European Commission

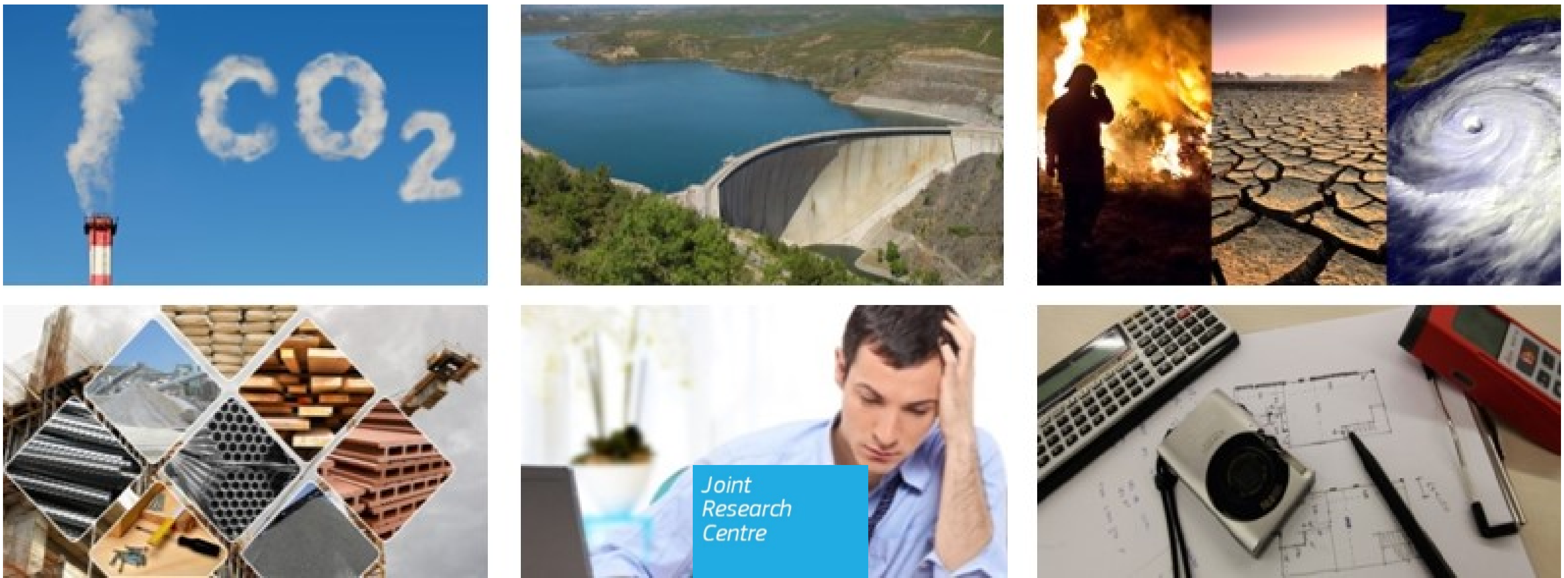
JRC TECHNICAL REPORTS

Level(s) indicator 4.4: Acoustics and protection against noise

User manual: introductory briefing, instructions and guidance
(Publication version 1.1)

Nicholas Dodd, Shane Donatello (JRC, Unit B.5)
With support from members of the
EURIMA Acoustics Working Group

January 2021



European Commission
Joint Research Centre
Directorate B, Growth and Innovation
Unit 5, Circular Economy and Industrial Leadership

Contact information
Nicholas Dodd and Shane Donatello
Address: Edificio Expo. c/ Inca Garcilaso, 3. E-41092 Seville (Spain)
E-mail: jrc-b5-levels@ec.europa.eu
https://ec.europa.eu/jrc
https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/412/home

How to cite: Dodd N. & Donatello S., 2021. Level(s) indicator 4.4: Acoustics and protection against noise user manual: introductory briefing, instructions and guidance (Publication version 1.1)

Title
Level(s) indicator 4.4: Acoustics and protection against noise user manual: introductory briefing, instructions and guidance (Publication version 1.1)

Credits
The JRC would like to thank the EURIMA Acoustics Working Group for their technical support in developing this User Manual. The Rockwool International also provided specific technical input.

Abstract

Developed as a common EU framework of core indicators for assessing the sustainability of office and residential buildings, Level(s) can be applied from the very earliest stages of conceptual design through to the projected end of life of the building. As well as environmental performance, which is the main focus, it also enables other important related performance aspects to be assessed using indicators and tools for health and comfort, life cycle cost and potential future risks to performance.

