\left(\frac{W_{inc}}{W_{tr,dir} + W_{tr,flanking}}\right)\ \text{dB}$$

It is also worth remembering that, in building acoustics, other quantities can be defined, like the *sound level difference D*, normalized with the *receiving* room *sound absorption:* D_n, or with the *receiving* room *reverberation time:* D_{nT}.

For NB, a laboratory test method has been standardized in **EN 1793-2** [33] adapting the ISO 10140 procedure; therefore, it **holds only under the assumption of using the tested NB under *diffuse sound field conditions***, i.e. it is only valid for NB to be installed in deep trenches, tunnels and other situations where a nearly reverberant sound field exists.

A different test method has been standardized in **EN 1793-6** [34] assessing the *intrinsic airborne sound insulation performance* of NB to be installed not under *diffuse sound field conditions*, but under ***direct sound field conditions*, i.e.: the one corresponding to the normal *intended use* of NB in *open environments***. Those tests can be carried out anyway, as soon as the *direct sound field conditions* are met, whatever indoors or outdoors. Indoors, it can be applied in purposely built test facilities (of course respecting *direct sound field conditions*). Outdoors, it can be applied in purposely built test facilities, e.g. near a factory or a laboratory, but also *in situ*, i.e. where the NB are installed. The results of this method are expressed as values of the *sound insulation index SI*.

Some research studies found good correlation between the two methods [35] , [36] : ***SI* values are *comparable, but not identical,* with the values of *R* from the EN 1793-2 method, mainly because the EN 1793-6 method assumes *direct sound field conditions*, while the EN 1793-2 method assumes a *diffuse sound field, this one implying additional physical phenomena, as the coincidence effect*.**

For example, Figure 52 shows the comparison of the *SI* values measured in a *direct sound field* and the *R* values measured in a *diffuse sound field* for the same acrylic NB. The *diffuse sound field coincidence* effect in the 1600 Hz *one-third band* is evident.

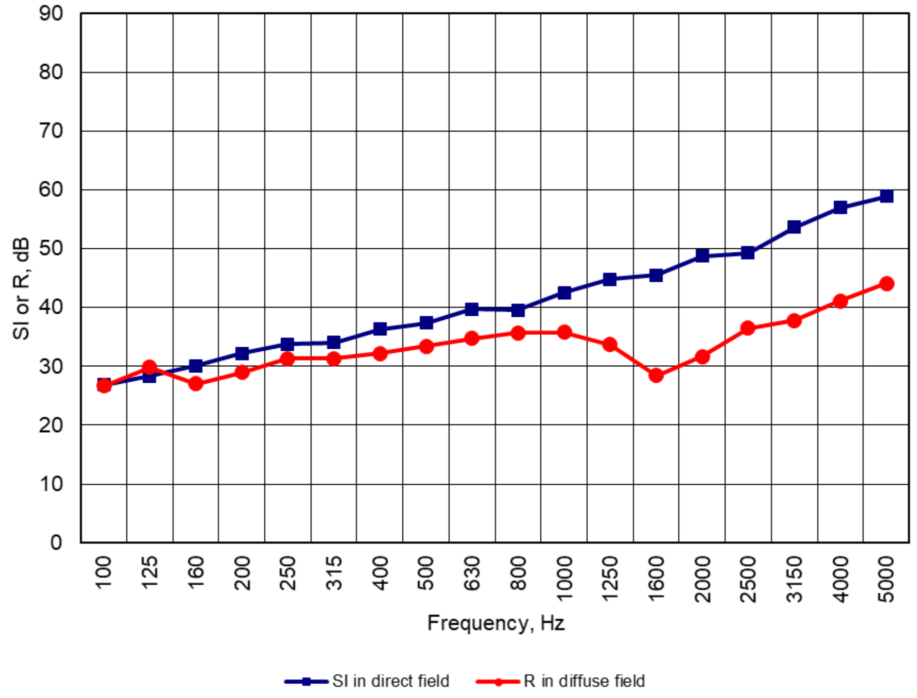


Figure 52: *Sound insulation index SI* measured in a *direct sound field* and *sound reduction index R* measured in a *diffuse sound field* for a NB made of polymethyl methacrylate sheets, thickness 20 mm (adapted from [35])

3.4 Intrinsic sound diffraction

The *noise reduction* obtained by *sound diffraction* of a NB depends on many parameters, as explained in Section *2 Extrinsic performances of Noise Barriers*: among them are the shape and materials at the top edge of the NB which do not depend on the environment where the NB is placed, i.e.: they can be considered *intrinsic* to the NB. Thus, the *diffraction effect* specifically due to the shape and materials of the NB top edge is an *intrinsic characteristic.*

This is particularly relevant when there is the need to increase the *noise reduction* of a NB without increasing its height. For example, this happens in new design process when the NB height is limited due to aesthetic reasons, or when retrofitting an old NB whose supports cannot withstand a further increase in height. In these cases, a *device* is added on the top of the NB, having specifically designed shape and materials, to contribute to sound attenuation acting primarily on the diffracted sound field: these devices are called *added devices*.

EN 1793-4 [37] describes a test method for determining the *intrinsic* characteristics of *sound diffraction* of such added devices: this method prescribes measurements of the *sound pressure level* at several *reference points* near the top of a NB, the effectiveness being calculated as the difference between the measured values with and without the *added devices* installed, correcting for any change in height. In fact, the method gives the *acoustic benefit* over a simple barrier of the same height; however, in practice the *added device* can raise the height, and this could provide *additional screening* depending on the source and receiver positions.

Figure 53 shows practical arrangement of measurements according to EN 1793-4.

Figure 53: *Sound diffraction index* measurements according to EN 1793-4 on a prototype *added device*

4 Conclusions

The present report presents, in a compact and easy-to-read format, the physical phenomena that rule the *noise reduction* performance of Noise Barriers (NB) (*extrinsic characteristics* / performances), as well as the *intrinsic characteristics* of the products used to build-up NB.

Many factors need to be considered in the detail design of NB, but a simple "gold rule" applies:

whatever the situation, physics definitely rules the NB effectiveness.

The *noise reduction* achieved by NB in their environment is characterized by the Insertion Loss (IL), i.e.: the difference in *sound level* at a receiver location with and without the presence of the NB. This is an *extrinsic* characteristic that involves a lot of factors, all influencing the final NB effective performance. All these factors have been systematically introduced, including some having a greater importance while being too often neglected, such as *multiple reflections* of the *sound waves* between the NB and the body of the vehicles, or the relevance of *sound transmission* through the NB in the IL, all of that not forgetting the *time dimension* of traffic noise.

It can be concluded that:

- *Sound-absorbing* NB are definitively the best ones to dissipate the incident energy as soon as it hits the NB surface. They are even more efficient to reduce noise where *multiple reflections* occur (*parallel surfaces* facing each other).
- *Airborne sound insulation* of NB is of primary importance, because the noise perceived within the protected area (also called *shadow zone*) of the NB always correspond to the sum of the energy diffracted at its top and the energy transmitted through it.
- The greater the *sound reduction* by *sound diffraction*, the greater the performance to reduce *airborne sound transmission* must be. However, over a certain minimum directly linked to the *sound reduction* by *pure sound diffraction* of the NB, higher values are useless as they will give no further total performance.
- The effect of *sound attenuation* at the top edge of NB is due to *sound diffraction*, ruled by the Huygens-Fresnel principle.
- Road vehicles and trains do have specific *sound directivity*, which affects how the energy is reduced by NB.
- Wind and temperature gradients play on the *sound speed* and mainly influence the *long-range sound propagation*: their effect have to be considered when designing NB.

Thus, IL is an *extrinsic* characteristic of NB that involves a lot of factors pertaining both to the NB and their entire environment.

On the other hand, NB do have *intrinsic* characteristics, inherent to the products used to build up NB: they are very important because they also condition the IL as far as *sound reflection*, *airborne sound transmission* and *sound diffraction* are concerned.

In order to understand and to control all these effects, when designing the best *traffic noise mitigation*, it should be kept in mind that ***traffic noise* is a complete 5 dimensions phenomenon (x, y, z, t, f)**.

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CEDR TRANSNATIONAL ROAD RESEARCH PROGRAMME 2018

SOPRANOISE

T5.3 State of art on the today's NB use within the EU Market

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1 Introduction

Whether used for protecting against road or railway noise, Noise Barriers (NB) have been widely used in the EU since the early seventies and even earlier. Since then, huge progress has been achieved; in particular, one can consider:

- Improved modelling, leading to improved designs and implementation;
- Improved characterization of performance (whether the acoustic or the non-acoustic characteristics);
- Framework of standards (CEN standards started early 1990s) allowing fair comparison of the manufactured products used;
- Improved / appropriate tender specifications and controls at the installation and / or during the NB lifetime.

All those improvements help all stakeholders to optimize the performance of NB during their whole life cycle.

This part of the SOPRANOISE research aims to summarize the State Of the Art (SOA) about the current use of NB within the EU market: this survey is based on a questionnaire, which has been circulated to the relevant road and railway authorities, as well as to the relevant stakeholders involved in the NB implementation and maintenance process.

2 Questionnaire

As this questionnaire was the second one circulated by the SOPRANOISE consortium (the first one targeting a SOA on the assessment / control / maintenance / behaviour of NB during their lifetime), this questionnaire has been named "2nd list of Questions" / "LOQ2".

The LOQ2 questionnaire contains the following seven questions:

a. *Which **kind of noise barrier's types are currently used** in your country or on the road / rail network you are managing?*

b. *Which are the **specifications and requirements** in case of a call for tenders?*

c. *Which **type of contract awarding process** is currently used for noise barriers? (e.g. performance, costs, delays, installation concerns, safety concerns, durability concerns, mixt of…)?*

d. ***Do you control the installation process of new noise barriers**?*

e. ***How are noise barriers maintained over the time**?*

f. ***Who is responsible for the maintenance**?*

g. *How do you manage the **end-of-life phase** of a noise barrier (**decommissioning**)?*

To obtain the most relevant and representative replies, the questionnaire has been circulated: through the CEDR network, the CEN TC226 WG6 (road) network, the CEN TC256 SC1 WG40 (railway) network and through the ERF network (manufacturers and contractors association).

3 Replies to the questionnaire

The questionnaire has been circulated on the 29th of October 2020 and, up to the 12th of January 2021, a total of 32 replies has been received from 18 different countries with different stakeholders (see details in Chapter 4, Table 1):

18	countries
21	road authorities (national, regional, local) (ROA)
6	railway authorities (RAI)
3	national associations of NB manufacturers / NB contractors (MAA)
2	NB manufacturers (MAN)

The number of responses collected can be considered as very significant and representative for the current use of NB in the European market, as several different stakeholders including manufacturers, national and local road and railway authorities from several European countries replied to the questionnaire.

3.1 *Quality of the replies*

Some words about the replies: as expected, some replies were very detailed, while some others were very short, some used other units than the commonly used m², some refer to external documents for which the links could be corrupted, so it was quite difficult to strictly compare the replies between each other. Despite this, we can consider this collection of information as a very good summary of what is the current situation, as of today, by a representative sample of different stakeholders within the European market.

3.2 *Assembling the replies*

As mentioned hereabove, the replies are numerous and diverse: to ease their reading and analysis, all the replies have been compiled into a single XLS "database" file. A copy of it is presented in Annex 6 under the form of 7 groups of A3 sheets, one for each question (see Figure 1; a more convenient / enlarged view of this figure is also presented in Annex 6.8):

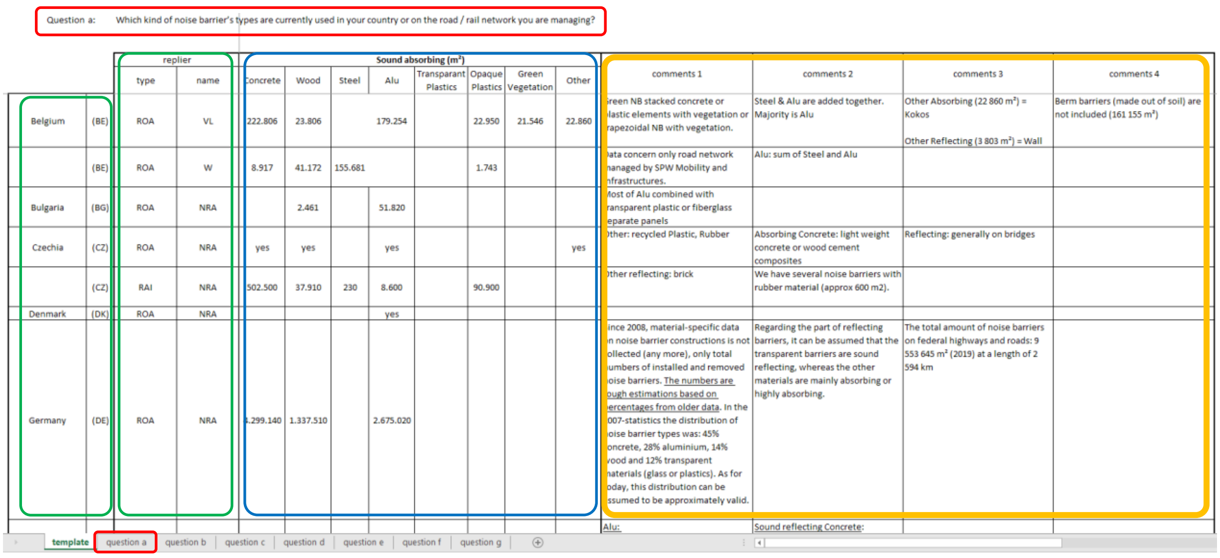

Figure 1: the LOQ2 database, each sheet summarising the replies to the corresponding question.

Each separate sheet presents the replies to the corresponding question, with their 4 first columns identifying the replier: its country, its country code, its type of stakeholder[1] and, if specified, its name / region…, **the 4 last columns presenting comments**, and the columns *in between* presenting the replies from each replier to the specified question / characteristic (as detailed in the following chapters 3.2.1. to 3.2.7).

3.2.1 Question a

Which kind of noise barrier's types are currently used in your country or on the road / rail network you are managing?

(m²)	*Concrete*	*Wood*	*Steel*	*Alu*	*Transparent Plastics*	*Opaque Plastics*	*Other (specify)*
Sound absorbing							
Sound reflecting							

Facing the diversity of the replies, 3 groups of similar columns have been integrated: one for *sound absorbing NB*, one for *sound reflecting NB*, and last one for *other (?)* due to some answers. The detailed information for each group of columns is the following:

Sound absorbing (m²)							
Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other

3.2.2 Question b

Which are the specifications and requirements in case of call for tenders?
If official documents exist please attach, otherwise please specify the relevant specifications required:

	DL_{RI} (dB)	*DL_{SI} (dB)*	*Safety*	*Durability*	*Sustainability*	*# years warranty*	*Other (specify)*
Requirement 1 usage							
Requirement 2 usage							
Requirement 3 usage							

In the same way than for question a, the replies are presented under 3 groups of similar columns, one per usage. As many repliers referred to previous DL_{α} and DL_R, those have been added in the list of parameters. The detailed information for each group of columns is:

Requirement 1										
DL_{RI} (dB)	DL_{SI} (dB)			DL_{α} (dB)	DL_R (dB)	Safety	Durability	Sustainability	# years warranty	Other (specify)
	element $DL_{SI,E}$	post $DL_{SI,P}$	both global							

[1] ROAD for road authorities, RAI for railways authorities, MAA for manufacturer associations and MAN for manufacturers

3.2.3 Question c

Which type of contract awarding process is currently used for noise barriers? (e.g. performance, costs, delays, installation concerns, safety concerns, durability concerns, mixt of…)? Even if roughly explained this indication is important for the EU market stakeholders.

Following the replies got, one single group of columns is presented as being what we named *Contract awarding process - Key parameters.* The detailed information for this group of columns is:

Contract awarding process - Key parameters									
Performance	Costs	Delays	Installation	Safety	Durability	Sustainability	# years warranty	Maintenance	Other (specify)

3.2.4 Question d

Do you control the installation process of new noise barriers?
If yes: what do you control?

In a similar way than for question c, one single group of columns is presented as being what we named *Control the installation process - Key parameters*: it is very similar to question c., with a reduced list of parameters.
The detailed information for this group of columns is:

Control the installation process - Key parameters				
Performance	Delays	Installation	Safety	Other (specify)

3.2.5 Question e

How are noise barriers maintained over the time?

For this question, and again following the replies got, one single group of columns is presented as being what we named *Barrier maintenance - Key aspects*. The detailed information for this group of columns is:

Barrier maintenance - Key aspects					
Performance acoustical	Structural Stability	Elements (settings)	Visual aspects	Safety	Other (specify)

3.2.6 Question f

Who is responsible for the maintenance?

Here, it was much simpler to integrate the replies. It has been done as follows:

Barrier maintenance - Actors			
Contracting Authority	Contractor	Manufacturer	Other (specify)

3.2.7 Question g

How do you manage the end-of-life phase of a noise barrier (decommissioning)?
If possible, please provide examples and relevant documents

For this question, for the ensemble of replies got, the answers were just dichotomic (Yes or No), but interesting comments help to understand how the repliers are considering the topic.

4 Analysis

The database built from the replies to the LOQ2 is very large and detailed (see Annex 6).

The following analysis aims to visualise and present those data in an even more synthetic way, without any judgement about the replies, nor any conclusion: it is a presentation of the facts that have been assembled.

