# LIFE E-VIA

## Electric Vehicle noIse control by Assessment and optimisation of tyre/road interaction

LIFE18 ENV/IT/000201

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| **Deliverable** | Guidelines B6 |
| **Content** | Guidelines for public and private bodies on implementation of mitigation actions |
| **Action/Sub-action** | Action B6: *Evaluation of EV noise emission* – Sub-action B6.4 |
| **Status - date** | Final draft version – 31-01-2023 |



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## Document history

| Version | Date | Contributor | Input |
|---|---|---|---|
| 0.0 | 01-10-2022 | F.Bianco and F.Brocchi | Document created |
| 1.0 | 06-11-2022 | F.Bianco and F.Brocchi | Draft of the document completed |
| 1.5 | 11-12-2022 | F.Bianco and F.Brocchi | Second draft |
| 1.9 | 13-01-2023 | F.Bianco and F.Brocchi | Third draft |
| 1.95 | 31-01-2023 | F.Bianco and F.Brocchi | Final draft |

**Keywords**: electric vehicles, vehicle noise emission, tyre-road noise, close-proximity noise, low-noise asphalt concretes, rubberised asphalt concrete, crumb rubber, surface texture, sound absorption, tenders, noise reduction in urban environments.

# Table of contents

# 1 Introduction

Noise exposure data from the European Environment Agency (EEA) [1] showed that more than 100 million EU citizens are exposed to noise levels that impact human health. Specifically, road traffic alone is a source of health hazard for nearly one in three people in the EU. At least one in five people are regularly exposed to potentially health-damaging nighttime noise levels, especially in highly urbanized areas. To address this, an increased attention is needed on the acoustic impact topic, particularly to reduce noise directly from the sources, but also to implement additional measures such as improving the noise emission performance of road surfaces or tires. Careful urban planning is another important factor to contain noise emission, potentially impacting both the strength of the sources and their proximity to the receivers.

The main objective of the Life E-VIA project is to reduce road noise within densely populated urban areas through the implementation of mitigation measures aiming at optimizing the road surface and tires of electric vehicles.

The Life E-VIA project focuses attention on evaluating and reducing the noise emitted by the future electric mobility, specifically addressing the optimization of tire/surface interaction. This noise contribution (dominant for stationary speeds greater than 40km/h) is actually even more prevalent, compared to the noise emitted by the engine, for electric vehicles.

From the results of the project, on the basis of what has been achieved in terms of design, application, experimental results, and on the outputs obtained, these guidelines have been drawn up, with the aim of giving support to public administrations and private entities on:

- Raising awareness related to the problem of road noise in densely populated urban areas;
- The application of noise mitigation measures, such as ***Low Emission Noise Asphalt***;
- The drafting of the call for proposals;
- The experimental validation of the results obtained;
- The predictive evaluation that can be carried out, based on the results of the project.

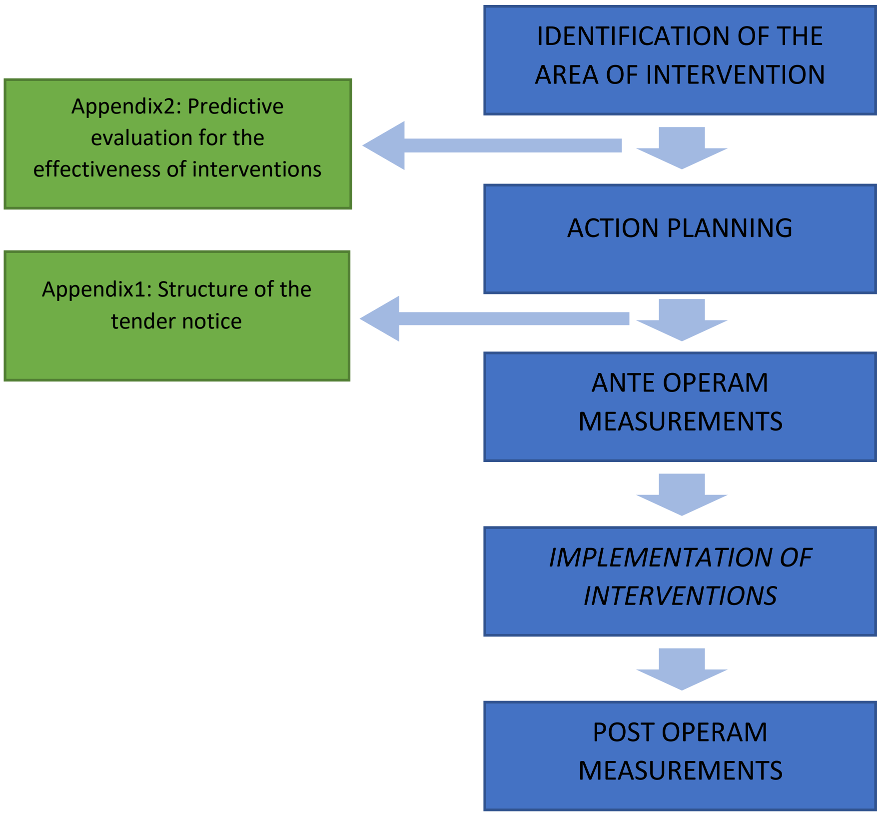
# 2 Relevant regulations and standards

The following is a non-exhaustive list of reference regulations and technical standards useful in the application of the guidelines.

- EU Directive:
  - Environmental Noise Directive 2002/49/EC [2]: The Directive aims to establish a common EU approach to avoid, prevent or reduce the harmful effects of exposure to environmental noise;
  - COMMISSION DIRECTIVE (EU) 2015/996 [3]: The Directive establish common noise assessment methods according to Directive 2002/49/EC of the European Parliamen;
- Technical Standard:
  - ISO 11819-2:2017 Acoustics — Measurement of the influence of road surfaces on traffic noise — Part 2: The close-proximity method [4]: ISO 11819-2:2017 specifies a method of evaluating different road surfaces with respect to their influence on traffic noise, under conditions when tyre/road noise dominates;
  - ISO 13472-1:2022 Acoustics — Measurement of sound absorption properties of road surfaces in situ — Part 1: Extended surface method [5]: This document describes a test method for measuring in situ the sound absorption coefficient of road surfaces as a function of frequency in the range from 250 Hz to 4 kHz;
  - ISO 13472-2:2010 Acoustics — Measurement of sound absorption properties of road surfaces in situ — Part 2: Spot method for reflective surfaces [6]: ISO 13472-2:2010 specifies a test method for measuring in situ the sound absorption coefficient of road surfaces for the one-third-octave-band frequencies ranging from 250 Hz to 1 600 Hz under normal incidence conditions. For special purposes, the frequency range can be changed by modifying the dimensions of the system.
  - ISO 13473-1:2019 Characterization of pavement texture by use of surface profiles — Part 1: Determination of mean profile depth [7]: This document describes a test method to determine the average depth of pavement surface macrotexture by measuring the profile of a surface and calculating the texture depth from this profile. The technique is designed to provide an average depth value of only the pavement macrotexture and is considered insensitive to pavement microtexture and unevenness characteristics.
- Italian National Standard:
  - DMA 16/03/1998 [8]: The decree specifies techniques for detecting and measuring noise pollution;

# 3 Work flowchart

The elements that make up the application of the guidelines are summarized in the following flow chart.