Level(s) aims to provide a common language of sustainability for buildings. This common language should enable actions to be taken at building level that can make a clear contribution to broader European environmental policy objectives. It is structured as follows:

1. Macro-objectives: An overarching set of 6 macro-objectives for the Level(s) framework that contribute to EU and Member State policy objectives in areas such as energy, material use, waste management, water and indoor air quality.
2. Core Indicators: A set of 16 common indicators, together with a simplified Life Cycle Assessment (LCA) methodology, that can be used to measure the performance of buildings and their contribution to each macro-objective.

In addition, the Level(s) framework aims to promote life cycle thinking. It guides users from an initial focus on individual aspects of building performance towards a more holistic perspective, with the aim of wider European use of Life Cycle Assessment (LCA) and Life Cycle Cost Assessment (LCCA) methods.

Contents

The Level(s) document structure

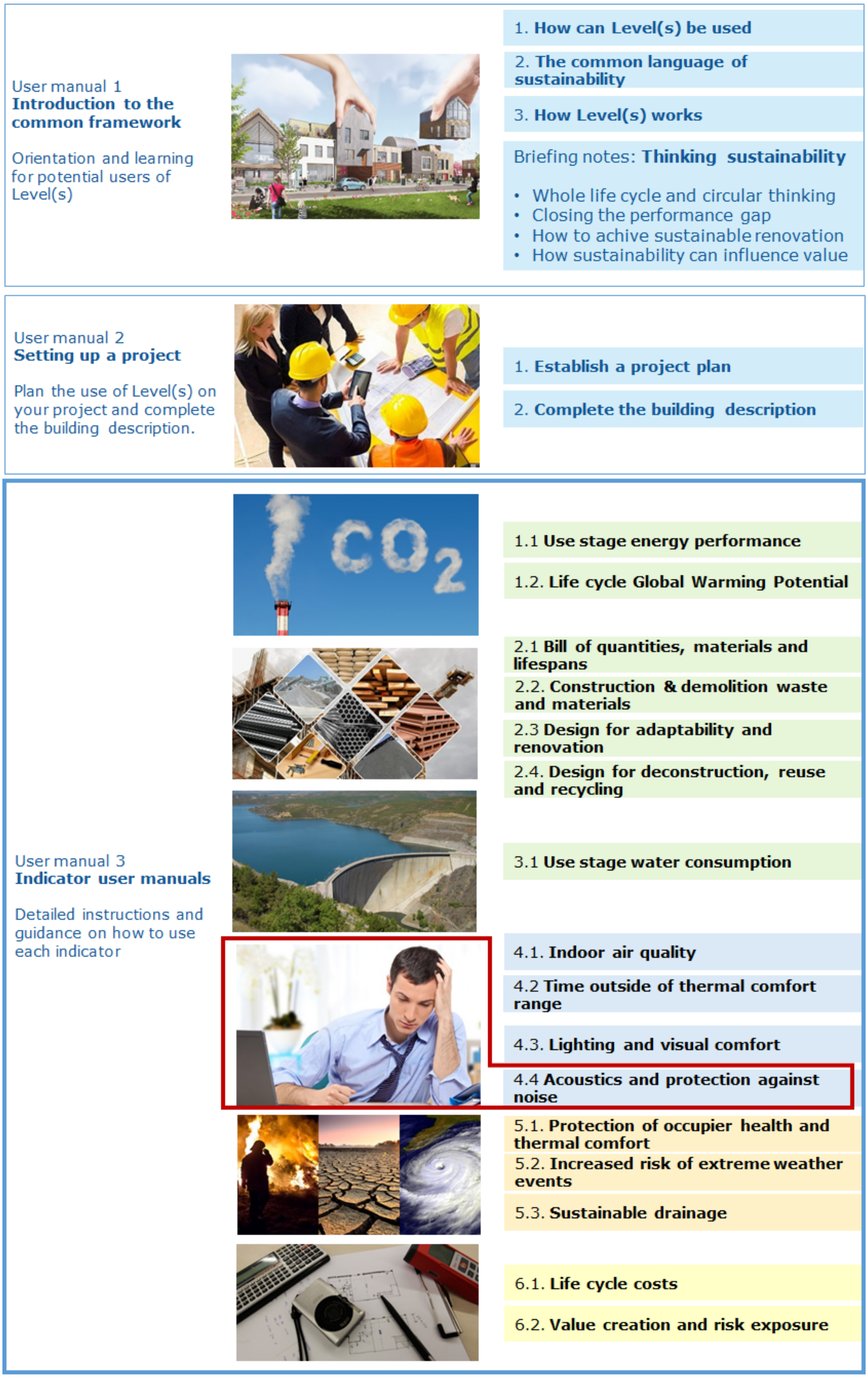


Figure 1. The Level(s) document structure

How this indicator user manual works

Level(s) is a framework of core indicators of sustainability that can be applied to building projects in order to report on and improve their performance. The supporting documentation has been designed to be accessible to all the actors that may be involved in this process.