Some countries have been represented by several stakeholders (national, regional, local, road and railways authorities, associations of manufacturers and single manufacturers): Table 1 shows a detailed list of all the stakeholders having replied to the LOQ2 (some missing names have been tentatively named). As an example, the 2 replies from Belgium came from Flanders (VL) and from Wallonia (W). The replies from Italy were numerous, but the road authorities presented here did not reply directly, while we got their relevant tender requirements. In Finland and Norway, the same national authority manages both the road and the railway networks.

Table 1: list of the different stakeholders having replied.

		replier	
		type	name
Belgium	(BE)	ROA	VL
	(BE)	ROA	W
Bulgaria	(BG)	ROA	NRA
Czechia	(CZ)	ROA	NRA
	(CZ)	RAI	NRA
Denmark	(DK)	ROA	NRA
Germany	(DE)	ROA	NRA
Ireland	(IE)	ROA	NRA
Spain	(ES)	RAI	ADIF
	(ES)	MAA	ANIPAR
France	(FR)	ROA	NRA
	(FR)	MAA	SER
	(FR)	RAI	SNCF
Italy	(IT)	ROA	AUTOSTRADE
	(IT)	ROA	A. BRENNERO
	(IT)	ROA	ATIVA
	(IT)	ROA	A.VENETE
	(IT)	MAA	UNICMI
	(IT)	MAN	CIRAMBIENTE
Hungary	(HU)	ROA	NRA
Netherlands	(NL)	ROA	NRA
Austria	(AT)	ROA	ASFINAG
	(AT)	RAI	OEBB
	(AT)	MAN	FORSTER
Poland	(PL)	ROA	NRA
Finland	(FI)	ROA	?
	(FI)	RAI	?
Sweden	(SE)	ROA	TRV
	(SE)	RAI	TRV
Iceland	(IS)	ROA	NRA?
Norway	(NO)	ROA	NRA
United Kingdom	(UK)	ROA	England Highways

The following analysis is based on the numerous data received and assembled.

All the replies and their attached information are saved under electronic files and are thus available for any further request of detailed information.

4.1 Question a: types of NB used

The detailed (initial) results are presented in Annex 6.1.

The replies to question *a* are very interesting for information on how each country / region / stakeholder is considering the NB. However, even by doing statistics on how many m² of each type of NB a replier is using, it is difficult to establish trends *between* different countries / regions to conclude on a *common* trend within the *entire EU market*. This is because interpretation is definitely not in numbers: every single country has its own way to implement the different types of barriers. Every single country has its own approach, logically affected by local considerations as: climate, local manufacturers / industries, budget, "green" approach, and even their own way of life …

It should be noted that, instead of stating the total amount of existing NB on their market in m², some repliers placed only "yes", Finland stated the length in Km, and France stated the "annual" averages over 10 years: the repliers having just stated "yes" or nothing have been taken away from this analysis. For France, we made a rough hypothesis by multiplying the "annual" averages quantities by a factor 40, considering that the use of NB started in the early 70s. For Finland, we made a rough hypothesis by multiplying the numbers by a factor 3, considering that 3 m could be an average NB height in Finland. After having "harmonised" the quantities (total surfaces on NB in m²), we can make just a tentative analysis: Table 2 summarises the numbers for the *sound absorbing NB*, Table 3 for the *sound reflecting NB*, and Table 4 for the *"other?" (undefined) NB*.

Table 2: replies on the installed *sound absorbing NB*

		replier		Sound absorbing (m²)								
		type	name	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Total
Belgium	(BE)	ROA	VL	222.806	23.806		179.254		22.950	21.546	22.860	493.222
				45%	5%		36%		5%	4%	5%	100%
	(BE)	ROA	W	8.917	41.172	155.681			1.743			207.514
				4%	20%	75%			1%			100%
Bulgaria	(BG)	ROA	NRA		2.461		51.820					54.281
					5%		95%					100%
Czechia	(CZ)	RAI	NRA	502.500	37.910	230	8.600		90.900			640.140
				78%	6%	0%	1%		14%			100%
Germany	(DE)	ROA	NRA	4.299.140	1.337.510		2.675.020					8.311.670
				52%	16%		32%					100%
Ireland	(IE)	ROA	NRA		24.775		1.136					25.911
					96%		4%					100%
Spain	(ES)	MAA	ANIPAR	175.000	20.000	250.000	75.000			20.000		540.000
				32%	4%	46%	14%			4%		100%
France	(FR)	MAA	SER	2.112.000	896.000	224.000	40.000		40.000		40.000	3.352.000
				63%	27%	7%	1%		1%		1%	100%
Italy	(IT)	MAA	UNICMI	20.000	20.000	30.000	90.000		5.000			165.000
				12%	12%	18%	55%		3%			100%
Hungary	(HU)	ROA	NRA	272.699	128.011	3.781			956		2.864	408.311
				67%	31%	1%			0%		1%	100%
Netherlands	(NL)	ROA	NRA	434.000							1.546.000	1.980.000
				22%							78%	100%
Austria	(AT)	ROA	ASFINAG	108.000	9.000		54.000	9.000				180.000
				60%	5%		30%	5%				100%
Finland	(FI)	ROA	?	738.000	138.000	96.000	30.000	6.000		771.000	33.000	1.812.000
				41%	8%	5%	2%	0%		43%	2%	100%
Iceland	(IS)	ROA	NRA?								1.325	1.325
											100%	100%
Norway	(NO)	ROA	NRA	2.500	490.400	2.200			7.700	1.300	166.424	670.524
				0%	73%	0%			1%	0%	25%	100%
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%

The *sound absorbing NB* market is quite broad: about 19 million of m², even if limited to those countries having replied. One can notice how diverse the approaches could be: some countries use more *concrete NB* (VL, CZ, FR, AT, FI), some others *wood NB* (IE, NO), some others *metallic (steel / aluminium) NB* (ES, W). In total, *concrete NB* are predominant, then *metallic NB (steel / aluminium)*, then *wood NB*. The Netherlands state 1,5 million m² of *"other" NB*, while Austria and Finland stated using some *transparent* plastics *NB* in this *sound absorbing NB* category.

Table 3: : replies on the installed *sound reflecting NB.*

		replier		Sound reflecting (m²)								
		type	name	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Total
Belgium	(BE)	ROA	VL				7.171	6.675	22.860		3.803	40.509
							18%	16%	56%		9%	100%
	(BE)	ROA	W					382				382
								100%				100%
Bulgaria	(BG)	ROA	NRA									
Czechia	(CZ)	RAI	NRA	70.800				13.620			2.200	86.620
				82%				16%			3%	100%
Germany	(DE)	ROA	NRA					1.146.437				1.146.437
								100%				100%
Ireland	(IE)	ROA	NRA	50.651	116.713		2.536	218	2.839			172.958
				29%	67%		1%	0%	2%			100%
Spain	(ES)	MAA	ANIPAR	50.000				75.000			5.000	130.000
				38%				58%			4%	100%
France	(FR)	MAA	SER	528.000	224.000	56.000		240.000				1.048.000
				50%	21%	5%		23%				100%
Italy	(IT)	MAA	UNICMI	20.000	2.000			70.000			30.000	122.000
				16%	2%			57%			25%	100%
Hungary	(HU)	ROA	NRA	15.904	894	1.455		9.245	222		3.301	31.021
				51%	3%	5%		30%	1%		11%	100%
Netherlands	(NL)	ROA	NRA	101.000	160.000			828.000	52.000			1.141.000
				9%	14%			73%	5%			100%
Austria	(AT)	ROA	ASFINAG									
Finland	(FI)	ROA	?									
Iceland	(IS)	ROA	NRA?	830	13.796			1.660		30.906	4.880	52.072
				2%	26%			3%		59%	9%	100%
Norway	(NO)	ROA	NRA	5.800	137.900	2.200		2.700			101.675	250.275
				2%	55%	1%		1%			41%	100%
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%

Table 4: replies on the *"other?" (undefined) NB.*

		replier		Other? (m²)								
		type	name	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Total
Belgium	(BE)	ROA	VL									
	(BE)	ROA	W									
Bulgaria	(BG)	ROA	NRA									
Czechia	(CZ)	RAI	NRA									
Germany	(DE)	ROA	NRA									
Ireland	(IE)	ROA	NRA		4.514					14.072	279	18.865
					24%					75%	1%	100%
Spain	(ES)	MAA	ANIPAR									
France	(FR)	MAA	SER									
Italy	(IT)	MAA	UNICMI									
Hungary	(HU)	ROA	NRA	8.162	100.628			2.487	609		3.003	114.889
				7%	88%			2%	1%		3%	100%
Netherlands	(NL)	ROA	NRA			274.000					142.000	416.000
						66%					34%	100%
Austria	(AT)	ROA	ASFINAG									
Finland	(FI)	ROA	?									
Iceland	(IS)	ROA	NRA?									
Norway	(NO)	ROA	NRA	8.600	980.100	20.300		8.200	2.900	4.700	149.400	1.174.200
				1%	83%	2%		1%	0%	0%	13%	100%
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%

Analysis of Table 3:

Even if about 4 times lower than the *sound absorbing NB* market, the *sound reflecting NB* market is important: about 4 million of m², even if limited to those countries having replied. Here, logically, the predominant *sound reflecting NB* are the *transparent plastics* ones, then come the *concrete NB* and the *wood NB*, the other categories being negligible. Austria, Bulgaria and Finland stated no *sound reflecting NB.*

Analysis of Table 4:

Only 4 countries have stated "other?" (undefined) NB: Ireland, Hungary, the Netherlands and Norway. This category is a bit of a catch-all and, used as this, can possibly bias the comparison with the other categories, while also unbalancing the other categories.

A more attentive look at the comments partly explains what about:

Ireland: those correspond to Wooden Screens that (could?) have some acoustic properties, but also earth berms (thus not true *NB products*) as well as *NB* with no further accessible data.

Hungary: those mainly correspond *NB* with incomplete data.

The Netherlands: mainly earth berms, while "others" in the *sound reflecting NB* could be earth berms topped with NB.

Norway: a quite important market with 2,1 millions of m², 32% of those being *sound absorbing,* 12% *sound reflecting and …* 56% stated as "*other type"* (98% of those *"other type"* NB are made of wood).

Analysis of the 3 tables:

Table 5 summarises the total amount of NB divided in *sound absorbing*, *sound reflecting* and *"other"* categories: the *sound absorbing NB* effectively represents 76% of the data compiled here, the *sound reflecting* ones represents 17%, while the "*others*" represent 7%: this is a very interesting finding on the trends on the NB European market.

Table 5: 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		

Beyond those statistics, Question *a* contains very interesting additional information, especially to properly contextualize the replies to the following questions: for these questions, the analysis will be quite different.

4.2 *Question b: tender specifications / requirements*

The detailed (initial) results are presented in Annex 6.2. Those initial results respect the original replies as they have been received. However, some mistakes / misplacements / misunderstandings have been discovered in those replies: the following analysis is based on the “guessed” correct data corresponding to the relevant characteristics.
The reader has always the possibility to read / use the complete (initial) results, the most valuable information being the comments that are impossible to summarise here.

Important preliminary finding:

While the LOQ2 questionnaire clearly asked for the DL_{RI} (following EN 1793-5) and DL_{SI} (following EN 1793-6) values referred in their requirements, many repliers still respectively refer to DL_{α} (following EN 1793-1, 21 repliers) and DL_{R} (following EN 1793-2, 22 repliers), while those methods are now restricted to diffuse sound field conditions, thus not applicable to *free standing NB*. To document the numerous requirements still using DL_{α} and $DL_{R,}$ the corresponding replies have also been presented. Possible confusion between the values given for DL_{RI} and those from DL_{α} could probably explain some quite high values required for DL_{RI}.

4.2.1 Sound absorption characteristics

DL_{RI} (sound reflection under direct sound field conditions)

The following analysis is limited to the repliers considering DL_{RI}, while the other ones referring to DL_{α} and other performance indices for sound absorption are presented later in this chapter: Table 6 summarises the replies on DL_{RI}.

Table 6: replies considering DL_{RI}.

		replier		usage	DL_{RI} (dB)	usage	DL_{RI} (dB)	usage	DL_{RI} (dB)
		type	name						
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				

One can notice that some repliers are using a single requirement: for those countries, the most common value is 5 dB, a value that is easily reached by the majority of the EU NB. Germany defines 3 different usages (*reflecting*, *reducing reflections*, *highly reducing reflections*) with respective requirements of 0.5 , 3.0 and 5.0 dB), the 5 dB being in accordance to what the other repliers do consider as the minimal value for all the NB, while the other repliers do not require any DL_{RI} for *non absorbing NB*. Spain, as well as different Italian highways authorities specify different values following the type of the barrier, with values from 2 to 8 dB. Finally, SNCF is the only one requiring values starting from 8 up to 11 dB, what is very difficult to reach by the existing EU NB as we already know that even 8 dB is rather challenging to reach.

DL_{α} (sound absorption under diffuse sound field conditions) and other performance indices for *sound absorption*:

This analysis is limited to the repliers considering DL_{α} and other performance indices for *sound absorption*: Table 7 summarises those replies.

Table 7: replies considering DL_{α} and other performance indices for *sound absorption.*

		replier		usage	DL_{α} (dB)	usage	DL_{α} (dB)	usage	DL_{α} (dB)
		type	name						
Belgium	(BE)	ROA	VL	all	10				
	(BE)	ROA	W	all	10				
Czechia	(CZ)	ROA	NRA	all	08-15				
Denmark	(DK)	ROA	NRA	all	A3 (8-11)				
Ireland	(IE)	ROA	NRA	all	A3 (8-11)				
Spain	(ES)	MAA	ANIPAR	Metallic panels (Timber) panels	≥ 15	Concrete panels	≥ 12	Transparent panels	-
Italy	(IT)	ROA	AUTOSTRADE	traditional NB	> 11	integrated NB	> 7	double sided integrated NB	> 7
	(IT)			mix (**) traditional NB transparent < 30%	> 7	mix (***) traditional NB transparent > 30%	-		
	(IT)	ROA	A. BRENNERO	concrete	5	metal	15	metal double-sided	13
	(IT)			transparent absorbent	5	transparent	-	wood	11
	(IT)	ROA	ATIVA	Metallic panels	A4 > 11	concrete, wood, plastic	A3 (8-11)	transparent	-
Netherlands	(NL)	ROA	NRA	all	8	all	10	all	12
Austria	(AT)	ROA	ASFINAG	all	8				
	(AT)	RAI	OEBB	V < 160 km/h	8	V 160-250 km/h	8		
Poland	(PL)	ROA	NRA	sound-absorbing non-transparent	10	transparent	-		
Finland	(FI)	ROA	?	all	8				
	(FI)	RAI	?		> 8				
Sweden	(SE)	ROA	TRV	all	8				
Sweden	(SE)	RAI	TRV	all	8				
Iceland	(IS)	ROA	NRA?	1		2	A3		
United Kingdom	(UK)	ROA	England Highways	all	single < 4 parallel 8-11				

One can notice that many repliers are still writing their requirements on *sound absorption* without referring to the EN 1793-5, but to part 1 instead, some repliers even referring to *both* parts 1 & 5. The most common value here is 8 dB, a value easily reached by the majority of the EU *sound absorbing NB*.

The Netherlands have 3 categories (8, 10 and 12 dB) that could logically be used for more requiring situations; United Kingdom (in facts: only England has replied) uses the same logic with 2 categories, but with lower values.

Spain, as well as different Italian highways authorities specify different values following the type of barrier, but not following their usage, with values from 5 to 15 dB.

The logic for the transparent elements is respected as no performance is required here, as these materials have usually no absorption properties.

4.2.2 7Airborne sound insulation characteristics

DL_{SI} (airborne sound insulation under direct sound field conditions):

The present analysis is limited to the repliers considering DL_{SI}, while the other ones referring to DL_R and other performance indices for *airborne sound insulation* are presented later in this chapter: Table 8 summarises the replies on DL_{SI}.

Table 8: replies considering DL_{SI}.

		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									

One can notice that some repliers are using a single requirement for all their NB: for those, the minimal values range from 24 to 28 dB.

Bulgaria specifies 3 categories progressively more requiring, from 24 to 30 dB.

Belgium specifies different values for the acoustic element (28 dB) and for post (26 dB), while other countries like France are specifying only one global value (e.g. 28 dB for roads and 24 dB for railways).

Spain specifies 3 "categories": metallic and (timber) panels, concrete panels and transparent panels, each one keeping the same requirements (34, 30, 32 dB, respectively for the acoustic element, for post and for global value).

Different Italian highways authorities specify different values following the type of the barrier and separating the performance evaluation of acoustic element and post, with values from 25 to 34 dB.

DL_R (airborne sound insulation under diffuse sound field conditions) and other performance indices for *airborne sound insulation*:

This analysis is limited to the repliers considering DL_R and other performance indices for *airborne sound insulation*: Table 9 summarises those replies.

For those replies on DL_R, 25 dB is the most frequently requested requirement.

Czech Republic specifies a range between 15 and 34 dB.

The Highways of Brennero (IT) require 33 dB for concrete NB.

The Netherlands demand on DL_R = IL + 10 +3 (safety margin for decrease), the minimum value being 25.

Furthermore, one can notice that few repliers use their own way: Poland refers to R_w 20 dB and 29 dB, Norway specifies "it will not leak", and England specifies "IL+15".