# 4 Identification of the area of intervention

Sites of potential interest for the implementation of the indicated mitigation strategies will be selected by public administrations (or private operators) basing the decision on specific needs. This should be done within the implementation of the Action Plans for Agglomerations and Major Roads as indicated in the Environmental Noise Directive 2002/49/EC [2].

The definition of critical areas, functional for the application of the above strategies, may be conducted on a subset of areas in the city agglomeration that meet the characteristics necessary for efficient application of mitigation strategies. Specifically, all those areas should be considered:

- Located within densely populated urban fabric;
- Affected by traffic flows with a high proportion of electric vehicles;
- With traffic flow speeds between 40 and 70 km/h;
- With moderate traffic flow of heavy vehicles.

Once the urban areas and contextual roadways that comply with the above indications have been identified, critical areas may be identified from the point of view of noise, both with respect to the level of noise (daytime, evening, and nighttime) assessed in front of receptors and the number of people exposed. Alternatively, if the managing body is aware of areas that are particularly critical and in need of noise mitigation measures, these may also be evaluated regardless of the algorithmic assessment that may be present within the Action Plan.

Where no specific information is available, ad hoc mapping can be carried out using the criteria described in the Environmental Noise Directive 2002/49/EC [2] and Directive 996/2015 [3]. These methods, by means of specific noise propagation models (e.g., the CNOSSOS method), together with input information such as orography of the territory, characterization of the built-up area, number of exposed residents, etc., allow to assess the level of noise perceived at the façade of buildings, based on physical and acoustic characteristics of the sources under investigation (for roads: traffic flow divided into categories, speed, type of asphalt...). By means of such modeling carried out specifically for areas under investigation by the managing body, the current state of the area and the noise reduction offered by mitigation interventions such as the adoption of traffic policies that favor the presence of electric vehicles or the construction of new asphalts, in line with what has been carried out in the E-VIA project, can be evaluated, even forecasted (See Appendix 2). Such interventions can of course be coupled with other types of mitigation if deemed necessary.

# 5 Action planning

As already specified, the noise contribution related to road traffic in urban areas is a function of the characteristics of vehicular flow on the roadway. Based on the interventions implemented, a reduction (or, predictively, an assessment of the potential reduction) of the noise emitted by the road system under analysis is aimed at. The planned interventions on the road system can, in a twofold way, both foster electric mobility policies that will increase the percentage of electric vehicles in the area, and carry out asphalt resurfacing, in accordance with the results obtained in the E-VIA project.

The study of asphalt mixes and tire-road interaction has enabled in recent years the identification of mixtures that best meet the needs of designers involved in the mitigation of noise from traffic, without neglecting the standards of safety and durability of the materials used.

"Rubberized asphalts," i.e., asphalt mixes asphalts modified with crumb rubber, have been known for more than four decades, but only recently have attracted the attention of designers of road infrastructure, precisely because of their lower noise levels compared to other conventional materials.

Low-noise pavements represent the main tool for direct source noise reduction, and several technologies are now available that differ in composition, materials used and field of use. Proposed below is a review of the main alternatives.

There are several paving methodologies that contribute to noise mitigation. Open pavements (draining and sound-absorbing) have some constraints: the surface layer must be generally at least 4 cm thick, below which it is recommended that a layer of open binder also be paved, with a larger grain size to promote the flow of water from the layer on top. In addition, such pavements, require maintenance, as, in case of pore occlusions, performance is significantly lowered. Such pavements are recommended on high-flow, and high-speed roadways so that the pores can be cleaned by the air pressure exerted by the wheels hitting the asphalt. All these constraints make open pavement an unrecommended choice for the urban area of thin pavements, underlying layers that do not usually allow drainage, and flow characterized by modest speeds and frequent "stop & go." Therefore, low-emission pavements, such as optimized texture pavements, are recommended in urban area with moderate flow.

# 6 Pavement technology and Tender specifications

Following the selection of the focus area, planning a tender is recommended according to the specifications described in Appendix 2. The data and technical specifications of the maintenance and acoustic mitigation works to be carried out on the road surface, in accordance with the results obtained in the E-VIA project, are given. A complete description of both specific characteristics and mechanical or rheological tests is well described in the B1 Action Report, particularly related to the B1.5 sub-action on the final pavement design, while here the main results are presented in order to define the tender characteristics.

## *6.1 Pavement technology*

The pavement industry is constantly trying to develop new solutions to obtain a better, from a mechanical, acoustic and durability points of view, and eco-friendly product. Within a strict collaboration with the EU and its funded research and innovation project new technologies are constantly developed and put to the test. One specific result is taken as an important part of the E-VIA new pavement mixture, the RARX crumb rubber addictive developed during the project Silent Rubber Pave [13],[14]. This particular solution overcomes many problems that arise from the introduction of crumb rubber in bitumen mixes, leading to a potential increase in fatigue resistance and, consequently, in the asphalt pot life.

## *6.2 Pavement costs and LCA*

The E-VIA Project conducted studies on both the expected long term costs and LCA (life cycle analysis) that allow a very extensive comprehension of what can be expected from the developed crumb rubber pavement solution not only from a performance point of view, but on the impact it can have during all its expected lifetime. The analysis approach can be described as “from cradle to grave”: laying (with its inherent necessities in terms of milling the old pavement, the production of the new one, the transportation of components and finally the construction), maintenance and dismission are all taken into account.

Details on all the procedure are showed in the C2 Report of the Project, but can be summarized as a cost that is essentially equivalent to the one of a reference pavement when the longer expected life of the E-VIA solution is taken into account. The agency costs are calculated in the range of 31 to 34 €/m$^2$, with the main contributions from the maintenance and production phases. This calculation is including a main maintenance operation (surface milling and reconstruction of the friction layer) during the lifecycle of the pavement of about 16 to 18 years.