If you are new to the assessment of building sustainability, we recommend reading the **first part of the Level(s) user manual**. This will provide you with an introduction to the basic concepts behind Level(s) and how you can apply it to a building project.

If you haven't yet set up your building project to use Level(s), including completing the project plan and the building description, then we recommend reading the **second part of the Level(s) user manual**.

This indicator user manual forms part of the third part of the Level(s) user manual where you will find instructions on how to use the indicators themselves. It is designed to help you apply your chosen indicator to a building project. It will help you to do this in the following way:

- **Introductory briefing:** This section provides an overview of the indicator, including:
  - ✓ why you may wish to measure performance with it,
  - ✓ what it measures,
  - ✓ at which stages in a project it can be used,
  - ✓ the unit of measurement, and
  - ✓ the relevant calculation method and reference standards.
- **Instructions on how to use the indicators at each level**: This section provides:
  - ✓ step by step instructions for each level,
  - ✓ what is needed to make an assessment,
  - ✓ a design concept checklist (at Level 1), and
  - ✓ the reporting formats.

  The instructions often refer to the guidance and further information section, which can be found after the instructions.
- **Guidance and further information for using the indicator**: This section provides more background information and guidance to support you in following specific steps in the instructions, including the design concepts introduced at Level 1 and the practical steps to calculate or measure performance at Levels 2 and 3. They are all cross-referenced to specific instruction steps at either level 1, 2 or 3.

This indicator user manual is structured so that once you are familiar with using the indicator and you know how to work with it, you may no longer need to refer to the guidance and background information, but only work directly with the instructions at the level of your choice.

Technical terms and definitions used

Term	Definition
Airborne sound	Sound that is generated in air and is radiated towards the building structure. Examples are speech, television, radio, airplane noise.
Impact sound	Sound that is generated by a mechanical interaction of an object with the building structure causing it to vibrate. Examples are footsteps, moving of furniture, dropping objects, drilling.
Common access area	Any type of area which is accessible to all occupants of the building, such as stairwells, corridors, central lobby areas, atria, passageways and other communal areas.
Habitable room	Room which provides the accommodation of a dwelling, including living room, dining room, study, home office, conservatory, etc., excluding bathroom, kitchen, WC, utility room, storeroom and circulation space.
High confidentiality space	Space where speech privacy is important, like offices for managers
Noise sensitive space	Space where unwanted sounds are disturbing at very low levels, like bedrooms, video conferencing rooms, isolated cubicles for concentrated work.
Open plan office	Office designed to accommodate more than four people without complete separations between workstations.
Reverberation time [s]	Time required for the sound pressure level in a room to decrease by 60dB after the sound source has stopped.
Single Number Quantity (SNQ)	A quantifier used to assess an acoustical performance aspect in a global way, i.e. without highlighting frequency-dependent values.

Introductory briefing

Note for users: This indicator only has instructions and guidance for using the indicator at **Level 1** at this moment. For those who wish to work at **Level 2 and 3,** it provides some initial information about possible units of calculation and measurement, as well as reference standards that could be used.

Why measure performance with this indicator?

The potential for acoustic disturbance, from both inside and outside a building, is cited as an important influence on the health, comfort and wellbeing of building occupants [1]. Noise disturbance can have a significant and detrimental impact on people's health and quality of life. It can also affect productivity and the quality of communication in a work environment.

The importance of protecting citizens from noise is recognised in European policy, with Directive 2002/49/EC on the assessment and management of environmental noise[2] requiring external noise source mapping at dwelling level, at least for the most exposed façades. It also requires reporting on the number of residents exposed to differing levels of noise. Annex VI of the Directive provides a technical definition of a 'quiet façade', referring to the facades of buildings where residents are exposed to lower relative noise levels. Annex III of the Directive provides health calculation methods, to assess the health effects of noise from roads, railways, industrial activities and aircrafts.

In the context of seeking to measure the acoustic performance of a building, the selected design solutions need to protect its users from both the acoustic climate outside and from unwanted noise generated inside the building, or coming from neighbouring buildings. Moreover, a good internal acoustic environment, both inside and between specific spaces, especially bedrooms, office workstations and meeting rooms, is also indispensable to ensure user satisfaction and to optimise productivity.

What does it measure?

In dwellings, the acoustic insulation of noises coming from the street or from the sky are important for occupant wellbeing. In both office and residential buildings, external sources of noise disturbance such as traffic, pedestrian activity in streets and commercial or industrial activity can be of significance. In commercial buildings, this can lead to decisions to seal windows and mechanically ventilate spaces, so outdoor noise levels are an important technical consideration.