Table 9: replies considering DL_R and other performance indices for *airborne sound insulation.*

		replier		usage	DL_R (dB)	usage	DL_R (dB)	usage	DL_R (dB)
		type	name						
Belgium	(BE)	ROA	VL	all	25				
	(BE)	ROA	W	all	25				
Czechia	(CZ)	ROA	NRA	all	15-34				
Denmark	(DK)	ROA	NRA	all	B3 > 24				
Germany	(DE)	ROA	NRA	all	> 24				
Ireland	(IE)	ROA	NRA	all	B3 > 24				
Spain	(ES)	MAA	ANIPAR	all	≥ 27				
Italy	(IT)	ROA	AUTOSTRADE	all	> 24				
	(IT)	ROA	A. BRENNERO	concrete	33	metal	26	metal double-sided	26
	(IT)			transparent absorbent	26	transparent	26	wood	26
	(IT)	ROA	ATIVA	all	B3 > 24				
Netherlands	(NL)	ROA	NRA	all	≥ 25				
Austria	(AT)	ROA	ASFINAG	all	24				
	(AT)	RAI	OEBB	all	27				
Poland	(PL)	ROA	NRA	sound-absorbing non-transparent	R_w 20 dB	transparent	R_w 29 dB		
Finland	(FI)	ROA	?	all	25				
	(FI)	RAI	?		> 24				
Sweden	(SE)	ROA	TRV	all	25				
Sweden	(SE)	RAI	TRV	all	25				
Iceland	(IS)	ROA	NRA?	all	B3				
Norway	(NO)	ROA	NRA	all	It will not leak sound				
United Kingdom	(UK)	ROA	England Highways	all	IL + 15				

4.2.3 Safety

The Safety concern is very important: this is stated by 15 repliers, 6 of which just stating “yes”, while the others specifying the safety concern or, even better, the referred standard used. Many additional and interesting information are provided in the comments as detailed in Annex 6.2.

Table 10 presents the list of replies about safety.

Table 10: replies about safety.

		replier		usage		usage	
		type	name		Safety		Safety
Belgium	(BE)	ROA	VL	all	NBN EN 1794-1 (strength); NBN EN 1794-2 (environmental protection); NBN EN 1991-1 (wind); NBN EN 1794-1 (safety); EN 13501-1(fire)		
	(BE)	ROA	W	all	NBN EN 1794-1 (strength, wind, stones, impact safety); NBN EN 1794-2 (fire, falling débris, light reflexion)		
Germany	(DE)	ROA	NRA	all	Yes		
Ireland	(IE)	ROA	NRA	all	1791-1 1794-2		
France	(FR)	RAI	SNCF	all	Ballast peak resistance Snow loads and wind loads depending of the area		
Hungary	(HU)	ROA	NRA	all	Yes		
Netherlands	(NL)	ROA	NRA	all	Construction	all	Road traffic forward visibility
				all	Falling debris NEN-EN-1794-2	all	(sun) light reflection
				glass pannels	Impact of stones NEN-EN-1791-1 Annex C	all	Exit doors every 400 meters
Austria	(AT)	RAI	OEBB	V < 160 km/h	RVE 04.01.01	V 160-250 km/h	RVE 04.01.01
Finland	(FI)	ROA	?	all	Yes		
	(FI)	RAI	?		Yes		
Sweden	(SE)	ROA	TRV	all	Yes		
	(SE)	RAI	TRV	all	Yes		
Iceland	(IS)	ROA	NRA?	1	Glass EN 1794-2 ISO 527 DIN 5036	2	Glass EN 1794-2
Norway	(NO)	ROA	NRA	all	Safe against climbing Fundations Wind		
United Kingdom	(UK)	ROA	England Highways	all	brush fire, shatter (wilful damage) properties, light reflectivity;		

Flanders and Wallonia refer to specific parts of the EN 1794-1 & 2, and to EN 13501.

Ireland also refers to both EN 1794-1 and 2, the Netherlands to some parts of those standards.

England lists the concerns that are, in facts, part of EN 1794-2.

The Netherlands refers to construction, forward visibility and (sun) light reflection, falling debris, as well as to EN1794-1 for glass panels.

Both SNCF (French railways) and OEBB (Austrian railways) refer to their own safety concerns and methods.

4.2.4 Durability, Sustainability, Warranty

In this chapter, we regroup the replies received relating to durability, sustainability and warranty:
Many additional and interesting information are provided in the corresponding comments detailed in Annex 6.2.

Table 11 presents the list of replies about those concerns. Many additional and interesting information are provided in the corresponding comments detailed in Annex 6.2.

Table 11: replies about durability, sustainability and warranty.

		replier		usage				usage			
		type	name		Durability	Sustainability	# years warranty		Durability	Sustainability	# years warranty
Belgium	(BE)	ROA	VL	all			3				
	(BE)	ROA	W	all	Not in general *Specific cases* *NBN EN 14389-1* *NBN EN 14389-2*		5				
Bulgaria	(BG)	ROA	NRA	1				2			
Czechia	(CZ)	ROA	NRA	all	30 Years		25				
	(CZ)	RAI	NRA	all	yes						
Denmark	(DK)	ROA	NRA	all	decrease absorption ≤3 dB insulation ≤2 dB	CO2, demolition, reusability	25				
Germany	(DE)	ROA	NRA	all	Yes	Yes	5				
Ireland	(IE)	ROA	NRA	all	Yes	No	30				
Spain	(ES)	MAA	ANIPAR	Metallic panels (Timber) panels	15 Years (Railways)		See Comments	Concrete panels	30 Years (Railways)		See Comments
				Transparent panels	15 Years (Railways)		See Comments				
France	(FR)	ROA	NRA	all			30-50				
	(FR)	RAI	SNCF	all	In theory an engineering structure located near the track should be dimensioned for 100 years	We choose materials to ensure the long term sustainability of the noise barrier	30				
Italy	(IT)	MAA	UNICMI	Metallic panels (Timber) panels			20 (10)	Concrete panels and transparent panels			20
Hungary	(HU)	ROA	NRA	all	10 Years		3 Years generally				
Netherlands	(NL)	ROA	NRA	all	50 yr Posts 30 yr Panels	MKI value tbd	7	all	Glass panels Impact of stones NEN-EN-1791-1 Annex C	Panels must be detachable	
	(AT)	RAI	OEBB	V < 160 km/h	RVE 04.01.01	RVE 04.01.01	5	V 160-250 km/h	RVE 04.01.01	RVE 04.01.01	5
	(AT)	MAN	FORSTER	all			5				
Poland	(PL)	ROA	NRA	sound-absorbing non-transparent	25 Years			transparent			
Finland	(FI)	ROA	?	all	Yes	Yes	VAR project and contract				
	(FI)	RAI	?		30 Years	Yes	VAR project and contract				
Sweden	(SE)	ROA	TRV	all	20 Years		2 & 5				
	(SE)	RAI	TRV	all	40 Years		2 & 5				
Iceland	(IS)	ROA	NRA?	1	ISO 527		Glass 25	2			25
Norway	(NO)	ROA	NRA	all			3 or 5 years depending on contract				
United Kingdom	(UK)	ROA	England Highways	all	acoustic: maximum of 0.25 dB loss per year non-acoustic: at least 20 years	aesthetics and sustainability with reference to GG 103					

Durability:

Only Wallonia refers, in special cases, to EN 14389-1 & 2, while many repliers state the amount of years that are considered for durability in a range from 10 years up to 100 years (France / SNCF railways) concerning the structure located near the track.

Denmark and England specify requirements about the degradation of the acoustic characteristics.

Sustainability:

Only 8 repliers have replied about sustainability, 3 of which replying simply 'yes', while each of the others refer to their own and different approach: sustainability is a quite 'new' concern on the EU NB market and progress has still to come.

Warranty:

The range for the numbers of years for the warranty is widespread, from 2 up to 50 years: this could also be confronted to the duration specified in the durability requirements (from 10 to … 100).

4.2.5 Other tender specifications / requirements

Some other less generic requirements are also stated by the repliers: many additional and interesting information are provided in the corresponding comments detailed in Annex 6.2.

Table 12 presents those additional requirements, additional details are provided in the corresponding comments detailed in Annex 6.2.

Table 12: other tender specifications / requirements.

		replier		usage	Other (specify)	usage	Other (specify)
		type	name				
Belgium	(BE)	ROA	VL	all	Declaration of conformity with NBN EN 14388		
	(BE)	ROA	W	all	Declaration of conformity with NBN EN 14388		
Ireland	(IE)	ROA	NRA	all	Yes	refer to CC-SPW-00300	
Hungary	(HU)	ROA	NRA	all	Yes	contractor references (with respect to the size of the noise barrier according to the tender) expert's work experience as project manager (minimum 3 years required)	
Netherlands	(NL)	ROA	NRA	all	Visibility for birds (Transparent panels)	aesthetic design	Landscape and visual impact
Austria	(AT)	RAI	OEBB	V < 160 km/h		V 160-250 km/h	Dynamics RVE 04.01.01
				All elements must be pass the FSV advisory board; an official admission will handed out after the positive approval.			
Finland	(FI)	ROA	?	all	Yes	Design guidelines and requirements for noise barriers along roads and railways are currently under revision. New specifications will be published in 2021.	
	(FI)	RAI	?				
Sweden	(SE)	ROA	TRV	all	Yes		
	(SE)	RAI	TRV	all	Yes		
Iceland	(IS)	ROA	NRA?	all	CE Certificate		
Norway	(NO)	ROA	NRA	all	CO_2 usage		
United Kingdom	(UK)	ROA	England Highways	all	landscape and visual impact		

3 repliers (VL, W and IS) specify CE marking, while the other replies concern mores specific topics shortly stated in table 12 .

4.3 Question c: contract awarding process

In order to have a clear overview of the numerous and diverse replies received, for questions *c* (contract awarding process), *d* (controlling the NB installation process), and *e* (maintenance), series of key parameters / aspects have been defined: each time the parameter / aspect is taken into account, a 'Yes' is placed in the corresponding cell.

When a 'Yes' occurs, explanatory notes are placed in the 4 "comments" columns: stating all those comments does exactly correspond to the detailed sheets presented in Annex 6.3: the only way to read those is thus to directly jump to the corresponding sheets.

The next summaries / tables give quick overviews of the key parameters / aspects taken into account by the different repliers.

In that way, Table 13 lists the replies about the contract awarding process, replier by replier.

Table 13: key parameters taken into account in the contract awarding process.

		replier		**Contract awarding process - Key parameters**									
		type	name	Performance	Costs	Delays	Installation	Safety	Durability	Sustainability	# years warranty	Maintenance	Other (specify)
Belgium	(BE)	ROA	VL	Yes	Yes		Yes		Yes		Yes	Yes	
	(BE)	ROA	W	Yes	Yes						Yes	Yes	
Bulgaria	(BG)	ROA	NRA										
Czechia	(CZ)	ROA	NRA	Yes				Yes	Yes				
	(CZ)	RAI	NRA	Yes	Yes								
Denmark	(DK)	ROA	NRA		Yes					*not yet*			
Germany	(DE)	ROA	NRA	Yes	Yes			Yes	Yes	Yes			
Ireland	(IE)	ROA	NRA	Yes	Yes	Yes	Yes	Yes	Yes (timber)	Yes (timber)			Yes
Spain	(ES)	RAI	ADIF										
	(ES)	MAA	ANIPAR	Yes	Yes								
France	(FR)	ROA	NRA	Yes	Yes	Yes							
	(FR)	MAA	SER	Yes	Yes				Yes				
	(FR)	RAI	SNCF	Yes		Yes	Yes	Yes	Yes	Yes	Yes		
Italy	(IT)	ROA	AUTOSTRADE										
	(IT)	ROA	A. BRENNERO										
	(IT)	ROA	ATIVA										
	(IT)	ROA	A.VENETE										
	(IT)	MAA	UNICMI	Yes	Yes	Yes	Yes	Yes	Yes				
	(IT)	MAN	CIRAMBIENTE	Yes	Yes	Yes	Yes		Yes				
Hungary	(HU)	ROA	NRA	Yes	Yes	Yes	Yes	Yes			Yes		Yes
Netherlands	(NL)	ROA	NRA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Austria	(AT)	ROA	ASFINAG										
	(AT)	RAI	OEBB	Yes			Yes	Yes					
	(AT)	MAN	FORSTER	Yes	Yes								
Poland	(PL)	ROA	NRA										
Finland	(FI)	ROA	?	Yes									
	(FI)	RAI	?	Yes									
Sweden	(SE)	ROA	TRV										
	(SE)	RAI	TRV										
Iceland	(IS)	ROA	NRA?		Yes								Yes
Norway	(NO)	ROA	NRA										
United Kingdom	(UK)	ROA	England Highways										
Total				**17**	**14**	**7**	**7**	**8**	**7**	**3**	**4**	**1**	**4**

The "Total" line shows how many repliers do consider the parameters as important in their contract awarding process: *performances* are the most cited, then *costs*, then *safety*, while *maintenance* is cited just once (Belgium), and sustainability only 3 times.

4.4 Question d: controlling the NB installation process

To the question *d*: "*do you control the installation process of new noise barriers?" and if yes, what do you control?*", a list of the controlled parameters has been defined from the replies: each time the parameter is controlled, a 'Yes' is placed in the corresponding cell.

When a 'Yes' occurs, explanatory notes are placed in the 4 "comments" columns: stating all those comments does exactly correspond to the detailed sheets presented in Annex 6.4.

Table 14 just gives a quick overview of the key parameters controlled by the different repliers.

Table 14: key parameters controlled during the NB installation process.

		replier		**Control the installation process - Key parameters**				
		type	name	Performance	Delays	Installation	Safety	Other (specify)
Belgium	(BE)	ROA	VL	Yes		Yes	Yes	
	(BE)	ROA	W	Yes		Yes	Yes	
Bulgaria	(BG)	ROA	NRA			Yes		
Czechia	(CZ)	ROA	NRA			Yes		
	(CZ)	RAI	NRA			Yes	Yes	Yes
Denmark	(DK)	ROA	NRA			Yes		
Germany	(DE)	ROA	NRA	Yes		Yes		
Ireland	(IE)	ROA	NRA	Yes		Yes		
Spain	(ES)	RAI	ADIF					
	(ES)	MAA	ANIPAR	Yes		Yes		
France	(FR)	ROA	NRA	Yes				
	(FR)	MAA	SER	Yes				
	(FR)	RAI	SNCF	Yes				
Italy	(IT)	ROA	AUTOSTRADE					
	(IT)	ROA	A. BRENNERO					
	(IT)	ROA	ATIVA					
	(IT)	ROA	A.VENETE					
	(IT)	MAA	UNICMI	Yes		Yes		
	(IT)	MAN	CIRAMBIENTE			Yes		
Hungary	(HU)	ROA	NRA	Yes		Yes		Yes
Netherlands	(NL)	ROA	NRA	Yes	Yes	Yes	Yes	Yes
Austria	(AT)	ROA	ASFINAG	Yes				
	(AT)	RAI	OEBB			Yes		
	(AT)	MAN	FORSTER			Yes		
Poland	(PL)	ROA	NRA			Yes		
Finland	(FI)	ROA	?			Yes		
	(FI)	RAI	?			Yes		
Sweden	(SE)	ROA	TRV					
	(SE)	RAI	TRV					
Iceland	(IS)	ROA	NRA?			Yes		
Norway	(NO)	ROA	NRA			Yes		Yes
United Kingdom	(UK)	ROA	England Highways	Yes		Yes		
Total				**12**	**1**	**20**	**3**	**4**

The "Total" line shows how many repliers do consider the parameter as important during the NB installation process: *installation* is the most cited, then *performance*, then *'other'*, then *safety*, while the *delays* are cited just once.

4.5 Question e: maintenance – how?

To the question *e*: "*How are noise barriers maintained over the time?"*, a list of the considered aspects of the maintenance has been defined from the replies: each time an aspect is considered, a 'Yes' is placed in the corresponding cell.

When a 'Yes' occurs, explanatory notes are placed in the 4 "comments" columns: stating all those comments does exactly correspond to the detailed sheets presented in Annex 6.5.

The following Table 15 just gives a quick overview of the key aspects considered for the maintenance of the NB.