Other direct impacts can be considered when discussing the E-VIA pavement: the depreciation induced by noise on houses surrounding a given area and the landfill space avoided in terms of exhausted tyres. The first factor is linked directly on the better acoustic performances of the pavement, while the other on the use of crumb rubber in its composition.

## *6.3 Tender specifications*

Before on-site construction works, the contractor must produce aggregate qualification certificates complying with requirements.

This mixture is going to include mineral aggregates, crumb rubber (dry method) and bitumen.

Both the specification for the gradation, bitumen, coarse aggregate, fine aggregate and filler are provided in the tables below.

*Table 1 - Aggregate gradation and bitumen percentage*

| Sieve openings [mm] | Min | Max |
|---|---|---|
| 14 | 100 | 100 |
| 8 | 99 | 100 |
| 5.6 | 75 | 97 |
| 4 | 58 | 92 |
| 2 | 26 | 61 |
| 1 | 20 | 45 |
| 0.5 | 15 | 28 |
| 0.25 | 9 | 18 |
| 0.063 | 6 | 11 |
| | | |
| Bitumen percentage [% w/w] | 5.2 | 6.1 |
| RARX percentage [% w/w] | 1.8 | 2.0 |

*Table 2 - Bitumen quality, with an expected asphalt binder type 50/70; in case of the inclusion of additives (including fibers) the performances specified are still to be met*

| Parameter | Standard | TypeA |
|---|---|---|
| Penetration at 25°C [dmm] | EN1426, CNR24/71 | 50-70 |
| Softening point [°C] | EN1427, CNR35/73 | ≥ 65 |
| Breaking point (Fraass) | EN 12593 CNR43 /74 | ≤ -15 |
| Dynamic viscosity at 160°C, $\gamma = 10s^{-1}$ | PrEN 13072-2 | ≥ 0,4 |
| Elastic recovery at 25 °C | EN 13398 | ≥ 75% |
| Storage stability 3days at 180°C- softening point variation | EN 13399 | ≤ 0,5 |
| After RTFOT | EN12607-1 | |
| Volatility | CNR54/77 or equivalent | ≤ 0,8 |
| Residual Penetration at 25°C | EN1426, CNR24/71 | ≥ 60 |
| Increase in softening | EN1427, CNR35/73 | ≤ 5 |

*Table 3 – Coarse Aggregate*

| Retained at 5mm round sieve (UNI n. 5) | | | |
|---|---|---|---|
| **Parameter** | **Standard** | **Unit of measure** | **Threshold** |
| Los Angeles | CNR 34/73-UNI EN 1097-2 | % | ≤ 20 |
| Micro Deval | CNR 109/85-UNI EN 1097-1 | % | ≤ 15 |
| Crushed and broken surfaces | UNI EN 933-5 | % | 100 |
| Maximum size of aggregates | CNR 23/71 - UNI EN 933-1 | mm | 20 |
| Freezing and thawing cycles. | CNR 80/80 – UNI EN 1367-1 | % | ≤ 30 |
| Boiling water stripping test | CNR 138/92 - UNI EN 12697-11: | % | 0 |
| Passing to 0.075mm | CNR 75/80 - UNI EN 933-1 | % | ≤ 1 |
| Shap coefficient | CNR 95/84-UNI EN 933-4 | | ≤ 3 |
| Aggregate flakiness | CNR 95/84- UNI EN 933-3 | | ≤ 1,58 |
| Flakiness index | CNR 95/84 -UNI EN 933-3 | % | ≤ 20 |
| Porosity | CNR 65/78 - UNI EN 12697-8 | % | ≤ 1,5 |
| Polishing stone value | CNR 140/92-EN 1097-8 | % | ≥ 45 |

*Table 4 – Fine Aggregate*

| Fine aggregates (passing to the round sieve n.5mm, UNI n. 5) | | | |
|---|---|---|---|
| **Quality indicators** | | | |
| ***Parameter*** | ***Standard*** | ***Unit of measure*** | ***Threshold*** |
| Sand equivalent | CNR 27/72 – EN 933-8 | % | ≥ 80 |
| Passing percentage at 0.075mm | CNR 75/80 -UNI EN 933-1 | % | ≤ 2 |
| Percentage of crushed and broken surfaces in coarse aggregate particles | CNR 109/85 – UNI EN 933-5 | % | 100 |

*Table 5 – Filler*

| Filler (lower than 0.075mm) | | | |
|---|---|---|---|
| ***Parameter*** | ***Standard*** | ***Unit of measure*** | ***Threshold*** |
| Boiling water stripping test | CNR 138/92 – UNI EN 12697-11 | % | ≤ 5 |
| Passing percentage at 0.18 mm | CNR 23/71- UNI EN 933-1 | % | 100 |
| Passing percentage at 0.075 mm | CNR 75/80 – UNI EN 933-1 | % | ≥ 80 |
| Plasticity index | CNR-UNI 10014- ASTM D4318 | | N.P. |
| Rigden voids - voids of dry compacted filler | CNR 123/88- EN 1097-4 | % | 30-45 |
| Stiffening Power (filler/bitumen = 1.5) | CNR 122/88- EN 13179-1 | ΔPA | ≥ 5 |

Admissible time between mixture production and on-site laying: approximately less than two hours under given assumptions and conditions (insulated truck beds, tarps covering the load, and many other boundary conditions).
Minimal temperature during laying process: about 125-140°C.
Compactor suggested: <10 tons, static mode.

On-site construction, including machines (and their characteristics), joints, procedures, materials, timing, temperatures, will be detailed by the contractor and submitted to the client for approval. The client will carry out controls and will apply pay adjustments based on acceptance procedures. On site density, in 95 cases out of 100, must be higher than the 95% of in-lab density (DG or DM).

# 7 Ante-Post Operam Measurements

This section focuses on methods for experimental evaluation of the acoustic performance of interventions implemented in accordance with these guidelines.

Measurement protocols are established based on current regulatory standards that can help stakeholders evaluate the acoustic performance of interventions.