In addition, the consideration of party walls and floors is particularly important to minimise sound transmission between properties. The measurement of both impact and airborne transmission of sound is therefore important in these cases.

In office buildings, noise problems may relate to disturbance in open plan environments or, in more traditional office layouts, poor acoustic separation between cellular offices or conference rooms. In this case, the measurement of both impact and airborne transmission of sounds is relevant for measurement. Servicing such as air conditioning, as well as printers and server rooms, can also cause disturbance and so require a specific focus. The reverberation of sound inside spaces is an important consideration, as it can affect the concentration of noise within a shared office space, as well as speech intelligibility and the indoor background noise level, so this is also an important aspect to measure.

At what stage of a project?

Although this guidance currently only provides instructions for Level 1, there is the potential to start working at Levels 2 and 3 by using currently available units of measurement, calculation methods and reference standards. Information on these is provided later in this section of the User Manual. The stages in a project at which an assessment can be at the three 'levels' are identified below:

[1] World Green Building Council, *Health, Wellbeing and Productivity in Offices: The Next Chapter for Green Building*, September 2014.

[2] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise

Level	Activities related to the use of indicator 4.4
1. Conceptual design (following design principles)	✓ Conceptual design: The main considerations in creating a quality acoustic environment and for controlling noise can be used by designers to already assess the potential risks based on the building uses, the location and potential configuration of spaces within the building.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ *Detailed design and construction: Upon moving into the detailed design of the building, the acoustic performance can be calculated and estimated for the main aspects addressed by the indicator. The design team can then focus on material selection and detailing required to achieve a specific level of technical performance.*
3. As-built and in-use (based on commissioning, testing and measuring)	✓ *As-built and in-use: Upon completion, it will become possible to carry out field surveys and measurements in order to determine the as-built performance of the building and its internal spaces.*

Units of measurement

The focus of this first version of the indicator is on addressing the five main acoustics and noise protection design aspects. Although this manual currently only provides instructions at Level 1, for those that want to go further, initial suggestions for measurement indicators that could be used are made based on the framework of existing EN and ISO standards (see the table below).

Table 1. Measurement indicators for acoustic quality and protection against noise

Acoustic design aspects	Description	Level 2 and 3 Quantities to be assessed		
		Related to	**Index**	**Description**
1. Façade sound insulation	Protection from noise coming from the outside	Façade insulation	$D_{2m,nT,w}$	Weighted standardized level difference for traffic noise (sound insulation)
			R'_w	Weighted apparent sound reduction index
			$R'_{45°}$	Apparent sound reduction index
		Indoor noise level	L_{Aeq}	A-weighted equivalent continuous sound pressure level
			L_{Amax}	A-weighted maximum sound pressure level
			$L_{den,indoor}$	Indoor day-evening-night sound pressure level
		Environmental noise	L_{day}	Day period average noise level
			L_{night}	Night period average noise level
			L_{den}	Day-evening-night period average noise level
2. Airborne sound insulation	Protection from airborne noise within adjacent rooms and spaces or buildings	Airborne sound insulation	R'_w	Weighted apparent sound reduction index
			$D_{nT,w}$	Weighted standardized level difference.
			$R'_w + C$	Weigthed apparent sound reduction index + spectrum adaption term
			$D_{nTw} + C$	Weighted Standardized Level Difference + spectrum adaption term
			$R'_w + C_{tr}$	Apparent sound reduction index + spectrum adaption term for traffic noise

<table>
<tr><th rowspan="2">Acoustic design aspects</th><th rowspan="2">Description</th><th colspan="3">Level 2 and 3
Quantities to be assessed</th></tr>
<tr><th>Related to</th><th>Index</th><th>Description</th></tr>
<tr><td rowspan="4"></td><td rowspan="4"></td><td></td><td>$D_{nT} + C_{tr}$</td><td>Weighted Standardized Level Difference + spectrum adaption term for traffic noise “</td></tr>
<tr><td rowspan="3">Indoor noise level</td><td>L_{Aeq}</td><td>A-weighted equivalent continuous sound pressure level</td></tr>
<tr><td>L_{Amax}</td><td>A-weighted maximum sound pressure level</td></tr>
<tr><td>$L_{den,indoor}$</td><td>Indoor day-evening-night sound pressure level</td></tr>
<tr><td rowspan="2">3. Impact sound insulation</td><td rowspan="2">Protection from the sound of impacts within adjacent spaces or an adjacent floor or wall</td><td rowspan="2">Impact sound insulation</td><td>L’n,w</td><td>Weighted normalized impact sound pressure level</td></tr>
<tr><td>L’nT,w</td><td>Weighted standardized impact sound pressure level</td></tr>
<tr><td rowspan="2">4. Service noise equipment</td><td rowspan="2">Protection from noise generated by service equipment</td><td rowspan="2">Noise generated by service equipment</td><td>$L_{Aeq,nT}$</td><td>A-weighted standardized continuous sound pressure level</td></tr>
<tr><td>$L_{AFmax,nT}$</td><td>Maximum time-averaged and frequency-weighted standardized sound pressure level</td></tr>
<tr><td rowspan="3">5. Sound absorption in enclosed spaces / room acoustics</td><td rowspan="3">Acoustic indoor comfort</td><td rowspan="2">Control of the reverberation time</td><td>T</td><td>Reverberation time</td></tr>
<tr><td>A_{eq}</td><td>Equivalent sound absorption area</td></tr>
<tr><td>Background noise level and speech intelligibility</td><td>STI</td><td>Speech intelligibility</td></tr>
</table>