Table 15: key aspects considered for the maintenance of the NB

		replier		**Barrier maintenance - Key aspects**					
				Performance acoustical	Structural Stability	Elements (settings)	Visual aspects	Safety	Other (specify)
Belgium	(BE)	ROA	VL		Yes	Yes	Yes	Yes	
	(BE)	ROA	W	Yes	Yes	Yes	Yes	Yes	
Bulgaria	(BG)	ROA	NRA					Yes	
Czechia	(CZ)	ROA	NRA		Yes		Yes	Yes	
	(CZ)	RAI	NRA		Yes		Yes	Yes	
Denmark	(DK)	ROA	NRA				Yes		
Germany	(DE)	ROA	NRA		Yes			Yes	
Ireland	(IE)	ROA	NRA	Yes	Yes	Yes	Yes	Yes	
Spain	(ES)	RAI	ADIF						
	(ES)	MAA	ANIPAR		Yes			Yes	
France	(FR)	ROA	NRA						
	(FR)	MAA	SER						
	(FR)	RAI	SNCF		Yes				
Italy	(IT)	ROA	AUTOSTRADE						
	(IT)	ROA	A. BRENNERO						
	(IT)	ROA	ATIVA						
	(IT)	ROA	A.VENETE						
	(IT)	MAA	UNICMI						
	(IT)	MAN	CIRAMBIENTE		Yes		Yes	Yes	
Hungary	(HU)	ROA	NRA		Yes	Yes	Yes	Yes	Yes
Netherlands	(NL)	ROA	NRA		Yes	Yes		Yes	
Austria	(AT)	ROA	ASFINAG						
	(AT)	RAI	OEBB						
	(AT)	MAN	FORSTER						
Poland	(PL)	ROA	NRA				Yes		
Finland	(FI)	ROA	?		Yes		Yes	Yes	
	(FI)	RAI	?		Yes		Yes	Yes	
Sweden	(SE)	ROA	TRV	Yes	Yes	Yes	Yes	Yes	
	(SE)	RAI	TRV	Yes	Yes	Yes	Yes	Yes	
Iceland	(IS)	ROA	NRA?						
Norway	(NO)	ROA	NRA				Yes		
United Kingdom	(UK)	ROA	England Highways		Yes?	Yes?	Yes		Yes
Total				**4**	**14**	**6**	**14**	**14**	**2**

The "Total" line shows how many repliers do consider the aspect as important for the maintenance of the NB: *structural stability*, *safety* and *visual aspects* are the most considered, while the *performances* are much less considered: all the corresponding explanations are stated in the comments within the detailed sheet in Annex 6.5.

4.6 Question f: maintenance – who?

To the question *f*: "*Who is responsible for the maintenance?*", a list of possible actors has been defined from the replies: each time an actor is involved, a 'Yes' is placed in the corresponding cell. When a 'Yes' occurs, explanatory notes are placed in the 4 "comments" columns: stating all those comments does exactly correspond to the detailed sheets presented in Annex 6.6.

The following Table 16 gives a quick overview of the actors who are responsible for the maintenance of the NB.

Table 16: actors who are responsible for the maintenance of the NB.

		replier		Barrier maintenance - Actors			
		type	name	Contracting Authority	Contractor	Manufacturer	Other (specify)
Belgium	(BE)	ROA	VL	Yes	Yes		
	(BE)	ROA	W	Yes	Yes		
Bulgaria	(BG)	ROA	NRA	Yes			
Czechia	(CZ)	ROA	NRA	Yes			
	(CZ)	RAI	NRA	Yes			
Denmark	(DK)	ROA	NRA	Yes	Yes		
Germany	(DE)	ROA	NRA	Yes			
Ireland	(IE)	ROA	NRA	Yes	Yes		
Spain	(ES)	RAI	ADIF				
	(ES)	MAA	ANIPAR	Yes			
France	(FR)	ROA	NRA	Yes			
	(FR)	MAA	SER	Yes			
	(FR)	RAI	SNCF	Yes			
Italy	(IT)	ROA	AUTOSTRADE				
	(IT)	ROA	A. BRENNERO				
	(IT)	ROA	ATIVA				
	(IT)	ROA	A.VENETE				
	(IT)	MAA	UNICMI	Yes	Yes	Yes	
	(IT)	MAN	CIRAMBIENTE	Yes			
Hungary	(HU)	ROA	NRA	Yes	Yes		
Netherlands	(NL)	ROA	NRA	Yes	Yes		
Austria	(AT)	ROA	ASFINAG	Yes			
	(AT)	RAI	OEBB	Yes			
	(AT)	MAN	FORSTER	Yes			
Poland	(PL)	ROA	NRA	Yes	Yes		
Finland	(FI)	ROA	?	Yes			
	(FI)	RAI	?	Yes			
Sweden	(SE)	ROA	TRV	Yes	Yes		
	(SE)	RAI	TRV	Yes	Yes		
Iceland	(IS)	ROA	NRA?				Yes
Norway	(NO)	ROA	NRA	Yes	Yes		
United Kingdom	(UK)	ROA	England Highways	Yes			
Total				**25**	**10**	**1**	**1**

The contracting authority is the major actor: to some extent, the contractor could be involved for example by a specific part of the contract (limited maintenance period) (VL, DK) or during the warranty period (W, UNICMI), some authorities transfer maintenance to external contractors or private contractors (FI). For UNICMI, manufacturers can sometimes be involved in case of products defects.

4.7 Question g: end of life / decommissioning

For the question *g*: *How do you manage the end-of-life phase of a noise barrier (decommissioning)?*, we have noted if the replier does manage the NB end-of-life (EOL): explanatory notes are placed in the 4 "comments" columns: stating all those comments does exactly correspond to the detailed sheets presented in Annex 6.7.

Table 17 just gives a quick overview of the replies about the NB EOL.

Table 17: do you consider the EOL / decommissioning of NB?

		replier		**Barrier EOL (decommissioning)**
		type	name	considered?
Belgium	(BE)	ROA	VL	No
	(BE)	ROA	W	Yes
Bulgaria	(BG)	ROA	NRA	No
Czechia	(CZ)	ROA	NRA	No
	(CZ)	RAI	NRA	Yes
Denmark	(DK)	ROA	NRA	Yes
Germany	(DE)	ROA	NRA	Yes
Ireland	(IE)	ROA	NRA	No
Spain	(ES)	RAI	ADIF	
	(ES)	MAA	ANIPAR	No
France	(FR)	ROA	NRA	No
	(FR)	MAA	SER	No
	(FR)	RAI	SNCF	No
Italy	(IT)	ROA	AUTOSTRADE	
	(IT)	ROA	A. BRENNERO	
	(IT)	ROA	ATIVA	
	(IT)	ROA	A.VENETE	
	(IT)	MAA	UNICMI	No
	(IT)	MAN	CIRAMBIENTE	No
Hungary	(HU)	ROA	NRA	Yes
Netherlands	(NL)	ROA	NRA	Yes
Austria	(AT)	ROA	ASFINAG	Yes
	(AT)	RAI	OEBB	Yes
	(AT)	MAN	FORSTER	No
Poland	(PL)	ROA	NRA	Yes
Finland	(FI)	ROA	?	Yes
	(FI)	RAI	?	Yes
Sweden	(SE)	ROA	TRV	
	(SE)	RAI	TRV	
Iceland	(IS)	ROA	NRA?	No
Norway	(NO)	ROA	NRA	Yes
United Kingdom	(UK)	ROA	England Highways	Yes

On can notice that, on the 25 replies to this question *g*, 13 said 'Yes' and 12 said 'No', but all of those 25 repliers give explanations that can be usefully read within the corresponding sheet in Annex 6.7.

5 Conclusions

The target of this part of the SOPRANOISE research is to have an overview on how the NB are used in the European market.

A questionnaire with 7 key questions have been circulated to numerous EU NB stakeholders, via the CEDR network, the CEN TC226 WG6 network (roadside noise reducing devices), the CEN TC256 SC1 WG40 (railways noise barriers), and the ERF / ENBF (EU NB manufacturers / contractors).

The present report summarises the 32 replies received and the database that has been assembled from those replies.

The database is informative while possible rough analysis is presented in chapter 4.

The detailed assembly of all the replies is presented as 7 groups of A3 sheets in Annex 6.

Furthermore, an electronic copy of the complete replies will be available.

6 Annexes

The "LOQ2" database

6.1 Question a

		replier		Sound absorbing (m²)								Sound reflecting (m²)								Other? (m²)											
		type	name	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	comments 1	comments 2	comments 3	comments 4
Belgium	(BE)	ROA	VL	222.806	23.806	179.254			22.950	21.546	22.860				7.171	6.675	22.860		3.803									Green NB stacked concrete or plastic elements with vegetation or trapezoidal NB with vegetation.	Steel & Alu are added together. Majority is Alu	Other Absorbing (22 860 m²) = Kokos Other Reflecting (3 803 m²) = Wall	Berm barriers (made out of soil) are not included (161 155 m²)
	(BE)	ROA	W	8.917	41.172	155.681			1.743							382												Data concern only road network managed by SPW Mobility and Infrastructures.	Alu: sum of Steel and Alu		
Bulgaria	(BG)	ROA	NRA		2.461		51.820																					Most of Alu combined with transparent plastic or fiberglass separate panels			
Czechia	(CZ)	ROA	NRA	yes	yes		yes				yes					yes												Other: recycled Plastic, Rubber	Absorbing Concrete: light weight concrete or wood cement composites	Reflecting: generally on bridges	
	(CZ)	RAI	NRA	502.500	37.910	230	8.600		90.900			70.800				13.620			2.200									Other reflecting: brick	We have several noise barriers with rubber material (approx 600 m2).		
Denmark	(DK)	ROA	NRA				yes								yes	yes															
Germany	(DE)	ROA	NRA	4.299.140	1.337.510		2.675.020									1.146.437												Since 2008, material-specific data on noise barrier constructions is not collected (any more), only total numbers of installed and removed noise barriers. <u>The numbers are rough estimations based on percentages from older data</u>. In the 2007-statistics the distribution of noise barrier types was: 45% concrete, 28% aluminium, 14% wood and 12% transparent materials (glass or plastics). As for today, this distribution can be assumed to be approximately valid.	Regarding the part of reflecting barriers, it can be assumed that the transparent barriers are sound reflecting, whereas the other materials are mainly absorbing or highly absorbing.	The total amount of noise barriers on federal highways and roads: 9 553 645 m² (2019) at a length of 2 594 km	
Ireland	(IE)	ROA	NRA		24.775		1.136					50.651	116.713		2.536	218	2.839				4.514					14.072	279	<u>Alu:</u> includes sheet metal bridge parapets	<u>Sound reflecting Concrete</u>: includes Concrete Noise Barrier and Concrete and Stone Walls	<u>[Other] (neither abs. nor refl.)</u>: Wood: Wooden Screen (with some acoustic properties) Green: Bund (earth berm) Other: Unknown (as not accessible)	
Spain	(ES)	RAI	ADIF																												
	(ES)	MAA	ANIPAR	175.000	20.000	250.000	75.000			20.000		50.000				75.000			5.000									Reported quantities based on info given by manufacturers associated in ANIPAR (70% of the total number of noise barrier manufacturers). The information is pending verification with the administrators of the main roads and railways	Sound reflecting concrete is commonly used for the lower part of the noise barrier in contact with the ground and for the standard type of noise barrier on rare occasions.	The volume of transparent plastics (almost exclusively fully solid PMMA; solid polycarbonate has an unrepresentative market share) is mostly related to 15mm and rarely 20mm thick sheets.	<u>ABS</u>: Low absorption <u>green barriers</u> are of the type with a structure of ceramic elements, precast concrete elements or metallic cage elements, in more or less equal proportions <u>Other REFL</u>: <u>Laminated glass</u> , mainly of the type B19, 8+8 mm
France	(FR)	ROA	NRA																	64%	18%	9%		1%			8%	The global <u>surface of noise barriers by materials is currently not available,</u> but an <u>estimate of the global repartition %</u> (sum of absorbing + reflecting) is given			
	(FR)	MAA	SER	52.800	22.400	5.600	< 1 000		< 1 000		< 1 000	13.200	5.600	1.400		6.000												The given surfaces are <u>annual averages</u> over 10 years	The ratio absorbing / reflecting materials is approximately 80 / 20 and has been practically constant over the last 20 years		
	(FR)	RAI	SNCF	yes			yes	yes			Stone Gabions																	To protect people from railway noise SNCF Réseau <u>no longer</u> do sound <u>reflecting barrier</u>. The most used materials in France for noise barriers along railways are concrete and aluminium metal casings with absorption materials.	Transparent materials can be used for some barriers, mainly in dense area If houses or bulding are very close to the track or if dwellers ask for it. They are generally surrounded by aluminium metal casings with heavy absorption materials to avoid a strong reflecting effect.	Stone gabions could be used if there is no problem with limited space (outside urban areas). SNCF Réseau try to develop noise barriers made of sustainable or recycled materials (old tyres mixed in concrete for example, less carbonaceous concrete.	We avoid wood for the structure of regulatory noise barriers because we must assure that the acoustic performances will not decrease over time which could not be guaranteed with wood (voluntary degradation, event of a vehicle in fire near a noise barrier, deterioration of wood material, …). Wood may be use for an <u>esthetical/architectural barrier cladding.</u>
Italy	(IT)	ROA	AUTOSTRADE																												
	(IT)	ROA	A. BRENNERO																												
	(IT)	ROA	ATIVA																												
	(IT)	ROA	A.VENETE																												
	(IT)	MAA	UNICMI	20.000	20.000	30.000	90.000		5.000			20.000	2.000			70.000			30.000									Reported quantities are based on info from by manufacturers associated in UNICMI (70% of the total number of noise barrier manufacturers). Info has been cross checked with main road managers.	Concrete panels are mainly used for rail applications. <u>Sound reflecting concrete</u> is commonly used for the lowest part of noise barrier in contact with the ground and for standard type of noise barrier for rail applications	S<u>ound absorbing steel</u> panels is mainly related to corten steel. <u>Transparent plastics</u> (totally solid PMMA; solid Polycarbonate has an exceptionally low share of the market) is related to sheets 15 mm and 20 mm thickness.	<u>Opaque plastic</u> is proposed by 1 single manufacturer and volumes are expected to crease *(increase or decrease?)* <u>Reflecting Other</u>: <u>laminated glass</u>, mainly type 8+8 mm or 10+10 mm
	(IT)	MAN	CIRAMBIENTE			12.630	4.650					7.450	285			1.035			6.150									Current (2020) jobs in progress (achieved jobs since Jan 2020)	<u>Reflecting Other</u>: <u>glass</u>		
Hungary	(HU)	ROA	NRA	272.699	128.011	3.781		0	956		2.864	15.904	894	1.455		9.245	222		3.301	8.162	100.628			2.487	609		3.003	- In some cases, these are estimated values using average height data - For the cases where the data on sound shading effect and/ or on material were in-complete, we used the category of "other"	We can assume that most of the values classified into the category of "other" on the basis of their sound shading effect can be considered as sound absorbing barriers	- Sound absorbing = absorbing + partially sound absorbing barriers - Concrete = wood concrete - We have one database for steel and alu barriers (metal barriers) - Transparent plastics= Plexiglas - Opaque plastics = any other kind of plastics - <u>Other= mostly glass</u>	
Netherlands	(NL)	ROA	NRA	434.000							1.546.000	101.000	160.000			828.000	52.000					274.000					142.000	<u>Sound Absorbing Other</u>: <u>Earth berms, including noise walls on top</u> of an earth berm	<u>Unknown Metal [Steel/Alu]</u> : Type of metal not specified. Contains both: - steel and aluminium, - sound reflecting surfaces and sound absorbing, perforated cassettes		
Austria	(AT)	ROA	ASFINAG	108.000	9.000		54.000	9.000																				Die ASFINAG hat im <u>Jahr 2019</u> rd. <u>180.000 m²</u> Lärmschutzwände an Autobahnen und Schnellstraßen errichtet. Davon: Beton/Holzbeton ~60% Holz ~5% Alu ~30% Transparent ~5%			
	(AT)	RAI	OEBB	yes	yes		yes	yes	yes		yes					yes												<u>Other</u>: earth berms	There is no new opaque plastics used since more than 15 years.		

		replier		Sound absorbing (m^2)								Sound reflecting (m^2)								Other? (m^2)											
		type	name	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	Concrete	Wood	Steel	Alu	Transparent Plastics	Opaque Plastics	Green Vegetation	Other	comments 1	comments 2	comments 3	comments 4
	(AT)	MAN	FORSTER	yes	yes		yes									yes	yes											As a manufacturer of acoustic elements, we do not know the value of the square meters.	I am sure that the authority will deliver the relevant figures.		
Poland	(PL)	ROA	NRA																												
Finland	(FI)	ROA	?	246 km	46 km	32 km	10 km	2 km		257 km	11 km																	Most noise barriers made of concrete, wood or steel. Earth barriers are quite common. Transparent plastic or glass elements are typically used only in upper parts of noise barriers. Along roads, both absorbing and reflecting barriers exist.	Detailed information about the amounts is not available.	GreenVegetation = Earth berms	
Finland	(FI)	RAI	?	?	?	?	?	?		?	?																	Most noise barriers made of concrete, wood or steel. Earth barriers are quite common. Transparent plastic or glass elements are typically used only in upper parts of noise barriers. All noise barriers along railways are absorbing but sometimes they have transparent upper parts.	Detailed information about the amounts is not available.	GreenVegetation = Earth berms	
Sweden	(SE)	ROA	TRV	yes	yes	yes	yes		yes		yes	yes	yes	yes	yes	yes	yes		yes									<u>Concrete absorbing</u>: Some concrete barriers have a sound absorbing panel mounted on the surface.	Steel & Alu are just registrered as "metal" in TRV databases, can be metal sheets/panels or mesh combined with absorbants.	Other Absorbing: stone gabions, airbrick	Other Reflecting: Glass, brickwalls
Sweden	(SE)	RAI	TRV	yes	yes	yes	yes		yes		yes	yes	yes	yes	yes	yes	yes		yes									<u>Concrete absorbing</u>: Some concrete barriers have a sound absorbing panel mounted on the surface.	Steel & Alu are just registrered as "metal" in TRV databases, can be metal sheets/panels or mesh combined with absorbants.	Other Absorbing: stone gabions, airbrick	Other Reflecting: Glass, brickwalls
Iceland	(IS)	ROA	NRA?								1.325	830	13.796			1.660		30.906	4.880									Reflecting: Transparent plastics/wood (mixed)	Reflecting: Berm/Green	Other absorbing: modular panels /stone-wool	Other reflecting: Gabbion
Norway	(NO)	ROA	NRA	2.500	490.400	2.200			7.700	1.300	166.424	5.800	137.900	2.200		2.700			101.675	8.600	980.100	20.300		8.200	2.900	4.700	149.400	The data has been collected from NVDB ("National Road Database") were all the screens/barriers in Norway, along all kinds of roads, are registered	In the data, there has not been taken into consideration whether the barriers are along a private road, a county road or another type of road.	**OTHER = not specified** Not all barriers are listed as reflecting or absorbing, and is therefore listed as "not specified"	Steel+Alu= Metal Other materials/types: Turf Walls, Concrete Blocks, Tempered Glass, Natural Stone, Tile and 141 300 m^2 "unknown" (abs+refl)
United Kingdom	(UK)	ROA	England Highways																									Unfortunately, we do not have figures, but barriers in England are predominantly wooden, but in recent years we have started to increase the numbers of other materials, particularly steel and opaque plastics.			