A series of measurement methodologies are given, divided by type and including the normative references useful for understanding them, together with a brief description of the measurement protocol to be adopted. The following table shows the methods and indicators to be taken into account in connection with the application of the mitigation works under consideration, and will then be made explicit in the following paragraphs.

| Method | Ante Operam | Post Operam | Standards | Indicator | Mandatory/Facultative |
|---|---|---|---|---|---|
| Environmental Noise Levels | X | X | DMA 16/03/1998 [8] 2002/49/EC [2] | $L_{DEN}$, $L_{night}$, $L_D$, $L_N$, [...] | Mandatory |
| CPX | X | X | ISO 11819-2 [4] | $L_{CPX}$ | Mandatory |
| Sound Absorption | | X | ISO 13472-1 [5] ISO 13742-2 [6] | Spectrum of absorption | Facultative |
| Mechanical Impedance | | X | | | Facultative |
| Road texture level | X | X | ISO 13473 [7] | MPD, Texture spectrum | Facultative |
| Surveys | X | X | | Perception of traffic noise, soundscape quality, disturbance, etc… | Facultative |

## *7.1 Environmental Noise Levels*

The ante and post operam evaluation of noise levels produced by the roadway under investigation turns out to be indispensable in order to correctly characterize the area and the effect on any intervention carried out. Italian standards stipulate which specific parameters to measure, as well as the measurement setup and instrumentation required.

Spectral levels, in addition to the parameters already provided for in the standards described above, may also be evaluated in order to assess possible improvement in specific frequency bands.

It is recommended that acoustic monitoring measurements are carried out in the vicinity of the roadway under analysis for at least one week before and after construction. The microphone should be placed, where possible, at a height of 4m and at a distance of 1m from the facade of the building chosen as representative.

It is also recommended that, in addition to the phonometric assessment, measurements of traffic flow and meteorological conditions should also be carried out in order to exclude periods with conditions that are not accepted by the above standard.

As for limits, these must be evaluated according to specific national regulations (e.g. for Italy, DPR 142/2004 [9] or DPCM 14/11/97 [10]).

## *7.2 CPX*

The method is described in ISO standard 11819-2 [4], and allows the measurement and characterization of noise emitted from the road surface, as well as evaluating the effect of maintenance and homogeneity conditions along its length.

The indicator described in the standard is called "tire/road Sound Level" ($L_{CPX}$). It is recommended to evaluate both the absolute value and the ante and post operam difference, realized under the same driving and environmental conditions except for the mitigation measures taken (road surface renewal).

The CPX measurement is carried out using a trolley or a self-powered vehicle. Noise values are measured on the vehicle under test using two microphones, positioned 0.2m from the wheel axis and 0.1m from the road surface. The position of the microphones will allow only the noise contribution emitted by the wheel/asphalt contact to be evaluated. At least three passes will have to be made, for each reference speed that needs to be evaluated according to the typical use of the road.

This measurement protocol does not require road closure (although it is recommended): measurements can also be conducted, except in special cases, when the road is open, possibly during the night period, if it is verified that it is possible to properly perform the passages at a constant speed for the entire stretch of interest. Although it must be considered that the measuring vehicle should proceed on the road at a constant speed along all the length that must be evaluated, so it’s important to evaluate with care if safety can be assured without road closure or at least with controls at potential intersections.

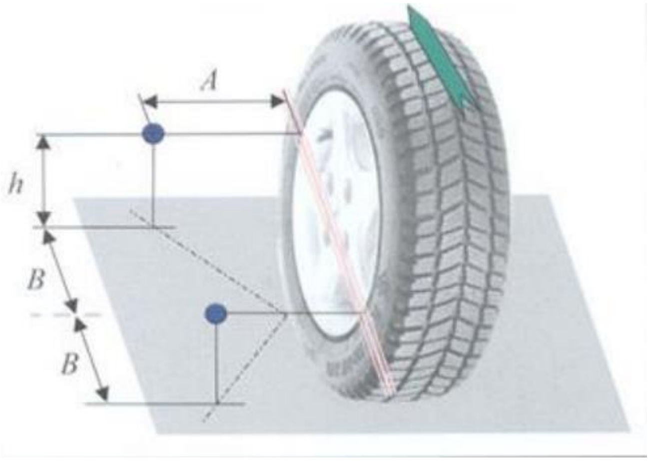
As for the limits on the measured levels, these will have to be evaluated according to specific regulations. For example, reference can be made to the Report "Revision of Green Public Procurement Criteria for Road Design, Construction and Maintenance" [11] (hereafter referred to as GPP), published by the European Commission, in order to indicate to member states the EU criteria for green public procurement in road design, construction and maintenance. According to this measurement protocol, the road section is to be divided into 20-m sections and the data are corrected in temperature and tire hardness. The analyzed pavement will then be described in terms of the spatial average valor, with associated measurement uncertainty, and the spatial variance of the estimated levels for each 20-m section.

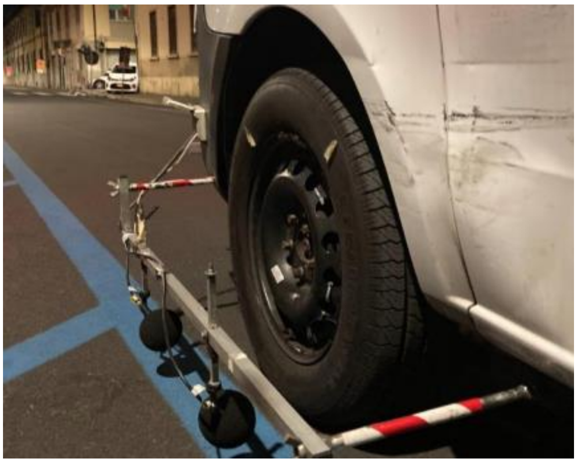
The results will then be compared with the upper limits that the GPP sets for verification of production compliance and durability of low-noise pavement acoustic performance. The limits are given below:

| | |
|---|---|
| **VERIFICATION OF PRODUCTION CONFORMITY**<br>(after 4-12 weeks from the opening of the road) | The results including their own uncertainty must not exceed the following limit values (*) by more than 1 dB(A):<br>- 90 dB(A) at 50 km/h,<br>- 95 dB(A) at 70 km/h,<br>- 98 dB(A) at 90 km/h.<br>In addition, no single element of the test section shall exceed the above limits by more than 2 dB(A). |
| **VERIFICATION OF THE DURABILITY OF PERFORMANCE**<br>(during the period of 5 years after the production conformity test) | The results including their own uncertainty must not exceed the following limit values (*) by more than 1 dB(A):<br>- 93 dB(A) at 50 km/h<br>- 98 dB(A) at 70 km/h<br>- 101 dB(A) at 90 km/h.<br>In addition, no single element of the test section shall exceed the above limits by more than 2 dB(A). |
| (*)The values not to be exceeded are those indicated with the project (if lower). | |

Having to compare the result with an upper bound value, the associated uncertainty is presented with 95% coverage factor of k = 1.645 calculated on a one-sided distribution.

A sample image of the measurement setup is shown.