System boundary

The indicator is related to the B6 stage (operational energy use) of the building life cycle, as per EN 15978. The material footprint of any associated windows, insulation used and façade materials to improve performance would fall under stages A1-A5 (production and construction). Specific provision is also made for reporting on building parts under Level(s) indicator 2.1 (Bill of quantities, materials and lifespans).

However, the main purpose of indicator 4.4 is to focus attention on occupant health and comfort based on scientific knowledge of acoustic and noise disturbance effects on health, wellbeing and productivity. In order to quantitatively or qualitatively assess any beneficial effects for the actual occupants, Annex III of Directive 2002/49/EC can be used or feedback would need to be obtained from via survey methods.

Scope

This indicator should consider the importance of architectural aspects including façade design, party walls, floors, internal subdivisions and partitions, surface finishing materials and treatments and other architectural elements that can affect acoustic performance. The indicator also considers the acoustic performance and the mitigation of service equipment noise.

Acoustic performance depends on the use activities in rooms. Therefore, all rooms and areas inside the building shall be categorised into typologies according to their usage. The following room types and areas can be considered to be of major importance:

- In dwellings: habitable rooms (e.g. living rooms and bedrooms), common access areas,.
- In office buildings: (open plan) offices, conference rooms, high confidentiality spaces, noise-sensitive spaces (tele-conferencing, concentration…), common access areas.

Other specific room types can also be considered, such as canteens, kitchens, dining rooms, bathrooms, restrooms, receptions and lift shafts. Noise from service equipment rooms and lift shafts shall be considered in other rooms but not in the equipment rooms themselves.

Further acoustic performance aspects, such as rain noise insulation or ground borne sound insulation (traffic, construction works etc.) are not considered, but may form part of national regulations and/or classification schemes.

Calculation methods and reference standards

The focus of this version of the indicator is on addressing the five main acoustics and protection against noise in building design aspects. Initial suggestions for the units of measurement that could be used are made based on the framework of existing EN and ISO standards (see Table 2). If no national classification scheme, guideline or similar is available for residential buildings, it is suggested to use the ISO TS 19488. Some initial supporting guidance is provided in this User Manual to inform decision making.

Table 2. Measurement standards and methods for acoustics and protection against noise

Acoustic design aspects	Description	Level 2 Calculation methods	Level 3 Field methods	
			Rating procedure	**Measurement method** (S = survey method) (M = measurement method)
1. Façade sound insulation	Protection from noise coming from the outside	EN 12354-3	Façade insulation: ISO 717-1	Façade sound insulation: ISO 10052 (S) ISO 16283-3 (M) Environmental noise: ISO 1996-1
2. Airborne sound insulation	Protection from airborne noise within adjacent rooms and spaces or buildings.	EN 12354-1	ISO 717-1	ISO 10052 (S) ISO 16283-1 (M)
3. Impact sound insulation	Protection from the sound of impacts within adjacent spaces or on an adjacent floor or wall.	EN 12354-2	ISO 717-2	ISO 10052 (S) ISO 16283-2 (M)
4. Service equipment noise	Protection from noise generated by service equipment	EN 12354-5	ISO 10052 ISO 16032	ISO 10052 (S) ISO 16032 (M)

Acoustic design aspects	Description	Level 2 Calculation methods	Level 3 Field methods	
			Rating procedure	**Measurement method** (S = survey method) (M = measurement method)
5. Sound absorption in rooms and enclosed spaces	Control of the reverberation time [3], background noise level and speech intelligibility/privacy within spaces.	EN 12354-6	ISO 11654[1]	ISO 3382-2 (S/M) ISO 3382-3 (M)

[3] Currently, no international standard exists that defines a SNQ to assess reverberation time in-situ. However, ISO 11654 defines a SNQ for the absorption coefficient of surfaces to be measured in laboratory. The latter quantity may alternatively be used to assess sound reverberation in enclosed spaces.