6.2 Question b

Country	Code	replier type	replier name	usage	DL_{RI} (dB)	DL_{SI} (dB) element $DL_{SI,E}$	DL_{SI} (dB) post $DL_{SI,P}$	DL_{SI} (dB) both global	DL_{α} (dB)	DL_R (dB)	Safety	Durability	Sustainability	# years warranty	Other (specify)
				Requirement 1											
Belgium	(BE)	ROA	VL	all	5	28	26	-	10	25	NBN EN 1794-1 (strength); NBN EN 1794-2 (environmental protection); NBN EN 1991-1 (wind); NBN EN 1794-1 (safety); EN 13501-1(fire)			3	Declaration of conformity with NBN EN 14388
Belgium	(BE)	ROA	W	all	5	28	26		10	25	NBN EN 1794-1 (strength, wind, stones, impact safety); NBN EN 1794-2 (fire, falling débris, light reflexion)	Not in general *Specific cases NBN EN 14389-1 NBN EN 14389-2*		5	Declaration of conformity with NBN EN 14388
Bulgaria	(BG)	ROA	NRA	1	-			24-30							
Czechia	(CZ)	ROA	NRA	all					08-15	15-34		30 Years		25	
Czechia	(CZ)	RAI	NRA	all	VAR*			VAR*				yes			
Denmark	(DK)	ROA	NRA	all	B3			A3				decrease absorption ≤3 dB insulation ≤2 dB	CO2, demolition, reusability	25	
Germany	(DE)	ROA	NRA	reflecting	0,5					> 24	Yes	Yes	Yes	5	
Ireland	(IE)	ROA	NRA	all					A3 (8-11)	B3 > 24	1791-1 1794-2	Yes	No	30	Yes
Spain	(ES)	RAI	ADIF												
Spain	(ES)	MAA	ANIPAR	Metallic panels (Timber) panels	≥ 7	≥ 34	≥ 30	≥ 32	≥ 15	≥ 27		15 Years (Railways)		See Comments	
France	(FR)	ROA	NRA	all	5			28						30-50	
France	(FR)	MAA	SER	all	5-6			28							
France	(FR)	RAI	SNCF	all	8-11			> 24			Ballast peak resistance. Snow loads and wind loads depending of the area	In theory an engineering structure located near the track should be dimensioned for 100 years	We choose materials to ensure the long term sustainability of the noise barrier	30	
Italy	(IT)	ROA	AUTOSTRADE	traditional NB	> 8	> 27	> 24		> 11	> 24					
Italy	(IT)			mix (**) traditional NB transparent < 30%	> 5	> 27 (*)	> 24		> 7	> 24					
Italy	(IT)	ROA	A. BRENNERO	concrete	4	34	32		5	33					
Italy	(IT)			transparent absorbent	2 (*)	27	25		5	26					
Italy	(IT)	ROA	ATIVA	Metallic panels					A4 > 11	B3 > 24					
Italy	(IT)	ROA	A.VENETE												

Country	Code	replier type	replier name	usage	DL_{RI} (dB)	DL_{SI} (dB) element $DL_{SI,E}$	DL_{SI} (dB) post $DL_{SI,P}$	DL_{SI} (dB) both global	DL_{α} (dB)	DL_R (dB)	Safety	Durability	Sustainability	# years warranty	Other (specify)
				Requirement 2											
Bulgaria	(BG)	ROA	NRA	2	-			30-36							
Germany	(DE)	ROA	NRA	reducing reflections	3,0					> 24	Yes	Yes	Yes	5	
Spain	(ES)	MAA	ANIPAR	Concrete panels	≥ 4	≥ 34	≥ 30	≥ 32	≥ 12	≥ 27		30 Years (Railways)		See Comments	
Italy	(IT)	ROA	AUTOSTRADE	integrated NB	> 6	> 23	> 20		> 7	> 24					
Italy	(IT)			mix (***) traditional NB transparent > 30%	-	> 27 (*)	> 24		-	> 24					
Italy	(IT)	ROA	A. BRENNERO	metal	7	27	25		15	26					
Italy	(IT)			transparent	-	27	25		-	26					
Italy	(IT)	ROA	ATIVA	concrete, wood, plastic					A3 (8-11)	B3 > 24					
				Requirement 3											
Bulgaria	(BG)	ROA	NRA	3	-			34-45							
Germany	(DE)	ROA	NRA	highly reducing reflections	5,0					> 24	Yes	Yes	Yes	5	
Spain	(ES)	MAA	ANIPAR	Transparent panels	-	≥ 34	≥ 30	≥ 32	-	≥ 27		15 Years (Railways)		See Comments	
Italy	(IT)	ROA	AUTOSTRADE	double sided integrated NB	> 6	> 22	> 19		> 7	> 24					
Italy	(IT)	ROA	A. BRENNERO	metal double-sided absorbent	5	27	25		13	26					
Italy	(IT)			wood	4	27	25		11	26					
Italy	(IT)	ROA	ATIVA	transparent					-	B3 > 24					

Country	Code	replier type	replier name	comments 1	comments 2	comments 3	comments 4
Belgium	(BE)	ROA	VL				
Belgium	(BE)	ROA	W	See Reference Document "Qualiroutes-J-1"	Durability Acoustical: No general requirement. For specific cases, requirements are according NBN EN 14389-1	Durability Non- Acoustical: No general requirement. For specific cases, requirements are according NBN EN 14389-2	
Bulgaria	(BG)	ROA	NRA	Overall the most common requirements in case of call for tenders are to comply with the requirements of all EU standards relating to noise reducing devices. No further specific requirements.			
Czechia	(CZ)	ROA	NRA	Technical conditions are provided by Ministry of Transport with specifications for all required characteristics of noise barriers	Requirements are based on Standards EN 1793 and EN 1794		
Czechia	(CZ)	RAI	NRA	We follow European and national standards for noise barrier' s. Safety, sustainability and warranty are given by our regulations	VAR*: According to current needs, we call walls with different efficiencies.		
Denmark	(DK)	ROA	NRA	The answers are provided by a Danish member of WG6 and only refers to TRNRD on state roads	Durability: In accordance to requirements in 14389-1it is accepted that sound absorption decreases with max. 3 dB and 2 dB for sound insulation	Safety: Risk of falling debris are normally not relevant in DK	
Germany	(DE)	ROA	NRA	Information is provided in the document "ZTV-Lsw 06" (Zusätzliche Technische Vertragsbedingungen und Richtlinien für die Ausführung von Lärmschutzwänden an Straßen; engl.: Additional Technical Contractual Conditions and Guidelines for the Implementation of Noise Barriers along Roads; https://www.fgsv-verlag.de/ztv-lsw)	The requirements for sound reflection depend on the reflection class needed in the specific case. The values are given in the document "RLS-19" (Richtlinien für den Lärmschutz an Straßen; engl.: Guideline for Noise Protection on Roads; https://www.fgsv-verlag.de/rls-19) and include the combined uncertainty to a level of 95% as an addition. For airborne sound insulation there is just one requirement existing. This is still referring to DIN EN 1793-2 (1997) and therefore to DL_R.	The ZTV-LSW 06 is currently being revised. Criteria for Safety, Durability and Sustainability are given in the ZTV-Lsw 06. The standard number of years of warranty for building structures granted in Germany is 5.	
Ireland	(IE)	ROA	NRA	Safety: Required to meet minimum requirements in standards	Durability: refer to S10.6 of CC-SPW-00300 Other: refer to CC-SPW-00300	The specification in relation to environmental noise barriers along national roads is CC-SPW-00300. The most recent iteration is 2018. However, the document is still heavily influenced by the original document prepared in the mid noughties.	TII, working with their consultant, are in the process of updating the standard to be more closely aligned to recent test standard updates whilst be fully cognisant to the existing regime to obtain CE marking through the harmonised EN 14388:2005 product standard.
Spain	(ES)	RAI	ADIF				
Spain	(ES)	MAA	ANIPAR	In Spain, until this year, in most cases, the technical specifications are drawn up by the engineering responsible for drawing up the infrastructure project, road or rail section, to be executed; in which, within the item of environmental protection works, the acoustic barriers to be installed are contemplated. Usually in these cases, the technical specifications included in the project are usually very general and do not include the degree of detail that they should, which allows the work contractor to include some changes according to their interest.	Much more rarely, it is the case that the project refers to the work of certain acoustic barriers exclusively. Then the engineering responsible for drafting the project tends to go deeper into the detail of the technical specifications. However, there is a greater tendency to use the European standards UNE-EN and the demand of requirements under CE marking, in the most recent technical specifications. Most of the technical specifications to date, refer to indices related to diffuse field.	In July 2020, and for the NBs in railways, ADIF published document ET.305.018.5 TECHNICAL SPECIFICATION - ACOUSTIC BARRIERS, drawn up by the standardization working group 119, in which ANIPAR participates and whose first working draft It was written by D. Alegre with the collaboration of C. Fernández representatives of ANIPAR. This document indicates that the responsibility for setting the acoustic absorption and acoustic insulation requirements corresponds to the drafter of the construction project, but that, in the event that the project does not specify the values for the DLRI and / or DLSI, the ones indicated in the table above must be applied by default.	This document specifies that the minimum useful life for transparent metallic and / or acrylic acoustic barriers must be equal to or greater than 15 years and for concrete acoustic barriers equal to or greater than 30 years. For railways the warranty period will be set by agreement between each supplier of the acoustic barriers and ADIF. For road projects, in general, the warranty period for noise barriers is established the same as for the entire construction work of the infrastructure section and is legally 2 years. The General Directorate of Roads of the Ministry of Development has requested ANIPAR to prepare a document that will serve as a starting point for the development of technical specifications on acoustic barriers, which would be applied in the road network of the Spanish state.
France	(FR)	ROA	NRA	To date, we have very few specifications regarding durability and sustainability.			
France	(FR)	MAA	SER				
France	(FR)	RAI	SNCF	There are no official documents: DLRI and DLSI are defined by engineering consultants in acoustics and specify for each site. It is part of the noise barrier sizing.			
Italy	(IT)	ROA	AUTOSTRADE				
Italy	(IT)			Mix (**): barrier type with less than 30 % transparancy	Mix (***): barrier type with more than 30 % transparancy	$DL_{SI,E}$(*): the test must be carried out at a section of barrier where metal and transparent panels are present and at any junction points (transparent - acoustic)	
Italy	(IT)	ROA	A. BRENNERO	The free field tests shall be repeated during testing of the installed barrier, at the request of the Works Management, in order to assess the correct installation, i.e. to assess the maintenance of the initial characteristics over time (checks to be carried out if provided for in the maintenance plan).	During testing, the tests shall be carried out in the positions identified by the Works Management.	Compared to the pre-qualification nominal values, a tolerance is allowed equal to the measurement declared in the product certification and, in any case, not more than 2 dB as regards the sound insulation expressed with the DL_{SI} index.	
Italy	(IT)			DL_{RI} (*): the figure is to be understood as an objective to be achieved. It is not to be considered binding in the absence of specific experimentation on existing products and solutions.			
Italy	(IT)	ROA	ATIVA				
Italy	(IT)	ROA	A.VENETE				

Requirement 1

		replier type	replier name	usage	DL_{RI} (dB)	DL_{SI} (dB) element $DL_{SI,E}$	DL_{SI} (dB) post $DL_{SI,P}$	DL_{SI} (dB) both global	DL_{α} (dB)	DL_{R} (dB)	Safety	Durability	Sustainability	# years warranty	Other (specify)
	(IT)	MAA	UNICMI	Metallic panels (Timber) panels	7 (6)		> $DL_{SI,E}$ - 2	27						20 (10)	
	(IT)	MAN	CIRAMBIENTE												
Hungary	(HU)	ROA	NRA	all	VAR*	VAR*	VAR*	VAR*			Yes	10 Years		3 Years generally	Yes
Netherlands	(NL)	ROA	NRA	all					8	≥ 25	Con-struction	50 yr Posts 30 yr Panels	MKI value tbd	7	Falling debris NEN-EN-1794-2
Austria	(AT)	ROA	ASFINAG	all	5 / 0			25	8 / 0	24					
Austria	(AT)	RAI	OEBB	V < 160 km/h					8	27	RVE 04.01.01	RVE 04.01.01	RVE 04.01.01	5	
Austria	(AT)	MAN	FORSTER	all	5-6			24-25						5	
Poland	(PL)	ROA	NRA	sound-absorbing non-transparent					10	R_w 20 dB		25 Years			
Finland	(FI)	ROA	?	all					8	25	Yes	Yes	Yes	VAR project and contract	Yes
Finland	(FI)	RAI	?						> 8	> 24	Yes	30 Years	Yes	VAR project and contract	
Sweden	(SE)	ROA	TRV	all					8	25	Yes	20 Years		2 & 5	Yes
Sweden	(SE)	RAI	TRV	all		25	25		8	25	Yes	40 Years		2 & 5	Yes
Iceland	(IS)	ROA	NRA?	1	no					B3	Glass EN 1794-2 ISO 527 DIN 5036	ISO 527		Glass 25	CE Certificate
Norway	(NO)	ROA	NRA	all						It will not leak sound	Safe against climbing Fundament Wind			3 or 5 years depending on contract	CO_2 usage
United Kingdom	(UK)	ROA	England Highways	all					single < 4 parallel 8-11	IL + 15	brush fire, shatter (wilful damage) properties, light reflectivity;	acoustic: maximum of 0.25 dB loss per year non-acoustic: at least 20 years	aesthetics and sustainability with reference to GG 103		landscape and visual impact

Requirement 2

		replier type	replier name	usage	DL_{RI} (dB)	DL_{SI} (dB) element $DL_{SI,E}$	DL_{SI} (dB) post $DL_{SI,P}$	DL_{SI} (dB) both global	DL_{α} (dB)	DL_{R} (dB)	Safety	Durability	Sustainability	# years warranty	Other (specify)
	(IT)	MAA	UNICMI	Concrete panels	4		> $DL_{SI,E}$ - 2	34						20	
	(IT)	MAN	CIRAMBIENTE												
Hungary	(HU)	ROA	NRA												
Netherlands	(NL)	ROA	NRA	all					10		Road traffic forward visibility	Glass panels Impact of stones NEN-EN-1791-1 Annex C	Panels must be detachable		Visibility for birds (Transparent panels)
Austria	(AT)	ROA	ASFINAG												
Austria	(AT)	RAI	OEBB	V 160-250 km/h					8	27	RVE 04.01.01	RVE 04.01.01	RVE 04.01.01	5	Dynamics RVE 04.01.01
Austria	(AT)	MAN	FORSTER												
Poland	(PL)	ROA	NRA	transparent						? R_w 29 dB					
Finland	(FI)	ROA	?												
Finland	(FI)	RAI	?												
Sweden	(SE)	ROA	TRV												
Sweden	(SE)	RAI	TRV												
Iceland	(IS)	ROA	NRA?	2					A3	B3	Glass EN 1794-2			25	CE Certificate
Norway	(NO)	ROA	NRA												
United Kingdom	(UK)	ROA	England Highways												

Requirement 3

		replier type	replier name	usage	DL_{RI} (dB)	DL_{SI} (dB) element $DL_{SI,E}$	DL_{SI} (dB) post $DL_{SI,P}$	DL_{SI} (dB) both global	DL_{α} (dB)	DL_{R} (dB)	Safety	Durability	Sustainability	# years warranty	Other (specify)
	(IT)	MAA	UNICMI	Transparent panels	-		> $DL_{SI,E}$ - 2	27						20	
	(IT)	MAN	CIRAMBIENTE												
Hungary	(HU)	ROA	NRA												
Netherlands	(NL)	ROA	NRA	all					12		(sun) light reflection				Landscape & visual impact Exit doors every 400 meters
Austria	(AT)	ROA	ASFINAG												
Austria	(AT)	RAI	OEBB												
Austria	(AT)	MAN	FORSTER												
Poland	(PL)	ROA	NRA												
Finland	(FI)	ROA	?												
Finland	(FI)	RAI	?												
Sweden	(SE)	ROA	TRV												
Sweden	(SE)	RAI	TRV												
Iceland	(IS)	ROA	NRA?												
Norway	(NO)	ROA	NRA												
United Kingdom	(UK)	ROA	England Highways												