The E-VIA special pavement has been studied to be a low noise surface, guaranteeing compatibility with the GPP [11] standard and exceeding it by presenting at production values below 88 dB(A) at 50 km/h (including uncertainty) as per results of the project.

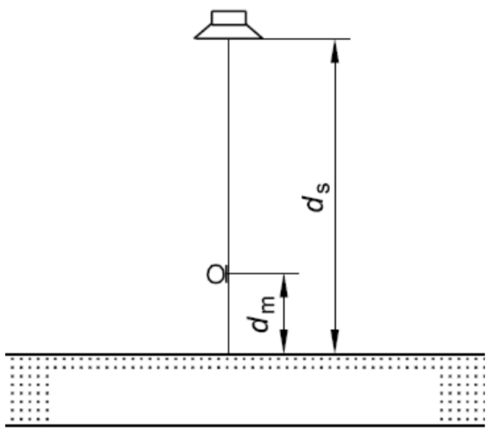
## *7.3 Sound Absorption*

The sound absorption of the pavements will be evaluated mainly in the post operam phase, although if deemed of interest it may also be carried out in the ante operam phases in order to assess the possible improvement achieved at least in terms of homogeneity along the road.

A summary description of the two main measurement methods is given.

### *7.3.1 Extended Surface*

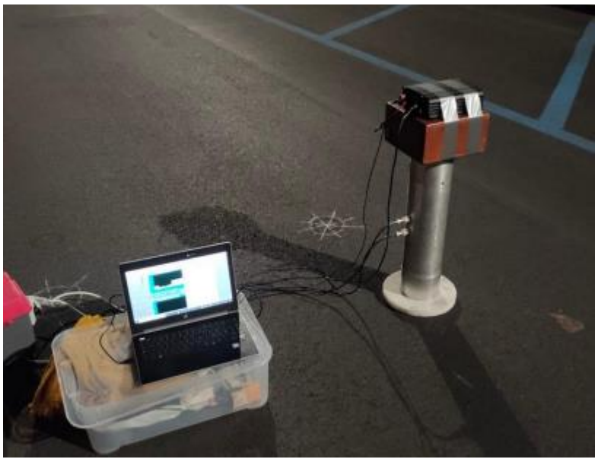
With reference to ISO 13472-1 [5] involves the use of a loudspeaker and from a signal acquisition microphone, using a time subtraction technique. Sample images of the measurement station are shown:

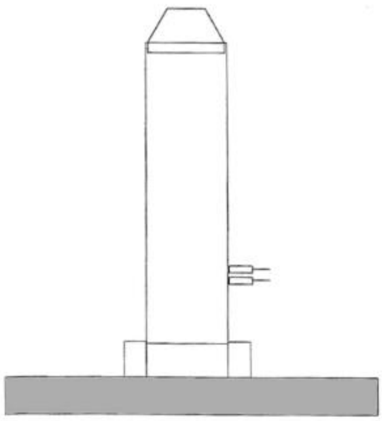



This measure, given its characteristics, is more appropriate for absorbent pavements.

### *7.3.2 Impedance/Kundt Tube on Site*

With reference to ISO 13472-2 [6] it involves the use of an impedance tube, with dual microphone and loudspeaker, using an FRF technique. It can be described as a "point" measurement. Sample images of the measurement station are shown:





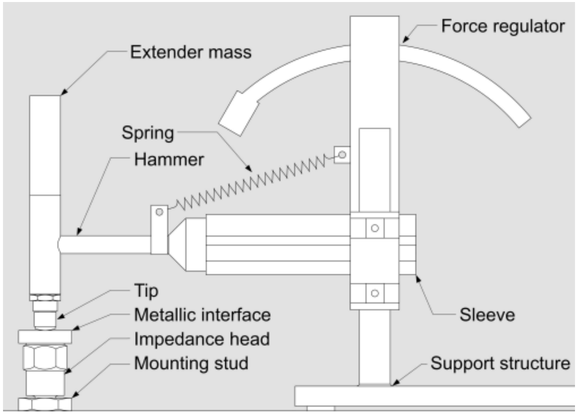
This measure, given its characteristics, is more appropriate for reflective pavements such as the E-VIA one.

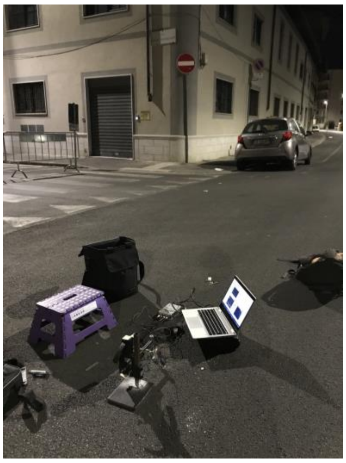
## 7.4 *Mechanical impedance*

Mechanical impedance is an important parameter for evaluating the stress resistance of road pavements, but it is also related to rolling noise. The mechanical impedance of a material is a measure of its resistance to elastic deformation, and is defined as the ratio of applied force to resultant displacement.

The measurement can be conducted by means of an instrumented hammer with impedance head, as comprehensively described in "Road pavements' dynamic stiffness measurements by means of impact hammer in a non-resonant configuration." [M.Bolognese, E.Greco, F.Bianco, G.Licitra] [12].

Images of the measurement setup, also carried out as part of the Life E-VIA project, are shown.



## 7.5 Road texture level

The protocol regarding the acquisition and subsequent processing of road texture data is expressed in the UNI EN ISO 13473 series [7]. Texture measurements are performed using a laser profilometer whose operation is based on the optical principle of triangulation. It is recommended, in order to maximize the correlation of data with $L_{CPX}$ levels, that the section be divided into sections of 20 m of length.

## 7.6 Surveys

Through the use of surveys, the perception of those exposed to noise, in the area where noise mitigation is planned, may be assessed. Such questionnaires may be conducted through on-site interviews, by telephone, or questionnaires (paper or web-based).

All surveys must comply with national privacy laws and ethical requirements.

The main objective of the surveys will be to assess the improvement in noise perception related to noise emitted as a result of noise mitigation. For the Life E-VIA project, the questionnaire consisted of 16 questions divided into two sections. The first section on "personal information," consisting of 6 questions, was designed to obtain data in relation to respondents' age, gender, education, occupation, city of residence and nationality. The second part turned out to consist of a set of 10 questions focusing on: dwelling location and window orientation, noise perception and annoyance, expected effects of the intervention and noise reduction, and noise sensitivity.

Managing bodies may, if necessary, supplement or customize the questionnaire based on the specific characteristics of both the area affected by the noise mitigation interventions, the type of road system in place, and specific characteristics of residents.