Instructions on how to use the indicator at each level

Note: this indicator is currently only specified with instructions for users at Level 1.

Instructions for level 1

L1.1. The purpose of Level 1

The main purpose of a level 1 assessment is to check whether the five acoustic and noise protection design aspects have been taken into account at the concept stage of a project. This will aid in understanding and prioritising the most important design aspects to focus attention on. This in turn will help those involved in a project to make the right decisions when setting requirements and specifications. *It also provides initial suggestions for how calculations and field measurements can be made at Levels 2 and 3.*

L1.2. Step-by step instructions

These instructions should be read in conjunction with the accompanying guidance and supporting information which is provided from page 15 onwards.

1. Consult the checklist of acoustics and noise protection design aspects under L1.4 and read the background descriptions in the Level 1 technical guidance
2. Within the design team, review and identify how the design aspects can be introduced into the design process.
3. Once the design concept is finalised with the client, record the acoustics and noise protection design aspects that were taken into account using the L1 reporting format.

L1.3. Who should be involved and when?

At the concept stage, the main actors could include the concept architect, the building owner or investor, representatives for the occupier and the relevant building planning authorities.

Later in the project, additional stakeholders would be likely to include detailed design architects, specifiers, interior designers, the main building contractor, acoustics specialists and the building occupiers

L1.4. Checklist of acoustic and noise protection design aspects

It is necessary to be aware of the design aspects and the related factors that influence the incorporation of design features and material selection to address acoustic performance. Each aspect informs what is required to ensure that the right decisions are made at concept design stage and in order to achieve better outcomes at later stages.

Considerations for <u>dwellings</u>

Acoustic design aspects	Description	Considerations
1. Façade sound insulation	Protection from noise coming from the outside	Is exterior noise likely to adversely affect habitable rooms and by how much? Are there requirements that should be met in order to ensure there is adequate noise protection? Are external noise levels likely to be above WHO's suggested limit of Lden = 55 dB(A) outside habitable rooms?
2. Airborne sound insulation	Protection from airborne noise within adjacent rooms and spaces or buildings.	Is airborne noise from: - rooms outside the dwelling, - common areas, or - between other spaces Is it likely to adversely affect habitable rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?

Acoustic design aspects	Description	Considerations
3. Impact sound insulation	Protection from the sound of impacts within adjacent spaces or on an adjacent floor or wall.	Is impact noise from: - rooms outside the dwelling, - common areas, or - between other spaces Is it likely to adversely affect habitable rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?
4. Service equipment noise	Protection from noise generated by service equipment	Is service equipment for: - the building as a whole, - specific floors, or - individual dwellings Is it likely to adversely affect habitable rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?
5. Sound absorption in rooms and enclosed spaces	Control of the reverberation time, background noise level and speech intelligibility/privacy within spaces.	Has the reverberation time and sound absorption been considered in common areas adjacent to habitable rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?

Considerations for office buildings

Acoustic design aspects	Description	Considerations
1. Façade sound insulation	Protection from noise coming from the outside	Is exterior noise likely to adversely affect: - workstations, - meeting and conference rooms and - noise sensitive spaces? Are there requirements that should be met in order to ensure there is adequate noise protection?
2. Airborne sound insulation	Protection from airborne noise within adjacent rooms and spaces or buildings.	Is airborne noise from: - other workstations, - meeting and conference spaces, - common areas or Is it likely to adversely affect other workstations or meeting rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?
3. Impact sound insulation	Protection from the sound of impacts within adjacent spaces or on an adjacent floor or wall.	Is impact noise from: - other workstations, - meeting and conference spaces, or - common areas Is it likely to adversely affect other workstations or meeting rooms? Are there requirements that should be met in order to ensure there is adequate noise protection?
4. Service equipment noise	Protection from noise generated by service	Is service equipment for: - the building as a whole,

Acoustic design aspects	Description	Considerations
	equipment	- specific floors/departments, or - individual spaces likely to adversely affect workstations, meeting rooms or other noise sensitive spaces? Are there requirements that should be met in order to ensure there is adequate noise protection?
5. Sound absorption in rooms and enclosed spaces	Control of the reverberation time, background noise level and speech intelligibility/privacy within spaces.	Has the reverberation time and sound absorption been considered workstations, meeting rooms and other noise sensitive spaces? What additional requirements need to be taken into account if open-plan offices are proposed (e.g. speech intelligibility, speech level decay with distance, sound masking, …)? Are there requirements that should be met in order to ensure there is adequate noise protection for either of these two aspects?