Comments

		replier type	replier name	comments 1	comments 2	comments 3	comments 4
	(IT)	MAA	UNICMI	$DL_{SI(panel)}$ - $DL_{SI(post)}$ < 2 : additional acoustic requirement commonly specified with the aim of avoiding gaps between panels and posts.	About safety requirements resistance to impact test (6 kJoule /no fragments) is widely specified. Also, to consider that a large amount of integrated noise and safety barriers are used where requirements is for performance declared according to hEN 1317 :2012. Also fire behavior for partial covering is acknowledged as "safety" requirement Durability: for acoustic durability in some cases test according to EN 1317-6 are performed manly for checking the respect of requirements in column 4	To ensure Non acoustic durability, specifications are given for material characteristics, e.g minimum thickness of aluminum / steel sheets, protective film and layers, type of sound absorbing material (polyester foam instead of mineral wool is commonly used), type of material for absorbing concrete. Inspection checks are commonly made on a periodical base only by some road concessionaires and railways authorities. In other situations, attention is given for repairing activities only.	Sustainability is promoted mainly asking for a percentage of recycled or reused material for the new products used. Performance indicators according to EN 15804 are rarely used
	(IT)	MAN	CIRAMBIENTE	See requirements CSA from AUTOSTRADE A. BRENNERO ATIVA A.VENETE			
Hungary	(HU)	ROA	NRA	VAR* : The parameters of the acoustic performance required by the advisory report on acoustic performance Durability: 10 years according to the applicable law 12/1988. (XII. 27.) ÉVM-IpM-KM-MÉM-KVM decree)	Other: contractor references (with respect to the size of the noise barrier ac-cording to the tender), ex-pert's work experience as project manager (minimum 3 years re-quired)	Safety is no requirement for contractors. The design of barriers is subject to safety obligation, therefore it is the obligation of the designer to take into account the safety requirements, such as : - static test for noise barrier foundations; - in case of existing engineering structures, static test of the structural elements involved and due to the extra load, static test of the entire bridge;	- for bridges where there are other trails for transport or spaces for human occupancy (e.g. pavement) under a narrow noise barrier, protection against falling shall be ensured for the noise barrier elements - installation of safety equipment (reinforced concrete guard rails, steel safety barriers) in front of the wall in order to avoid collisions
Netherlands	(NL)	ROA	NRA	DL_{α} [NEN-EN 1793-1]: value defined by modelling in TNM (Traffic Noise Model) DL_R [NEN-EN 1793-1]: value depends on effect in TNM (D_LSw) according : DL_R = D_LSw + 10 + 3 dB	NL requirement starts with location of the NRD in the HWN (road nr, direction, km from – to), and specific the position of the top of the NRD (distance, height) related to the nearest driving lane on the road (as in TNM in planning phase).	For situations where definitive road geometry (position of driving lanes, etc in realisation phase) deviates from the road design in planning phase, then the noise levels alongside the road (results TNM in planning phase) are taken as demands that have to be met. Result is that design of road + NRD is changed to meet calculated noise levels in planning phase.	
Austria	(AT)	ROA	ASFINAG	Alle Lärmschutzwände werden nach folgenden Spezifikationen ausgeschrieben: -Standardisierte Leistungsbeschreibung Verkehr und Infrastruktur LB-VI; Forschungsgesellschaft Straße – Schiene – Verkehr (www.fsv.at)	Der Großteil (über 80%) wird nach folgenden Werten ausgeschrieben. ÖNORM EN 1793 -1, -2, -5 and -6 - ZTV-LSW 06		
Austria	(AT)	RAI	OEBB	For the call of tenders, these requirements are necessary. All elements must be pass the FSV advisory board; an official admission will handed out after the positive approval.	For the acoustic after EN 16232 there are no conditions defined.		
Austria	(AT)	MAN	FORSTER	There are very different requirements, depending on the project. But the requirement for DLRI is common 5 up to 6 dB, DLSI is common 24 up to 25.	The warranty for Elements is normal 5 years		
Poland	(PL)	ROA	NRA	The noise barriers to be used must meet the minimum requirements regarding sound reduction, i.e.: Rw = 20 dB, the soundproofing efficiency of minimum 10 dB and have a valid IBDiM Approval granted	Materials for sound-absorbing non-transparent components must demonstrate the following features: a) the weighted sound reduction index Rw = 20 dB as a minimum, b) soundproofing efficiency of minimum 10 dB, c) aesthetically pleasing appearance, d) durability of at least 25 years, e) materials not covered by Polish Standards must have a valid Technical Approval granted by the Road and Bridge Research Institute in Warsaw.	Materials for walls of transparent boards (elements made of transparent, colourless polycarbonate or acrylic panels with a valid IBDiM Approval), Required technical parameters: sound suppression : 29 dB.	*Noise barriers must meet the following general requirements:* *- reducing the noise level during the day (6.00 - 22.00) down to 61-65 dB (in accordance with the land development design), and at night (22.00 - 6.00) down to 56 dB.*
Finland	(FI)	ROA	?	Safety: Aspects and requirements given in the design guidelines, for example regarding falling debris.	Durability: Requirements for life time of different materials in posts, elements and claddings are given in the guidelines. For acoustic durability, either the manufacturer must prevent changes or measure predicted changes with artificial test samples.	Sustainability: Some aspects are given in the design guidelines but there are not all-embracing requirements.	Other: See "Design of road traffic noise reducing devices" Design guidelines and requirements for noise barriers along roads and railways are currently under revision. New specifications will be published in 2021.
Finland	(FI)	RAI	?	Safety: Aspects and requirements are given in the design guidelines.	Durability: Requirements for life time with different materials in posts, elements and added cladding will be given in the guidelines. Now the requirement is normally 30 years.	Sustainability: Some aspects are given in the design guidelines but not allembracing requirements	Design guidelines and requirements for noise barriers along roads and railways are currently under revision. New specifications will be published in 2021.
Sweden	(SE)	ROA	TRV	The template Technical Description for Construction Work (for Design and Build Contracts) TMALL1085, chapter DB52 contains requirements for Sound absorption, Sound insulation, Safety, Durability and Working life is which refers to SS-EN1794-1 (dynamic forces from snow clearance) and SS-EN 1794-2 Annex B para B.3 (falling debris)	The template has also paragraps: "Acoustic elements shall be declared according to SS-EN 14388, concerning sound absorption, sound insulation, loads, durability and, if applicable, falling debris". "Light reflection shall also be declared for elements of glass, plastic or metal according to SS-EN 14388".	Required technical working life is at least 20 years (often 40 years though).	Warranty Five years for construction and two years for products or material.
Sweden	(SE)	RAI	TRV	Acoustic requirements are according to SS-EN 16272-2:2012 / 16272-3-1:2012, and SS-EN 16272-6:2014 / 16272-3-2:2014	Requirements for Safety, Durability, Working life according to: 1. Rules TRV-doc TRVINFRA-00227 (Bridges and similar constructions, Construction), Ch 7.3.5. Demands concerning load factors, aerodynamic loads and fatigue	2. SS-EN 16727-3:2017 concerning reaction to brush fire, shatter properties, reflection of light, and (partly) means of access or escape in emergency. 3. SS-EN 16951-1:2018 and SS-EN 16951-2:2018 for durability for relevant exposure classes	Warranty Five years for construction works and two years for products or material
Iceland	(IS)	ROA	NRA?	Steel in structure shall be CE labeled and according to Icelandic standard IS-EN 1990-2002: 2008	The glass shall be made of embedded polyamide threads (GS CC) that fulfills requirements for breaking shape according to EN 1794-2	Absorbing module units: Maintenance-free and long-life expectancy > 25yrs	Walls are placed outside the road's safe zone; otherwise requirement made for guardrails according to Icelandic road design rules
Norway	(NO)	ROA	NRA	These data and comments are valid for noise barriers owned by the Norwegian Roads Administration only			
United Kingdom	(UK)	ROA	England Highways	VAR*: Requirements are set on a project-by-project basis, as set out in document "DMRB LD119" and documents refereced therin.	DMRB: "Design Manual for Roads and Bridges" LD119: "Roadside environmental mitigation and enhancement"	GG 103, 'Introduction and general requirements for sustainable development and design	Structural: according BS EN 1997-1, 'Eurocode 7: Geotechnical design - Part 1: General rules' , 2004

6.3 Question c

		replier		Contract awarding process - Key parameters													
		type	name	Performance	Costs	Delays	Installation	Safety	Durability	Sustainability	# years warranty	Maintenance	Other (specify)	comments 1	comments 2	comments 3	comments 4
Belgium	(BE)	ROA	VL	Yes	Yes		Yes		Yes		Yes	Yes		Combination of cost as most important factor with certain installation and durability factors	The contract awarding process can vary in different situations, as in detail described in the published tender		
	(BE)	ROA	W	Yes	Yes						Yes	Yes		Cost is usually the only contract awarding considered in our contract.	Other elements are taken into account though the requirements in public standards doc_"QUALIROUTES"		
Bulgaria	(BG)	ROA	NRA											Before the installation of the noise barrier, an acoustic and construction parts are prepared, as well as projects in the part "Geodesy" and the part "Geology. Different solutions are developed, and the final decision is chosen by an expert council. The proposed materials and constructions should meet all national and European requirements and standards.	Most of installed barriers are parts of whole process of design and construction of new road sections.		
Czechia	(CZ)	ROA	NRA	Yes				Yes	Yes					The Road and Motorway Directorate RMD does not award contracts.	Contract awarding is handled by the construction contractor.	RMD asks the contractor the project documentation regarding specific characteristics: acoustical (insulation, absorption); safety concerns (according standards), durability and material	
	(CZ)	RAI	NRA	Yes	Yes									The most important thing is efficiency to share the limits	Another aspect is the price	Because we cannot identify suppliers directly, they must compete.	
Denmark	(DK)	ROA	NRA		Yes					*not yet*				Now: only lowest price, within few years hoping to put requirements in accordance to CO2, demolition and reusability.			
Germany	(DE)	ROA	NRA	Yes	Yes			Yes	Yes	Yes				Material and noise barrier characteristics in general are defined in the call for tenders. The acoustical performance and technical criteria are defined by the ZTV-Lsw 06	Thus, the main criterion for the contract awarding process is given by the costs.		
Ireland	(IE)	ROA	NRA	Yes	Yes	Yes	Yes	Yes	Yes (timber)	Yes (timber)			Yes	Environmental Impact Assessment Reports (EIARs) identify the requirements for barriers when planning is undertaken for new national road schemes. When planning permission is received, all environmental noise barriers are procured and installed as part of the main construction contracts for new national roads. Therefore, the main construction contractor can procure on their own terms (cost, speed of delivery etc.).	Very few barriers are installed once a scheme becomes operational. However, in accordance with the Environmental Noise Regulations which transpose the Environmental Noise Directive, some local authorities, as part of their Noise Action Plans, are starting to consider installation of additional barriers. In such instances, CC-SPW-00300 remains the only reference document. It is my understanding that procurement is based on both cost and quality criteria, once, the minimum performance standards set out in CC-SPW-00300 is achieved.	Other: Aesthetics requirements	
	(ES)	RAI	ADIF														

		replier		Contract awarding process - Key parameters													
		type	name	Performance	Costs	Delays	Installation	Safety	Durability	Sustainability	# years warranty	Maintenance	Other (specify)	comments 1	comments 2	comments 3	comments 4
Spain	(ES)	MAA	ANIPAR	Yes	Yes									In most cases, the administration responsible for the construction of the infrastructure, at the state, regional or local level for highways and at the state or regional level for railways, usually award construction contracts for a new section of infrastructure, the project of which includes corrective measures for acoustic impact and acoustic barriers.	The contract is awarded based on the administrative specifications for the offer of a large construction company or consortium through one of these two award processes: Type 1: lowest price based on fulfilments of technical specs Type 2: most advantageous offer based on multicriteria decision making method Usually, even if 70% of score is given for technical aspects and only 30 % for price, the offered price remains the most important criterium as all tenderers currently achieve a high score for technical criteria	Generally, the company or consortium that wins the tender is not, nor does it have, specialists in acoustic barriers, so it subcontracts the execution of these articles based on its own interests	
France	(FR)	ROA	NRA	Yes	Yes	Yes								The three main parameters accounting for the selection of noise barriers are the cost, the delays and the performances			
	(FR)	MAA	SER	Yes	Yes				Yes					The main parameters for contract awarding are the cost (50 %) and the performance (50 %)	For the cases with the construction being conceeded to road societies, durability of 30 years is asked. This corresponds to the average duration of the concession.		
	(FR)	RAI	SNCF	Yes		Yes	Yes	Yes	Yes	Yes	Yes			They must meet strict specifications established in a public consultation document: acoustics performances (DLRI, DLSI), safety, durability, sustainability, years warranty, delays, organization of the worksite and its logistics, sound level during construction (what specification to protect resident from the noise during works), …			
Italy	(IT)	ROA	AUTOSTRADE														
	(IT)	ROA	A. BRENNERO														
	(IT)	ROA	ATIVA														
	(IT)	ROA	A.VENETE														
	(IT)	MAA	UNICMI	Yes	Yes	Yes	Yes	Yes	Yes					Contract awarding process Type 1: lowest price based on fulfilments of technical specs Type 2: most advantageous offer based on multicriteria decision making method	Among technical criteria : technical performance , durability and installation rate and safety are the most important.	Note: even if 70% of score is given for technical aspects and only 30 % for price, the offered price remains the most important criterium as all tenderers currently achieve a high score for technical criteria	
	(IT)	MAN	CIRAMBIENTE	Yes	Yes	Yes	Yes		Yes					The tenders are awarded with an overall score. In order of importance of main items: 1- Costs 2 - Performance 3 - Durability 4 - Installation time and easiness			
Hungary	(HU)	ROA	NRA	Yes	Yes	Yes	Yes	Yes			Yes		Yes	The parameters of the noise barriers (starting and ending markers, height, acoustic requirements etc.) shall be determined at the time of design, on the basis of the advisory report based on noise measurement.	In case of newly constructed noise barriers, the tendering procedure for the design and execution is normally managed by Hungarian National Infrastructure Development Company (NIF) which is the company responsible for large infrastructure projects in Hungary.	In cases where the barrier is constructed on Hungarian Public Roads' (MK) account, the technical document specifies the quality requirements of the noise barrier, i.e. the sound absorption and sound reduction categories and provides for the completion deadline, the minimum warranty period, the minimum professional experience of the project manager (other)	The main award criterion is the price, however there can be additional criteria, such as more professional experience, longer warranty period, shorter execution time. Additional liabilities are also stipulated in the contract, including late payment charges, penalties for failure to comply, warranty period, performance guarantee, surety.

		replier		Contract awarding process - Key parameters													
		type	name	Performance	Costs	Delays	Installation	Safety	Durability	Sustainability	# years warranty	Maintenance	Other (specify)	comments 1	comments 2	comments 3	comments 4
Netherlands	(NL)	ROA	NRA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	NL system used is "best price quality ratio". Weighing factors for price (based on demands) and extra quality (nice to haves) must be determined in advance of procurement, example: price 50%, extra quality 50%. Quality can be defined by many aspects, but quality criteria must contribute to the goal of the contract (criteria are nice to haves!). No more than 3 criteria must be used to keep focus.	Examples of Prestatie criteria (SMART) - Extra life time expectancy - Less impact on traffic (availability of the road for traffic) - CO2-emission	Examples of Kwaliteit criteria (less SMART) - extra Risc management - reduction of environmental nuisance - circular use of materials - extra functionality - aesthetics / design.	
Austria	(AT)	ROA	ASFINAG														
	(AT)	RAI	OEBB	Yes			Yes	Yes						There are 2 options: - Performance description used directly from the construction projects or - With a so called "framework agreement"	For both contracts, it is required to pass the approval from the "FSV" (independent advisory board). The board is proving all regulations regarding noise barriers. (eg. Dynamics, statics, acoustic performances…)		
	(AT)	MAN	FORSTER	Yes	Yes									The requirements are principally necessary, or you are not allowed to get the contract ("retired"). The rest process is "cheapest offer" will get the contract. This is also the reason because the supplier of the acoustic elements is a subcontractor of the building company.	Because of this additional quality properties which are not required has no influence to the contract awarding - unfortunately		
Poland	(PL)	ROA	NRA														
Finland	(FI)	ROA	?	Yes										Depends on the project and contract.	Design guidelines and specifications are the basis		
	(FI)	RAI	?	Yes										Depends on the project and contract.	Design guidelines and specifications are the basis		
Sweden	(SE)	ROA	TRV														
	(SE)	RAI	TRV														
Iceland	(IS)	ROA	NRA?		Yes								Yes	The choice of contractor / developers is determined in each case by the project. Factors are such as ability, cost and quality certification and most often a mix of these factors.	Open tender		
Norway	(NO)	ROA	NRA											Often the noisebarrier is part of a bigger contract, as in building a new road, or a part of the operation and maintenance contract.	For new roads that can be a turnkey contract or an execution contract.	These data and comments are valid for noise barriers owned by the Norwegian Roads Administration only	
United Kingdom	(UK)	ROA	England Highways											Project by project basis- barriers are normally procured by a principal contractor working on behalf of Highways England.			