Questionnaires and surveys of the exposed population were conducted for the E-VIA project. An example of the questionnaires used is given in Appendix 3.

# 8 Expected pavement performances

E-VIA project results, reported in great detail within *Report B4 - Characterization of the Pilot Area and EV noise measure*, allow to have a first evaluation about what can be expected from the pavement's acoustic performances. The Pilot Area of Via Paisiello in Firenze was the first actual implementation in a real urban environment of the new solution and showed the following results, here shown for both the low noise reference pavement and the E-VIA one, for the first and last CPX measurements on the laying:

| Measurement session | Reference Lcpx dB(A) | **E-VIA Lcpx dB(A)** |
|---|---|---|
| First – October 2021 | 89.8 | **87.6** |
| Last – October 2022 | 90.4 | **89.3** |

The E-VIA pavement had an initial Lcpx value that is below the threshold of the verification of production conformity and almost presenting a value below the comprehensive limits for very low noise pavements of 87 dB(A). Better results should be expected with the consolidation of production and laying techniques for crumb rubber pavement in urban environments. The acoustic emission of the special pavement maintained the conformity with the stricter production limit even a year after the laying, when the actual reference limit should be the durability of performance of 93 dB(A). The aging is not expected to be linear, but it follows a logarithmic trend, allowing the compliance with the GPP limits event within the 5 year after the production.

# Appendix 1: Structure of the tender notice

Following the mitigation project in the identified area, in order to draft the tender notice, it will be necessary for the notice to contain both the minimum requirements that will ensure the proper implementation of the intervention and the specifications to which the contractor must adhere.

The contracting station shall provide, at the same time as the issued requests, all information relevant to the characterization of the project, such as:

- General planimetry of the intervention at a scale of 1:10000 and at a scale of 1:2000, where both the general context and the specific area of the intervention sections are indicated, including the areas being resurfaced;
- Detailed plans of intervention at a scale of 1:1000/1:500 showing the area of the roadway, any obstacles, precise dimensions of the work;
- Construction details of the type of road resurfacing at a scale of 1:25.

It then is necessary to specify:

- The methods and timing for acceptance of materials, the documentation to be provided, the person responsible for acceptance;
- The contractor's obligations regarding materials and the checks to be carried out on them, in accordance with the quality system adopted;
- The ante/post operam checks and eventually the values to be adhered to, as well as the possibility of implementing in-process checks. It is recommended that targets be set relative to expected performance, and used as rewarding criteria for the contractor. i.e.:
    - LCPX ≤ 87 dB(A);
    - Sound Absorption Index: homogeneous along the road surface and, possibly, with values less than 0.15 ÷ 0.20.

  In any case, non-derogable limits should be maintained, such as compliance with the values given in the GPP [11].

The criteria for selecting the tender will then have to be chosen. Italian law provides for two criteria: maximum bid and most advantageous economic bid.

Based on Italian law, depending on the value of the notice, different methods such as: direct award, negotiated procedure, open procedure may be evaluated.

It is preferable, in the case under consideration, to indicate as the criterion of choice that of the most advantageous economic offer: this criterion, in fact, requires that in addition to the economic offer, a technical offer be proposed, by the contractor, to which a score may be given (generally: 70 points for the technical offer and 30 points for the economic offer).

It is important to notice that, given the specificity of the work to be put in place, which cannot be standardized because it is still experimental, the contracting party will have to make sure that the contractor is able to complete the work and adhere to the criteria specified by the contracting station (see those above as examples). Moreover, in order to estimate the price of the work, it will not be possible to estimate it through approved price lists, but it will have to be appropriately estimated on the basis of the possibilities and skills of the parties involved.

A typological scoring scheme for the technical offer is given in tabular form, which, however, should in all cases depend on the characteristics of the planned intervention.

| | CRITERIA | MOTIVATIONAL CRITERIA | SCORES |
|---|---|---|---|
| A.1.1 | DEVELOPMENT AND PERFORMANCE OF WORK | The following elements will be evaluated:<br><br>- Improvement of the operational organization of the construction site, obtained through the optimization of the manpower employed and the use of equipment and machinery with a reduced environmental impact, which aims to reduce the negative effects of the construction site in environmental terms, as well as negative effects on the traffic and the resident population;<br><br>- Improvement of the work organization aimed at increasing the level of productivity with particular reference to the quality of the staff employed for the execution of the work and for the management of the construction site, referring to the qualification and previous experience, as well as the equipment used;<br><br>- Control system of the processes and materials used, in terms of methods of execution and efficiency | 20-30 |
| A.1.2 | DOCUMENTATION OF ACCEPTANCE OF THE MATERIAL AND OF THE MIX DESIGN, (IN THE PARTICULAR CASE THERE ARE DIFFERENT TYPES OF FLOORING AND THEREFORE DIFFERENT TYPES OF MIX DESIGN) | The following elements will be assessed:<br><br>- the definition of a program, related to the time schedule of the works, in which the steps for presenting the documentation relating to the acceptance of the mix design are detailed, consistent with the specifications, so that the transmission times of the documentation necessary for the acceptance checks and the installation of related materials;<br><br>- the definition of a control plan for the production plant that the contractor intends to implement to ensure consistency of production with that of the accepted mix design. | 20-30 |
| A.1.3 | COMMUNICATION MEASURES | The following elements will be evaluated:<br><br>- information plan designed to reach the widest catchment area to communicate deviations and changes in traffic;<br><br>- communication plan with the managing bodies of the roads in order to optimize the administrative acts functional to the construction site. | 10-20 |
| | | **Total technical offer score** | **60-70** |

# Appendix 2: Predictive evaluation for the effectiveness of interventions

Through the results obtained from the Life E-VIA project, coefficients were identified for calculating the noise of electric vehicles within the acoustic models required by EU Directive 2002/49/EC (CNOSSOS).

These coefficients will be of valuable help to managing bodies and specialists who will be able to carry out acoustic mitigation interventions, both with regard to the reorganization of mobility policies, favoring electric-powered vehicles, and through the resurfacing of asphalts consistent with what has been described.

Related to the CNOSSOS calculation method (EU Directive 996/2015), in order to estimate the sound power of a roadway, the report is to be used:

$$L_{WR,i,m} = A_{R,i,m} + B_{R,i,m} * \log\left(\frac{V_m}{V_{ref}}\right) + \Delta L_{WR,i,m}$$

The *i* and *m* indices represent the frequency in octaves and vehicle categories as defined by the CNOSSOS model. The octave bands cover the range from 63 Hz to 8 kHz, as stated in EU Directive 996/2015;

$v_m$ represents the speed of the vehicle belonging to category m;

$\Delta L_{W R,i,m}$ represents all contributions due to external conditions such as: pavement type, presence of studded tires, acceleration/deceleration, and temperature.