L1.5. Reporting format

To complete the reporting format for Level 1 you should answer yes or no for each of the design aspects that you have addressed and then provide a brief descriptions of the measures or decisions taken for each one.

Acoustic and noise protection design aspect	Has it been addressed? *(yes/no)*	How has it been addressed during the building design process? *(provide a brief description)*
1. Façade sound insulation		
2. Airborne sound insulation		
3. Impact sound insulation		
4. Service equipment noise		
5. Sound absorption in rooms and enclosed spaces		

Guidance and further information for using the indicator

For using level 1

In this section of the guidance, additional background guidance and explanations are provided in order to learn more about the design aspects introduced in the Level 1 acoustics and protection against noise checklist, namely:

- L1.4 Checklist concept 1 - Environmental noise
- L1.4 Checklist concepts 2 and 3 - Sound insulation
- L1.4 Checklist concepts 2 and 3 - Extending the performance criteria towards lower frequencies
- L1.4 Checklist concept 5 - Room Acoustics and ambient noise from human activity
- L1.4 Checklist concept 5 - Optimising room acoustics in open plan offices

L1.4. Checklist concept 1: Environmental noise

Environmental noise includes both noise from traffic and from industry. Traffic noise can include noise from airplanes, roads, railways and even boats. Industrial noise includes all continuous events and non-temporary work, which include plant operations, harbours, wind turbines, ships at anchor, concert venues, sports stations, outdoor activity from e.g. a restaurant, and building transmitted noise from e.g. ground floor bars and restaurants.

Noise levels at the facade of a building, due to environmental noise, are predicted as a yearly average (often with a daily penalty distribution) or a maximum level. Predictions can be made according to the calculation method described in Annex II of Directive 2002/49/EC. Commercial software programs perform three-dimensional calculations and provide estimates of the health burden. The models vary with the frequency range of concern, being adjustable according to the noise source type and the potential for noise annoyance. Input data for noise models should include data similar to the level of vehicle counts/estimations and sound power measurements of noise sources made according to the standard series ISO 3744 and ISO 9614 series. Data is also available from the NOISE database provided by the EU in support of Directive 2000/14/EC [4].

To predict indoor noise levels from environmental noise, either calculators included in acoustic software models can be used, or predictions may be based on the sound insulation properties of the facades and reverberation times of the receiving rooms using an building element approach.

L1.4. Checklist concepts 2 and 3: Sound insulation

Room acoustic conditions depend on their usage. The rooms of a building shall therefore be categorised into types based on the specific acoustic attributes required for each room type (e.g. hallway, auditorium, entry hall, open office, meeting room, canteen, operation room, tele-conference room, workshop, kitchen, etc.). It is not possible at the design phase to predict the actual noise scape in a room, whereas room acoustic performance based on design specifications is possible to predict.

As a general rule, an area can be defined by those areas which the owner or user controls. The limits of such an area are set by partitions, beyond which the owner does not "*own*" or rule the activities on the other side.

During design, more stringent performance criteria may be applied to certain spaces to add flexibility in the use of spaces during the whole building life cycle. Examples include:

- A home office may be acoustically designed considering a later possible reconversion into a bedroom.

[4] Noise emissions for outdoor equipment - database, https://ec.europa.eu/growth/tools-databases/noise-emissions-outdoor-equipment_en

- In apartments, the use of sufficiently heavy floating floors makes it possible for the tenants to change their floor finishing with only a minor influence on the impact sound insulation towards the neighbours below.
- A soundproof, modular and movable building system can be used to change floor plan in large office floors.
- Isolated cubicles can be added to an open plan office in order to provide spaces where a higher concentration is required for work and/or for a higher level of discretion for telephone calls.

Sound insulation issues are divided into airborne and impact sound insulation. The difference between these two types of sounds is that airborne sounds are generated in the air and are radiated towards the building structure, with examples including speech, television, radio, airplane noise, whereas impact sounds are generated by physical interaction with the building structure causing it to vibrate. Examples of impact sounds include footsteps, moving of furniture, dropping objects, drilling etc.

When estimating sound insulation or impact sound levels in a building one must also include flanking transmission via the party walls of adjacent buildings and spaces in order to include the apparent sound insulation and impact levels. Partitions between spaces often consist of different components (e.g. a glass part and a solid part). Also sometimes the sound insulation of doors is set separately, for example where it divides a residential space from communal space. Calculations of apparent sound insulation can be made using ISO 12354 parts 1 to 4 using laboratory measurements from ISO 10140 series or table values.