6.4 Question d

		replier		Control the installation process - Key parameters					comments 1	comments 2	comments 3	comments 4
		type	name	Performance	Delays	Installation	Safety	Other (specify)				
Belgium	(BE)	ROA	VL	Yes		Yes	Yes		Before execution: prove of sound insulation and absorption must be given by means of test results according NBN EN 1793-x + check calculation notes wind load/self weigth/… + check information fire, check materials panels, posts, …	Before installation: check in factory and on-site of the materials (e.g. aluminium, steel of the posts, conservation steel) + check of sealing system. During installation the local responsible checks the installation process: prescribed installation method being followed, special attention for placement of the joint tape, filling of lifting eye, tightening bolts, …	After installation, in-situ tests are conducted DLRI according 1793-5 & DLSI (panel & post) according 1793-6. Number of controls = total length / 1000 mL noise barrier, rounded up.	
	(BE)	ROA	W	Yes		Yes	Yes		Control 1 : before execution during the manufacture in factory. We analyse the elements used and control if they are related to the technical notice	Control 2 : during installation process. All elements are inspected before installation. Check of sealing and wedging system according technical notice. A complete inspection considering the walloon inspection method is done and used to consider if repairs or modifications have to be done according doc_"Rapport_InspectionEcran_x"	Control 3 : just before end of the warranty period. Considering the inspection in Control 2 we look if there are new defaults on the noise barrier. The company has to repair if these are linked to the installation process or due to intrinsic properties of the device	
Bulgaria	(BG)	ROA	NRA			Yes			Noise reducing devices built by noise reducing panels, steel columns on cast-in-site pile and continuous concrete footing – following the correct technology process given by the manufacturer if the devices	Following for the correct technology process when the concrete is cast-in-site.	The project for a noise barrier requires the issuance of a construction permit. The installation is monitored by construction supervision, and their operation is approved by an expert commission.	
Czechia	(CZ)	ROA	NRA			Yes			Focus on: fitting panels to posts, panel to panel, sealing of gaps, quality of absorptive layer, space behind barrier (for maintenance)			
	(CZ)	RAI	NRA			Yes	Yes	Yes	On construction sites, we monitor the quality of execution, according to standards. We have a whole department for that.	We check piles, concrete, columns, panels, installation accuracy, drainage, color standards, safety, etc.		
Denmark	(DK)	ROA	NRA			Yes			Control of “measurements” and used materials in accordance to the static calculation when the contractor is installing the RTNRD. Very important that the bolt group is strong enough to carry the weight of the noise barrier. The bolt group and the foundation are not part of the EN 14388, but it is very much part of the final calculation.	In Denmark noise barriers have reached a height of 8 meters and we calculate wind load up to 27 m/s.		
Germany	(DE)	ROA	NRA	Yes		Yes			The installation process is monitored and there is an official acceptance of the construction work. Here, constructional criteria are approved, e.g. statics, technical implementation, optical factors.	The acoustic properties are verified via certification. Currently, the certification by measurements in the reverberation chamber is sufficient (corresponding standard DIN EN 14388 still requires update).		

		replier		Control the installation process - Key parameters					comments 1	comments 2	comments 3	comments 4
		type	name	Performance	Delays	Installation	Safety	Other (specify)				
Ireland	(IE)	ROA	NRA	Yes		Yes			TII's Employers Representative (a consulting engineering firm) ensure that the required barrier is installed on the new schemes by the main construction contractor. The firm will also complete visual inspections upon a sample of barriers installed.	In recent years, TII have directly began undertaking testing in accordance with EN 1793-5 and EN 1793-6. However, such tests are undertaken for information purposes only and have no contractual weight		
Spain	(ES)	RAI	ADIF									
	(ES)	MAA	ANIPAR	Yes		Yes			Generally, the control of the installation of acoustic barriers corresponds to the organization or consulting company that has been awarded control of all the work of the infrastructure section and that is not usually a specialist in the field of acoustic barriers and its major or Less dedication is determined by their budgetary availability, resulting in very basic and insufficient cases in most cases. The successful bidders commonly subcontract the supply and installation. Manufacturers are often involved in the installation process and foundation work.	The Technical Assistance for the control of the work usually asks for the certificates of the initial type tests in accordance with EN 1793-1 and EN 1793-2 as well as the Declaration of Performance and the CE marking of the product to be installed.	For railways, the new document ET 03.305.010.5 of ADIF already requires the presentation of the initial type test certificates in accordance with EN 1793-5 and EN 1793-6, when applicable, as well as the rest of the requirements detailed in that document.	For roads, the professional associations of the sector, such as ANIPAR, are making a great dissemination effort to ensure that the technical specifications of the infrastructure projects consider minimum requirements, the presentation of the certificates of the initial type tests according to EN 1793-5 and EN 1793-6, when applicable, and appropriate control protocols to verify compliance with what is indicated by the manufacturer in the product's Declaration of Performance and CE Marking.
France	(FR)	ROA	NRA	Yes					Two types of measurements are performed to confirm the performance of noise barriers on site:	1) Noise barriers performance following EN 1793-5 and -6 2) Noise level (environmental) following NF S 31085 and NF S 31110 at proximity of buildings		
	(FR)	MAA	SER	Yes					Sound transmission & reflection			
	(FR)	RAI	SNCF	Yes					Control 1: Acoustics performance in laboratory (laboratory performance test carried out within researched parameters): quality PV to provided at the beginning of the NB building project	Control 2: Acoustics performance in situ: normalised test to verify the installed material (all frequency could may be not be verified if the NB is not high enough)	Control 3: Acoustics level at 2 meters in front of building facades (must be inferior to regulatory specified level, if not NB have to be modified or noise building insulation improve)	
Italy	(IT)	ROA	AUTOSTRADE									
	(IT)	ROA	A. BRENNERO									
	(IT)	ROA	ATIVA									
	(IT)	ROA	A.VENETE									
	(IT)	MAA	UNICMI	Yes		Yes			Tenders are commonly made for supply and installation. Manufacturers are commonly involved in the installation process and foundation works	Manufacturers are always involved for checking installation tolerances on site. Acceptance of the product is based on the fulfilment of material specifications. Very often before installation test are made according to EN 1793-5, 6 for further assessment of acoustic performance in situ.		

		replier		Control the installation process - Key parameters					comments 1	comments 2	comments 3	comments 4
		type	name	Performance	Delays	Installation	Safety	Other (specify)				
	(IT)	MAN	CIRAMBIENTE	No		Yes			Usullay pre-installation test are carried on (at workshop). Verification that all elements of each barrier's span have been installed	Not any acoustic test is carried on at the end of installation at site		
Hungary	(HU)	ROA	NRA	Yes		Yes		Yes	We always control the barriers at the handover, including the cases when the barrier is constructed on NIF's account and our Company is operator and maintainer of the barrier and also in the cases when the barrier is constructed on Hungarian Public Roads' account.	In case of NIF projects, technical inspection is carried out by an engineer entrusted by NIF and our company is only supervising the process and controls the barriers at the hando-ver. In case or our projects, technical inspection is carried out by our office responsible for the region concerned during the entire process.	If the barrier is constructed on our own account, we perform control during the entire con-struction process, including the quality of the materials and the acceptance of the com-pleted work. We perform control of the technical quality of the execution of works for narrow noise barriers according to the following aspects: - if the noise barrier's acoustic performance is acceptable, the components are tightly joined, there are no holes or cracks. Any visible aperture shall be considered as a fundamental deficiency. - if water drainage is working and is in accordance with the drainage design (runoff water drains with acoustic sealing).	We perform controls of the followings: - escape route signs, visibility, usability of escape gates, - if wooden components are without any damage (cracks, fractures) - in case of wood-concrete barriers, if wooden elements are coloured throughout the mass - if the completed construction work is in line with the visualized outcome - If steel structures are fully protected with intact galvanised coating - If caps are properly attached - control of materials and their parameters included in the product certification
Netherlands	(NL)	ROA	NRA	Yes	Yes	Yes	Yes	Yes	In all cases road works have to be planned and need a permit of the local traffic controller. Main focus is on minimising impact of road works on traffic.	Next aspects are: - limiting noise and vibration nuisance during construction conditioning the site before road work starts: - risc analysis on non detonated explosives - rerouting of cables and power lines - search on archaeological values		
Austria	(AT)	ROA	ASFINAG	Yes					Das Leistungsbild entspricht inhaltlich dem Prüfhandbuch zur akustischen Abnahmeprüfung von Lärmschutzwänden an Straßen und Autobahnen vom 27.1.2020 (Dokumentnummer PlaPB 800.100.1601, Version 2.00). (www.asfinag.net)			
	(AT)	RAI	OEBB			Yes			The construction management controls it.			
	(AT)	MAN	FORSTER			Yes			Mostly we realise the installation our self (acoustic elements).	Controlling is done based on our installation manual.		

		replier		Control the installation process - Key parameters					comments 1	comments 2	comments 3	comments 4
		type	name	Performance	Delays	Installation	Safety	Other (specify)				
Poland	(PL)	ROA	NRA			Yes			In accordance with the issued Design Specifications D-46.05.00 (appendix to standard maintenance documents), the inspection of workmanship regarding sound-absorbing components is carried out as follows: Each batch of sound-absorbing components should be examined randomly in terms of external features, i.e. the correctness of their shape as well as the cross-section in the thinnest and thickest place should be checked.	The surfaces of the components should be even, without scratches, cracks or chipping. The result of the inspection shall be considered as positive if the number of defective pieces does not exceed 3% of the entire batch. Should the total number of scrap items be greater than 3%, the entire batch is to be re-sorted, any items that do not meet the control requirements to be rejected. Damaged components must not be installed.	The producer (supplier) of sound-absorbing components shall be required to provide: - Declaration of Conformity, - The IBDiM Technical Approval, - The report on laboratory strength tests in accordance with the requirements contained in the IBDiM Technical Approval document.	
Finland	(FI)	ROA	?			Yes			The contractor has the main responsibility for delivering according the contracted specifications.	Also a supervisor can be used.		
	(FI)	RAI	?			Yes			The contractor has the main responsibility for delivering according the contracted specifications.	Also a supervisor can be used.		
Sweden	(SE)	ROA	TRV									
	(SE)	RAI	TRV									
Iceland	(IS)	ROA	NRA?			Yes			Control of the installation of sound barriers is carried out in the same way as supervision of other practical projects.	Where materials and their installation are monitored. Such as the walls sound insulation and that they are installed in the right place and with correct height		
Norway	(NO)	ROA	NRA			Yes		Yes	It is mostly «own control», however there are designated control engineers	Document control, and a review	These data and comments are valid for noise barriers owned by the Norwegian Roads Administration only	
United Kingdom	(UK)	ROA	England Highways	Yes		Yes			Visual inspections through installation process, checking product matches specification.			

6.5 Question e

		replier		Barrier maintenance - Key aspects						comments 1	comments 2	comments 3	comments 4
				Performance acoustical	Structural Stability	Elements (settings)	Visual aspects	Safety	Other (specify)				
Belgium	(BE)	ROA	VL		Yes	Yes	Yes	Yes		Inspections are organised every two years and result in a list of top five urgent sites where replacements or renovations are needed.	Small damages can be repaired faster, certainly is the safety of the road users is in danger		
	(BE)	ROA	W	Yes	Yes	Yes	Yes	Yes		Central Database Characteristics of the noise barriers with Health Indicator "HI" = function of [structural/stability; acoustical aspects (absorbing materials, insulation); setting of elements; visual aspects (rust, gaps)]	Upgrade of barrier for identified "hot spots" according the END noise maps. If no "hot spot", added to list of the to be restored barriers.		
Bulgaria	(BG)	ROA	NRA					Yes		There is no regulatory paper on maintaining the devices	Only when occurrence of car crashes with panel or structural damage on the steel columns or on the continuous concrete footing.		
Czechia	(CZ)	ROA	NRA		Yes		Yes	Yes		Preference for "maintenance free" materials (such as concrete).	Maintenance provided by visual control, local repairs or change of panels		
	(CZ)	RAI	NRA		Yes		Yes	Yes		Our administrators pay attention to the cleanliness of the panels, make repairs at predetermined times.			
Denmark	(DK)	ROA	NRA				Yes			No (for the time being) measure if the RTNRD still functions as assumed. No road administration has this kind of money.	Only "wash" when graffiti is applied. After "washing" the RTNRD one time, the treatment for graffiti is gone and a new treatment must be put on. Need to dismantle the barrier and send it to factory. No road administration has this kind of money.	Only once a year - replacement of cassettes when "hit by something".	
Germany	(DE)	ROA	NRA		Yes			Yes		Regular inspections, as described in review report M3.1. Inspections cover constructional aspects, like statics, stability etc. In case of damages, repairs are carried out depending on the degree of damage.	Generally, the lifetime is limited by the stability.		
Ireland	(IE)	ROA	NRA	Yes	Yes	Yes	Yes	Yes		TII have appointed a number of Motorway Maintenance and Renewal Contractors (MMaRCs) to manage national roads on our behalf. It is their duty to ensure barriers are maintained and replaced if required.	Since 2018 TII have also undertaken <u>visual inspections of up to 70kms per year.</u> An internal spreadsheet has been prepared to manage this process. Based on a traffic light system, this information is fed back to the MMaRCs to help supplement their maintenance.	In addition, in 2017 and 2018 TII procured an acoustic consultant to undertake <u>EN 1793-5 and EN 1793-6 tests</u> on four barriers <u>for information</u> purposes.	In 2019 TII procured an acoustic consultant to test 100 barriers over a five year period (20 per year). Testing for 2019 and 2020 has been successfully completed.
Spain	(ES)	RAI	ADIF										
	(ES)	MAA	ANIPAR		Yes			Yes		To date, in general, <u>no maintenance protocols have been established</u> for installed acoustic barriers, and this despite the fact that manufacturers attach the corresponding maintenance plan to their product documentation	<u>Only in case of deterioration of the acoustic barrier due to traffic accidents or structural failures</u>, the affected section is usually repaired, although not in all occasions.		
France	(FR)	ROA	NRA							Inspection works are organized at the scale of the national network by french government (DIR) and at the scale of the conceded French highway network (ASF, APRR, SANEF, Cofiroute).	These works are subcontracted to private engineering companies. Some actions are then proposed for the maintenance as a function of the inspection results.		

		replier		Barrier maintenance - Key aspects						comments 1	comments 2	comments 3	comments 4
				Performance acoustical	Structural Stability	Elements (settings)	Visual aspects	Safety	Other (specify)				
	(FR)	MAA	SER							There is no maintenance of the barriers, except for very rare cases (e.g. périphérique Paris)	Contracts regarding maintenance ("entretiens ou maintenance") are very rare		
	(FR)	RAI	SNCF		Yes					Only the structure is periodically verified to be sure that there is no risk for the people living near the NB or for trains traffic.	We don't clean the NB even if they are covered with graffiti. We try, as far it is possible to involved local authorities on this point for the residents' side, especially if plantations are established to mask the noise barrier on the opposite side to the track.		
Italy	(IT)	ROA	AUTOSTRADE										
	(IT)	ROA	A. BRENNERO										
	(IT)	ROA	ATIVA										
	(IT)	ROA	A.VENETE										
	(IT)	MAA	UNICMI							A maintenance control plan is provided by the manufacturer to the client.	Only main road managers (concessionaires and railway authorities make periodic tests Control made on site are mainly material oriented		
	(IT)	MAN	CIRAMBIENTE		Yes		Yes	Yes		A maintenance control plan is provided to client.	Periodic test of visual integrity of noise barrier's elements suche as carpentry, panels and bolts are to be carried on by final client.		
Hungary	(HU)	ROA	NRA		Yes	Yes	Yes	Yes	Yes	Since noise barriers are altered by weather conditions and due to other impacts during they lifetime, their visual aspect and their noise reduction effect is worsening over time. We strive to be fully compliant with the Technical Specifications for Roads that includes specific provisions for the installation and maintenance of noise barriers. Visual inspections shall take place once a year in order to check the noise barriers' alterations and deficiencies (concerning visual aspect, colour, corrosion etc.).	The periodic checks of noise barriers shall cover the following aspects: - if the wooden foundation components are damaged or affected by corrosion or rain-wash - if the noise shading wooden components and seals are damaged or effected by any deficiency - if there are any visual damages (e.g. graffiti) - presence and conditions of closure caps - condition of escape and service gates (proper closing, damages, deficiencies, visibility of pictograms) - condition of escape routes, guard rails, stairs - condition of drainage system and its functioning, if the components are undamaged	The usability of escape gates shall be regularly checked. Any deficiency shall be immediately addressed (replacement of damaged components, paint-ing of wood-concrete barriers constructed according to older requirements, etc.)	Noise barriers can be cleaned strictly according to manufacturer requirements (e.g. according to the new requirements, wood-concrete-based wall components cannot be painted, they shall be coloured throughout the mass).
Netherlands	(NL)	ROA	NRA		Yes	Yes		Yes		Maintenance is minimal, repair of local damages Main focus on structural safety	maintenance consists of - yearly visual inspection, focus on functional performance of exit/service doors and damages. If needed these are repaired. - every 7 years a more extensive inspection to determine the condition of the object		
Austria	(AT)	ROA	ASFINAG							Überprüfungen gemäß RVS 13.03.71 – Lärmschutzbauwerke 18.04.2016 (www.fsv.at)			
	(AT)	RAI	OEBB							Regular inspection based in the inspection plan. In general, there is no big maintenance work necessary. Depending on the material			

		replier		Barrier maintenance - Key aspects						comments 1	comments 2	comments 3	comments 4
				Performance acoustical	Structural Stability	Elements (settings)	Visual aspects	Safety	Other (specify)				
	(AT)	MAN	FORSTER							No maintenance is required, this is a “wish” of the authorities.	But the noise barriers are interval checked.		
Poland	(PL)	ROA	NRA				Yes			Requirements for the maintenance of noise barriers are included in standard maintenance documents. As part of this task, the Contractor shall be required to: a) wash once a year, after the winter season (April 15 and May 14), all the noise barriers (the road side surface of non-transparent boards, and both side surfaces in the case of transparent boards).	Washing and cleaning the panel with mild and biodegradable detergents. Due to the screen printing system (2 cm wide strips spaced every 10 cm) on transparent panels, the outer side of the boards should be washed without pressure.		
Finland	(FI)	ROA	?		Yes		Yes	Yes		Depends on the site and the barrier.	Significant damages are repaired especially if they have safety impacts.	Graffities are washed when the barrier is located in a valuable area.	Wooden barriers are repainted when needed and budget available
	(FI)	RAI	?		Yes		Yes	Yes		Depends on the site and the barrier.	Significant damages are repaired especially if they have safety impacts.	Graffities are washed when the barrier is located in a valuable area.	Wooden barriers are repainted when needed and budget available
Sweden	(SE)	ROA	TRV							Noise barriers are inspected at least once every week, most of them more often, by our contractor while inspecting the roads.	Any obvious damage is reported to our project manager, who if he think it is necessary order repairs.	The project manager can also order a more thorough inspection.	If they find maintenance needs the project manager requests funds from the central authority, which prioritize all the districts needs and allocate.
	(SE)	RAI	TRV										
Iceland	(IS)	ROA	NRA?							The maintenance of noise barriers is not in our care			
Norway	(NO)	ROA	NRA				Yes			Wood barriers are painted and washed	All noise barriers owned by the Norwegian Public Roads Administration are being replaced when needed, be aware that there is a backlog.	These data and comments are valid for noise barriers owned by the Norwegian Roads Administration only	
United Kingdom	(UK)	ROA	England Highways		Yes?	Yes?	Yes		Yes	Visual inspections to identify defects, keeping clear of vegetation	? Defects: which aspects?		