The coefficients to be used in commercial calculation codes in order to evaluate the noise emitted by electric vehicles are given in tabular form.

| CNOSSOS Coefficients | 63 Hz | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz |
|---|---|---|---|---|---|---|---|---|
| $A_R$ | 85.3 | 83.3 | 85.5 | 88.8 | 92.8 | 90.0 | 79.3 | 69.2 |
| $B_R$ | 21.6 | 21.5 | 12.4 | 26.9 | 34.60 | 36.7 | 33.7 | 14.6 |
| Speed ref (km/h) | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

Regarding the CNOSSOS calculation method (EU Directive 996/2015), in order to estimate the contribution of road surface, the report is to be used:

$$\Delta L_{WR,road,i,m} = \alpha_{i,m} + \beta_{i,m} \log\left(\frac{v_m}{v_{ref}}\right)$$

The coefficients to be used in commercial calculation codes in order to evaluate the contribution of road surfaces consistent with what is described in these guidelines referring to the application on electric vehicles are given in tabular form.

| CNOSSOS Coefficients | 63 Hz | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz |
|---|---|---|---|---|---|---|---|---|
| $\alpha_{i,m}$ | 2.3 | 2.4 | 1.6 | 0.3 | -0.7 | -0.9 | 0.5 | 1.7 |
| $\beta_m$ | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Speed ref (km/h) | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

# Appendix 3: Surveys

*LIFE/ENV/IT000201 LIFE E-VIA*
*Progetto co-finanziato dalla Commissione Europea nell'ambito del Programma LIFE+2018.*

COMUNE DI FIRENZE

Vie en.ro.se. Ingegneria

## THE PROJECT

Exposure data from the European Environment Agency demonstrate that more than 100 million EU citizens are affected by high noise levels negatively impacting human health. Traffic noise alone is harmful to the health of almost every third person in the World Health Organization European Region. 20% of Europeans are regularly exposed to night sound levels that could significantly damage health, especially in urban areas.
In this context, the LIFE E-VIA Project (Electric Vehicle noise control by Assessment and optimization of tire / road interaction / Control of noise of electric vehicles through evaluation and optimization of the tire-asphalt interaction - www.life-evia.eu) intends to address the problem of noise pollution due to road traffic noise, focusing on a future scenario in which electric and hybrid vehicles will be a significant part of the traffic flow, and combine knowledge of the optimization of asphalts and tires in order to test an optimized solution for noise reduction in urban areas and optimize the Life Cycle Cost with respect to current best practices.
The Project, co-financed by the European Union through the Life programme, started in July 2019 and will end in January 2023. The project is coordinated by the Municipality of Florence and involves as partners the Mediterranean University of Reggio Calabria, Continental, Vie en.ro.se Ingegneria, University Gustave Eiffel and I-POOL.

## THE QUESTIONNAIRE

The objective of this questionnaire is to collect data on the perception of the sound environment. In addition to some initial general questions, we kindly ask you to answer 8 questions relating to the perception of the soundscape at each listening point identified along the route. Your personal data will be treated as strictly confidential and the publication of the survey results will ensure the non-recognition of the responses. Please answer all questions in order, following the instructions provided.

### PERSONAL INFORMATION

I1. **Age**: ☐ 18-25 ☐ 26-40 ☐ 41-55 ☐ 56-65 ☐ 66-75 ☐ >75

I2. **Gender**: ☐ Female ☐ Male

I3. **Education**: ☐ Primary School ☐ Middle School ☐ High School
☐ Bachelor or Master's Degree ☐ PhD

I4. **Occupation**: ______________________________

I5. **City of residence**: ______________________________

I6. **Nationality**: ______________________________

I7. **Do you know/come to this place (via Paisiello)?**

☐ YES ☐ NO

I8. **If so, how often do you come to via Paisiello?**

☐ Everyday ☐ Once a week ☐ Twice a month ☐ Once a month ☐ Few times a year

I9. **If so, what is/are the reason/s?** *(you can select one or more answers)*

☐ Residence/home ☐ Residence of acquaintances ☐ Work ☐ Transit area to reach other destinations
☐ Leisure activities ☐ Shopping ☐ Other: ……………………………………………… (Please, specify)

I10. **How do you assess your sensitivity to sounds?** (Please tick one box)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Not at all*** | | | | | | | | | | ***Very High*** |

**Initial excercises**

Close sound:________________________________________

Distant sound: ________________________________________

Pleasant sound________________________________________

Unpleasant sound: ________________________________________

Natural/mechanical/anthropic sounds: ______________________________

Sounds in motion: ________________________________________

Static sound: ________________________________________

POINT OF LISTENING N. 1

**Q1. How do you assess the intensity of the following four types of sound in the soundscape around you?**
(Please tick one box for each row)

| *Type of sound* | *Very Low* | *Low* | *Fair* | *High* | *Very High* |
|---|---|---|---|---|---|
| ***Traffic*** (eg. Cars, motorcycles, clacson | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Mechanical/electrical sounds*** (eg. music, industries, sirens, construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Anthropic sounds*** (eg. voices, laughter, children, step) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Nature sounds*** (eg. wind, rustling leaves, birds) | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q2. How do you assess the quality of the soundscape around you?**
(Please tick one box)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Very Bad*** | | | | | | | | | | ***Excellent*** |

**Q3. Do you think the soundscape around you is appropriate for this place?**
(Please, tick one box)

| ***Absolutely inappropriate*** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ***Completely appropriate*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

**Q4. To what extent do you agree with the following statements about the soundscape around it?**
(Please tick one box for each row)

| The soundscape is: | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| ***Enjoyable*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Chaotic*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Interesting*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Boring*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Relaxing*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Disturbing*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Lively*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Monotonous*** | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q5. How do you assess the quality of the urban landscape around you?**
(Please tick the box that best matches your opinion)

| ***Very Bad*** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ***Excellent*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

**LISTENING POINT N. 2**

**Q1. How do you assess the intensity of the following four types of sound in the soundscape around you?**
(Please tick one box for each row)

| *Type of sound* | *Very Low* | *Low* | *Fair* | *High* | *Very High* |
|---|---|---|---|---|---|
| ***Traffic*** (eg. Cars, motorcycles, clacson | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Mechanical/electrical sounds*** (eg. music, industries, sirens, construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Anthropic sounds*** (eg. voices, laughter, children, step) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Nature sounds*** (eg. wind, rustling leaves, birds) | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q2. How do you assess the quality of the soundscape around you?**
(Please tick one box)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Very Bad*** | | | | | | | | | | ***Excellent*** |