L1.4. Checklist concepts 2 and 3: Extending the performance criteria towards lower frequencies

In most building codes or national assessment schemes, the units of measurement used to assess airborne and impact sound insulation take the standard building acoustical frequency range from 100 Hz to 3150 Hz into account.

The importance of sound in the frequency range < 100 Hz on the subjective impression of acoustic quality remains under debate. Until a conclusion is reached, it is recommended to ignore low frequency sound from Level 1 considerations. However, if users wish to take a more comprehensive and precautionary approach in the detailed design, then low frequency (< 100 Hz) sound can be accounted for in Level 2 and Level 3 (note that the exact approaches for Level 2 and 3 have not yet been set out in this version of the guidance document).

L1.4. Checklist concept 5: Room Acoustics and ambient noise from human activity

The acoustic attributes of a room can be characterised by numerous units of measurement. As a minimum, the reverberation times (T), shall be defined for each room type during normal usage of the building include people passing through or staying in the room. The chosen frequency range for the reverberation time is often in 1/1 octave bands of 125 or 250 Hz to 4kHz for rooms where people work, rest or stay for more than a few minutes. For rooms where people simply pass through, like hallways and staircases, the frequency range in octave bands is often 500 Hz to 2kHz. Additionally, descriptors like speech intelligibility (STI), equivalent sound absorption area (A_{eq}), Strength (G), Definition (D_{50}) and Clarity (C_{80}), can also be defined for certain relevant room types.

The reverberation time (T), and the equivalent sound absorption area (A_{eq}), can be estimated using EN ISO 12354-6, based on volume and sound absorption data obtained using ISO 354, ISO 12354-6 Annex B, EN 16487, ASTM 423 and/or ISO 20189.

Speech intelligibility (STI), Strength (G), Definition (D_{50}), and Clarity (C_{80}), can be estimated using numerical simulation or ray-tracing models for acoustic prediction. The reverberation time (T), and the equivalent sound absorption area (A_{eq}), can also be more precisely estimated using these calculation tools. Input data for the tools shall be sound absorption data obtained using ISO 354, ISO 12354-6 Annex B, EN 16487, ASTM 423 and/or ISO 21089.

Measurements of the relevant descriptors shall be performed according to the ISO 3382 series of standards.

L1.4. Checklist concept 5: Optimising room acoustics in open plan offices

The noise environment in open plan offices may be very different depending on the type of office and the type of activities. The acoustic design should attempt to minimise the sound transmission from a conversation held at a workstation that can be a source of disturbance for employees at another workstation, thus causing distraction. The acoustic design can also seek to provide separate rooms that are designated for specific forms of communication, such as those that are intended to be confidential or require a high level of interaction that could disturb other occupants of the space.

The speech intelligibility and discretion (or speech privacy) depend on both the speech level and the background noise level, e.g. the noise coming from outdoor or service equipment sources. The necessary background noise level to achieve speech privacy between two workstations depends on the speech level, the degree of speech privacy required, and the acoustic attenuation between the two workstations. The average background noise level in open plan offices should not be too high, otherwise it cannot guarantee a good level of intelligibility and concentration at workstations. Furthermore, sound absorption is necessary in order to reduce the overall ambient noise level in the open plan office.

To limit the minimum required background noise level for speech privacy, the acoustic attenuation between two workstations or workstation areas should be as large as possible. The acoustic attenuation depends on both the workspace layout and the room acoustics. Options include:

- Consideration of the **workspace layout and geometry** such that cooperating workstations are near to each other and independent workstations are as far away as possible.
- **The characteristic geometry of open-plan offices:** the general rule that the ceiling height should be much lower than the length and width of the room shall be conserved as best as possible in order to increase the spatial decay rate of speech level. If the room height is above 3 m, special care should be taken regarding potential acoustic problems that can occur.
- **The acoustic treatment of the room:** material coverings of the ceiling, floor and walls with absorbent acoustic material to limit reflection will increase the sound level decay. The treatment of the ceiling will have a significant impact in particular if the ceiling height is not too high (see the previous point). It is recommended to use a ceiling treatment with a high absorption coefficient (close to $\alpha p = 1.00$ in the main speech frequency bands of 500 Hz, 1000 Hz and 2000 Hz), especially in the zones between workstations. The use of materials on walls that absorb sounds can also limit reflections to and from workstations close to the walls and especially at corners in an open plan office.
- If the distance between two workspaces is too small, the **acoustic attenuation** can be increased by placing free-standing screens or low dividers (screens fixed to worktop) between the workstations. The performance of the screens depends on the type of screen facing material, their surface density and screen dimensions. The *in-situ* performance also depends on the absorption of ceilings and adjacent wall surfaces.