6.6 Question f

		replier		Barrier maintenance - Actors				comments 1	comments 2	comments 3	comments 4
		type	name	Contracting Authority	Contractor	Manufacturer	Other (specify)				
Belgium	(BE)	ROA	VL	Yes	Yes			Contracting authority is the Flemish Government is main responsible for overall and long-term maintenance	The contract can impose a certain (limited) period in which the contractor is responsible for the maintenance		
	(BE)	ROA	W	Yes	Yes			If problems appear during the warranty period and if the problems are due to intrinsic characteristics of the device the contractor has to repair.	After the warranty period the SPW Mobility and Infrastructures is responsible for the maintenance	As stated in public requirements, the contractor has to deliver the maintenance notice of the noise barrier before beginning the installation. This document is used for the maintenance after the warranty period.	
Bulgaria	(BG)	ROA	NRA	Yes				Road Infrastructure Agency			
Czechia	(CZ)	ROA	NRA	Yes				Responsibility of Highway Administration and maintenance centres alongside highways OR local administration and maintenance centres (14 regions if CZ)			
	(CZ)	RAI	NRA	Yes				Infrastructure manager -Správa železnic, státní organizace			
Denmark	(DK)	ROA	NRA	Yes	Yes			The road administration is responsible. The contractor responsible for the day-to-day operations, is responsible to report when a RTNRD is not as expected.	When receiving the report, the road administration will decide what to do and the contractor will perform the task.		
Germany	(DE)	ROA	NRA	Yes				The Road Administrations. (Starting from 2021 the so-called "Autobahn GmbH" will be responsible for National Highways).			
Ireland	(IE)	ROA	NRA	Yes	Yes			Motorway Maintenance and Renewal Contractors (MMaRCs) funded by TII.			
Spain	(ES)	RAI	ADIF								
	(ES)	MAA	ANIPAR	Yes				Main road managers, concessionaires and at the state, regional or local level authorities and railways managers at the state (ADIF) or regional level authorities, should be responsible for establishing maintenance plans and carrying them out. However, experience shows that rarely all this is put into practice	In many cases, a maintenance control plan is provided by the manufacturer to the client.		
France	(FR)	ROA	NRA	Yes				The state or the conceded highway network depending of the type of roads.			
	(FR)	MAA	SER	Yes				The State or the Departments.	The State directly or indirectly by 55 % in the concessed roads and by 15 % in the Departemental roads		
	(FR)	RAI	SNCF	Yes				SNCF Réseau maintenance department for the structure of NB.	Possibly local authorities for the cleaning of the residents' side or for plantations as the case may be		

		replier		Barrier maintenance - Actors				comments 1	comments 2	comments 3	comments 4
		type	name	Contracting Authority	Contractor	Manufacturer	Other (specify)				
Italy	(IT)	ROA	AUTOSTRADE								
	(IT)	ROA	A. BRENNERO								
	(IT)	ROA	ATIVA								
	(IT)	ROA	A.VENETE								
	(IT)	MAA	UNICMI	Yes	Yes	Yes*		Final client is always in charge of maintenance activities	Contractors are responsible for products defect emerging during the first decade of service life	* Manufacturers are sometimes involved in case of product defects	
	(IT)	MAN	CIRAMBIENTE	Yes				The final client is responsible. A maintenance control plan is provided to client.	Periodic test of visual integrity of noise barrier's elements suche as carpentry, panels and bolts are to be carried on by final client.		
Hungary	(HU)	ROA	NRA	Yes	Yes			Noise barriers shall be maintained by the operator of the road section concerned: Hungarian Public Roads. Inspection and maintenance as per point e) is carried out by our company. The maintenance centre operating the road section concerned is responsible for the task.	Noise barriers damaged by road accidents (which typically involves the replacement of spans) are usually repaired with the involvement of contractors. We always have a frame-work contract for the replacement of damaged panels, posts.	We conclude individual contracts for large-scale repairs and restructuring. In both cases, material (posts, panels etc.) are ensured by the contractor. The road operator specifies the quality requirements of the materials to be used.	In case of replacement, the products shall always have the same parameters (load bearing capacity, sound absorbing and sound reducing capacity) as the barrier that remained undamaged.
Netherlands	(NL)	ROA	NRA	Yes	Yes			Rijkswaterstaat (national road authority) is responsible for maintenance on Noise barriers along the national Highway network, unless there is an formal agreement with local government on maintenance of the object.			
Austria	(AT)	ROA	ASFINAG	Yes				ASFINAG BMG – Abteilung AS			
	(AT)	RAI	OEBB	Yes				The local performance management is responsible for the maintenance.	The central management makes the basic rules.		
	(AT)	MAN	FORSTER	Yes				The authority			
Poland	(PL)	ROA	NRA	Yes	Yes			During the warranty period, the Contractor who built the given road section shall be responsible for the maintenance of the boards. Whereas, after the warranty period expires, maintenance of the noise barriers shall become the responsibility of the road administrator.	In the case of GDDKiA, the maintenance of national roads is performed, as a rule, by contractors selected through tender procedures with whom GDDKiA branches have concluded contracts for the maintenance of the road network which is under administration of the latter.		
Finland	(FI)	ROA	?	Yes				Regional road authorities (Centre for Economic Development, Transport and the Environment) are responsible for the maintenance in the road sector.	The work is purchased from private contractors who are responsible of maintaining noise barriers as contracted.		
	(FI)	RAI	?	Yes				In the railway sector, The Finnish Transport Infrastructure Agency is responsible.	The work is purchased from private contractors who are responsible of maintaining noise barriers as contracted.		
Sweden	(SE)	ROA	TRV	Yes				see comments in question f			
	(SE)	RAI	TRV	Yes				see comments in question f			

		replier		Barrier maintenance - Actors				comments 1	comments 2	comments 3	comments 4
		type	name	Contracting Authority	Contractor	Manufacturer	Other (specify)				
Iceland	(IS)	ROA	NRA?				Yes	Other: The communities are responsible.			
Norway	(NO)	ROA	NRA	Yes	Yes			In the Norwegian Public Roads Administration, the Division of “Operation and Maintenance” is responsible and hands out contracts to contractors.	These data and comments are valid for noise barriers owned by the Norwegian Roads Administration only		
United Kingdom	(UK)	ROA	England Highways	Yes				Highways England Operational teams			

6.7 Question g

		replier		Barrier EOL (decommissioning) - Aspects			comments 1	comments 2	comments 3	comments 4
		type	name	Global	Detail 1	Detail 2				
Belgium	(BE)	ROA	VL	No			No decommissioning strategy. Expected life span 30-50 years, depending of the materials.	The inspections are meant to replace the oldest of most damaged noise barriers	Future plan for measuring acoustic performance over time of (older) barriers.	
	(BE)	ROA	W	Yes			Considering the HI of the noise barriers a program of restoring is implemented in the Walloon invest plan for roads and highways. Each 5 years a new plan is planned and devices are planned to be restore using the objective approach of inspection.	For example see attached the noise barrier in Hauts-Sarts (Liège). We analysed the need of restoring the device. It had a HI “A”.		
Bulgaria	(BG)	ROA	NRA	No			At this moment, no experience regarding end-of-life of the devices, because all of them are relevantly new.			
Czechia	(CZ)	ROA	NRA	No			There is no reason for complete decommiossioning, old one is replaced by new one.	Need for barriers is regulated by government regulation under the law setting the imposed noise limits		
	(CZ)	RAI	NRA	Yes			We have relatively new noise barriers. We have been building them massively since 1995. We still have to change only a small amount of them.	They are mainly plastic panels. We do ecological disposal and replacement of panels from new materials. We do not return plastic.		
Denmark	(DK)	ROA	NRA	Yes			The road administration will ask a contractor to dismantle the noise barrier in accordance with relevant legislation in the field.			
Germany	(DE)	ROA	NRA	Yes			The lifetime of a noise barrier is mainly determined by its stability. If this is not given any more due to damages etc., the decommissioning is planned. It is to decide whether a restoration or a complete renewal of the barrier is carried out.	In the latter case, a new noise assessment and a new dimensioning of the barrier might be useful to re-evaluate the situation and ensure a sufficient noise protection level.	The removal of the barrier and the disposal of the materials is carried out by external companies in agreement with the valid environmental requirements.	
Ireland	(IE)	ROA	NRA	No			Currently, end-of-life phase is not managed in accordance with circular economy thinking or sustainability. However, to date, we have had very few failures that require replacing.	The majority of our barrier asset has only been installed since 2004. Recent work by TC226/WG6/TG4 is being considered by MMaRCs and TII are currently finalising a companywide Sustainability Implementation Plan which will affect all aspects of TII business including environmental noise barriers.		
	(ES)	RAI	ADIF							

		replier		Barrier EOL (decommissioning) - Aspects			comments 1	comments 2	comments 3	comments 4
		type	name	Global	Detail 1	Detail 2				
Spain	(ES)	MAA	ANIPAR	No			In Spain, and although the oldest acoustic barriers installed already have around 30 years of service life, the authorities for the moment have not considered their dismantling or rehabilitation, so there is no experience in this regard			
France	(FR)	ROA	NRA	No			Reflexions are in progress on this aspect but main noise barries materials seem to be disposed of in landfills			
	(FR)	MAA	SER	No			There are only very few exemples of dismantling and recycling of barriers			
	(FR)	RAI	SNCF	No			We don't have decommissioned NB as far as known but we begin to consider this part of the work in our specifications established in a public consultation document (re-use of material, recycling solutions, …).			
Italy	(IT)	ROA	AUTOSTRADE							
	(IT)	ROA	A. BRENNERO							
	(IT)	ROA	ATIVA							
	(IT)	ROA	A.VENETE							
	(IT)	MAA	UNICMI	No			End of life phase is always responsibility of the road manager.	Manufacturers are often required to declare CER categories of products used. The aim is to manage the disposal of the barrier at the end of the life.		
	(IT)	MAN	CIRAMBIENTE	No			We do not manage the end of life phase.	It is in charge of the final client or owner of the infrastructure (or the managing company of the infrastructure).		
Hungary	(HU)	ROA	NRA	Yes			At the end-of-life phase of a noise barrier, we ensure for the planning of the new barrier, whereby we review its desired acoustic parameters and parameters concerning height, length. We conclude individual contracts for the planning and for the execution (decommis-sioning, installation).	Materials (posts, panels etc.) are purchased by the contractor. The contractor shall deliver the non-reusable components to our maintenance centre.	Undamaged components shall be considered as national assets and our Company shall strive to reuse them or they can be sold for a price above a state-imposed minimum price	The damaged, non-reusable components shall be considered as waste and accordingly transported by the contractor after scrapping
Netherlands	(NL)	ROA	NRA	Yes			We have very little experience with NRD's that reach end of live stage. Most older NRD's are removed in road widening projects, decommissioning is then a responsibility of the contractor.	Recently 3 NRD's have been nominated for replacement, (bad maintenance situation). Also here the contractor will be responsible for removing the old existing structure, and building a new one.		

		replier		Barrier EOL (decommissioning) - Aspects			comments 1	comments 2	comments 3	comments 4
		type	name	Global	Detail 1	Detail 2				
Austria	(AT)	ROA	ASFINAG	Yes			Defekte Lärmschutzwände werden grundsätzlich saniert oder neu errichtet.	Die beauftragte Baufirma ist für die ordnungsgemäße Entsorgung der alten Lärmschutzwand verantwortlich		
	(AT)	RAI	OEBB	Yes			Changing the elements with new ones (same material)	There is again a “framework agreement” for disposals. That includes old noise barriers and there used materials.	Changing noise barriers for different elements and construction (including statics, track speed,…)	
	(AT)	MAN	FORSTER	No			Fortunately, at this time the end-of-life phase of aluminium noise barriers is not yet reached.	The wooden elements (damaged, …) are replaced after appr. 15 years.		
Poland	(PL)	ROA	NRA	Yes			The damaged noise barriers, the repair of which is not possible, shall be disposed of or recycled, depending on the type of material they are made of.			
Finland	(FI)	ROA	?	Yes			Measures depend on the barrier and it's material. Manufacturers are required to deliver detailed guidance. Some aspects are also given in the NRA's design guidelines.	Waste is handled according to waste legislation and municipal waste management regulation.		
	(FI)	RAI	?	Yes			Measures depend on the barrier and it's material. Manufacturers are required to deliver detailed guidance. Some aspects are also given in the NRA's design guidelines.	Waste is handled according to waste legislation and municipal waste management regulation.		
Sweden	(SE)	ROA	TRV							
	(SE)	RAI	TRV							
Iceland	(IS)	ROA	NRA?	No			Not in our care			
Norway	(NO)	ROA	NRA	Yes			Only authority demands due to waste management.	These data and comments are valid for noise barriers owned by the Norwegian Roads Administration only		
United Kingdom	(UK)	ROA	England Highways	Yes			On a project-by-project basis -normally an end-of-life barrier will be replaced by a new noise barrier- often the new barrier is upgraded in terms of size or performance compared to the old one.			

6.8 Figure 1 enlarged

		replier		Sound absorbing (m²)											
		type	name	Concrete	Wood	Steel	Alu	Transparant Plastics	Opaque Plastics	Green Vegetation	Other	comments 1	comments 2	comments 3	comments 4
Belgium	(BE)	ROA	VL	222.806	23.806		179.254		22.950	21.546	22.860	ireen NB stacked concrete or lastic elements with vegetation or rapezoidal NB with vegetation.	Steel & Alu are added together. Majority is Alu	Other Absorbing (22 860 m²) = Kokos Other Reflecting (3 803 m²) = Wall	Berm barriers (made out of soil) are not included (161 155 m²)
	(BE)	ROA	W	8.917	41.172	155.681			1.743			ata concern only road network nanaged by SPW Mobility and nfrastructures.	Alu: sum of Steel and Alu		
Bulgaria	(BG)	ROA	NRA		2.461		51.820					Most of Alu combined with ransparent plastic or fiberglass eparate panels			
Czechia	(CZ)	ROA	NRA	yes	yes		yes				yes	Other: recycled Plastic, Rubber	Absorbing Concrete: light weight concrete or wood cement composites	Reflecting: generally on bridges	
	(CZ)	RAI	NRA	502.500	37.910	230	8.600		90.900			Other reflecting: brick	We have several noise barriers with rubber material (approx 600 m2).		
Denmark	(DK)	ROA	NRA				yes								
Germany	(DE)	ROA	NRA	.299.140	1.337.510		2.675.020					ince 2008, material-specific data n noise barrier constructions is not ollected (any more), only total umbers of installed and removed oise barriers. The numbers are ough estimations based on ercentages from older data. In the 007-statistics the distribution of oise barrier types was: 45% oncrete, 28% aluminium, 14% vood and 12% transparent naterials (glass or plastics). As for oday, this distribution can be ssumed to be approximately valid.	Regarding the part of reflecting barriers, it can be assumed that the transparent barriers are sound reflecting, whereas the other materials are mainly absorbing or highly absorbing.	The total amount of noise barriers on federal highways and roads: 9 553 645 m² (2019) at a length of 2 594 km	
												Alu:	Sound reflecting Concrete:		

template | question a | question b | question c | question d | question e | question f | question g