**Q3. Do you think the soundscape around you is appropriate for this place?**
(Please, tick one box)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Absolutely inappropriate*** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ***Completely appropriate*** |

**Q4. To what extent do you agree with the following statements about the soundscape around it?**
(Please tick one box for each row)

| The soundscape is: | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| ***Enjoyable*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Chaotic*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Interesting*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Boring*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Relaxing*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Disturbing*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Lively*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Monotonous*** | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q5. How do you assess the quality of the urban landscape around you?**
(Please tick the box that best matches your opinion)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Very Bad*** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ***Excellent*** |

**LISTENING POINT N. 3**

**Q1. How do you assess the intensity of the following four types of sound in the soundscape around you?**
(Please tick one box for each row)

| *Type of sound* | *Very Low* | *Low* | *Fair* | *High* | *Very High* |
|---|---|---|---|---|---|
| ***Traffic*** (eg. Cars, motorcycles, clacson | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Mechanical/electrical sounds*** (eg. music, industries, sirens, construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Anthropic sounds*** (eg. voices, laughter, children, step) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Nature sounds*** (eg. wind, rustling leaves, birds) | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q2. How do you assess the quality of the soundscape around you?**
(Please tick one box)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Very Bad*** | | | | | | | | | | ***Excellent*** |

**Q3. Do you think the soundscape around you is appropriate for this place?**
(Please, tick one box)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Absolutely inappropriate*** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ***Completely appropriate*** |

**Q4. To what extent do you agree with the following statements about the soundscape around it?**
(Please tick one box for each row)

| The soundscape is: | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| ***Enjoyable*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Chaotic*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Interesting*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Boring*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Relaxing*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Disturbing*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Lively*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Monotonous*** | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q5. How do you assess the quality of the urban landscape around you?**
(Please tick the box that best matches your opinion)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Very Bad*** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ***Excellent*** |

**LISTENING POINT N. 4**

**Q1. How do you assess the intensity of the following four types of sound in the soundscape around you?**
(Please tick one box for each row)

| *Type of sound* | *Very Low* | *Low* | *Fair* | *High* | *Very High* |
|---|---|---|---|---|---|
| ***Traffic*** (e.g. Cars, motorcycles, clacson) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Mechanical/electrical sounds*** (e.g. music, industries, sirens, construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Anthropic sounds*** (e.g. voices, laughter, children, step) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Nature sounds*** (e.g. wind, rustling leaves, birds) | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q2. How do you assess the quality of the soundscape around you?**
(Please tick one box)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Very Bad*** | | | | | | | | | | ***Excellent*** |

**Q3. Do you think the soundscape around you is appropriate for this place?**
(Please, tick one box)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Absolutely inappropriate*** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ***Completely appropriate*** |

**Q4. To what extent do you agree with the following statements about the soundscape around it?**
(Please tick one box for each row)

| The soundscape is: | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| ***Enjoyable*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Chaotic*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Interesting*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Boring*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Relaxing*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Disturbing*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Lively*** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Monotonous*** | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q5. How do you assess the quality of the urban landscape around you?**
(Please tick the box that best matches your opinion)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Very Bad*** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ***Excellent*** |

**LISTENING POINT N.5**

**Q1. How do you assess the intensity of the following four types of sound in the soundscape around you?**
(Please tick one box for each row)

| *Type of sound* | *Very Low* | *Low* | *Fair* | *High* | *Very High* |
|---|---|---|---|---|---|
| ***Traffic*** (e.g. Cars, motorcycles, clacson | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Mechanical/electrical sounds*** (e.g. music, industries, sirens, construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Anthropic sounds*** (e.g. voices, laughter, children, step) | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***Nature sounds*** (e.g. wind, rustling leaves, birds) | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q2. How do you assess the quality of the soundscape around you?**
(Please tick one box)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Very Bad* | | | | | | | | | | *Excellent* |

**Q3. Do you think the soundscape around you is appropriate for this place?**
(Please, tick one box)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Absolutely inappropriate* | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | *Completely appropriate* |

**Q4. To what extent do you agree with the following statements about the soundscape around it?**
(Please tick one box for each row)

| The soundscape is: | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| *Enjoyable* | ☐ | ☐ | ☐ | ☐ | ☐ |
| *Chaotic* | ☐ | ☐ | ☐ | ☐ | ☐ |
| *Interesting* | ☐ | ☐ | ☐ | ☐ | ☐ |
| *Boring* | ☐ | ☐ | ☐ | ☐ | ☐ |
| *Relaxing* | ☐ | ☐ | ☐ | ☐ | ☐ |
| *Disturbing* | ☐ | ☐ | ☐ | ☐ | ☐ |
| *Lively* | ☐ | ☐ | ☐ | ☐ | ☐ |
| *Monotonous* | ☐ | ☐ | ☐ | ☐ | ☐ |

**Q5. How do you assess the quality of the urban landscape around you?**
(Please tick the box that best matches your opinion)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Very Bad* | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | *Excellent* |

**Case 1**

**Q6: Imagine you are sitting inside a vehicle with an internal combustion engine and listening to the noise produced inside it while passing through a certain type of road pavement/asphalt. How do you assess the quality of the soundscape?**

(Please tick the box that best matches your opinion)

| Very poor | Poor | Acceptable | Good | Very good |
|---|---|---|---|---|

**Case 2**

**Q7: Imagine you are sitting inside an electric vehicle and listening to the noise produced inside it while passing through a certain type of road pavement/asphalt. How do you assess the quality of the soundscape?**

(Please tick the box that best matches your opinion)

| Very poor | Poor | Acceptable | Good | Very good |
|---|---|---|---|---|

**Case 3**

**Q8: Imagine you are sitting inside an electric vehicle and listening to the noise produced inside it while passing through a different type of road pavement/asphalt. How do you assess the quality of the soundscape?**

(Please tick the box that best matches your opinion)

| Very poor | Poor | Acceptable | Good | Very good |
|---|---|---|---|---|

**Case 4**

**Q9: Imagine you are sitting inside a vehicle with an internal combustion engine and listening to the noise produced inside it while passing through a different type of road pavement/asphalt. How do you assess the quality of the soundscape?**

(Please tick the box that best matches your opinion)

| Very poor | Poor | Acceptable | Good | Very good |
|---|---|---|---|---|

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