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Part 2: Data collection and reporting requirements

Acoustique — Paysage sonore —

Partie 2: Collecte de données

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Foreword

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This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

A list of all parts in the ISO 12913 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 12913 series on soundscape was developed in order to enable a broad international consensus and to provide a foundation for communication across disciplines and professions with an interest in soundscape. ISO 12913-1 provides the definition of and a conceptual framework for the term "soundscape".

The concept of soundscape was adopted to provide a holistic approach to the acoustic environment, beyond noise, and its effect on the quality of life. Soundscape suggests assessing all sounds perceived in an environment in all its complexity. To do this, soundscape studies use a variety of data collection related to human perception, acoustic environment and context. Importantly, the study of soundscape relies primarily upon human perception and only then turns to physical measurement.

Acoustics — Soundscape —

Part 2:
Data collection and reporting requirements

1 Scope

This document specifies requirements and supporting information on data collection and reporting for soundscape studies, investigations and applications.

This document identifies and harmonizes the collection of data by which relevant information on the key components people, acoustic environment and context is obtained, measured and reported.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 532-1, *Acoustics — Methods for calculating loudness — Part 1: Zwicker method*

ISO 1996-1, *Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment procedures*

ISO 12913-1, *Acoustics — Soundscape — Part 1: Definition and conceptual framework*

ITU-T P.58:2013, *Head and torso simulator for telephonometry*

ANSI/ASA S 3.36:2012, *Specification for a Manikin for Simulated in-situ Airborne Acoustic Measurements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12913-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
background sound
sound which is heard continuously or frequently enough to form a background against which other sounds are perceived

Note 1 to entry: Often these sounds are not consciously perceived, but they act as conditioning agents in the perception of *foreground sounds* (3.3).

3.2
descriptor
term which is used to describe the perception of any acoustic environment

3.3
foreground sound
sound to which attention of a listener is particularly directed and which can be associated with a specific source

3.4
indicator
term which is used to predict a *descriptor* (3.2) or a part thereof

3.5
local expert
person who is familiar with the area under scrutiny either living in the area or having further daily routines related to the area

3.6
noise
sound that is deemed to be unpleasant, unexpected, undesired or harmful

Note 1 to entry: Exceptions in this document are cases where the term "noise" is used as an established term, e.g. broad-band noise or environmental noise.

3.7
soundwalk
method that implies a walk in an area with a focus on listening to the acoustic environment

3.8
total sound
totally encompassing sound in a given situation at a given time, usually composed of sound from many sources near and far

[SOURCE: ISO 1996-1:2016, 3.4.1, modified — The figure and notes have been deleted.]

4 Descriptors and indicators

4.1 General

It is central to soundscape research, studies and implementation to fit descriptors and indicators to the perception and the assessment of the concerned people. Classical indicators are known to show strong limitations under certain sound conditions (low frequency sound, tonal components, multi-source environments). The choice of indicators depends on the type of the investigated soundscape. It is important that the fit of indicators reflects the situation and context (personal, social, cultural, land use, economic, geographic) which define the acoustic environment, and also enables tracing dynamic changes like time variances of the soundscape over the day or season.

Soundscape studies shall always consider the key components: people, acoustic environment and context (see definitions and explanations in ISO 12913-1):

a) **people:**

— the participants shall be classified according to Annexes A and E;

— self-reported views of the participants (on the acoustic environment and on the context) shall be obtained via questionnaires and/or interviews (see Annex C);

— in certain cases, if determined appropriate by the investigator or researcher, data collection via non-participatory observations shall be obtained; this can include, for example, data collection of subject(s)' walking speed, proximity and/or openness to others (e.g. those not known to themselves), head movements, and occupation time (e.g. time spent in the observation area) [39][40].

NOTE It is recognized that there are current limitations in feasible techniques. There can be difficulties in trying to capture customary and holistic human response, by putting people into survey contexts which can change their listening and related states.

b) **acoustic environment:**

— it shall be reported whether a real, recorded or virtual environment (indoor or outdoor) is considered and whether it is a laboratory or field study (see Annex A);

— sound sources shall be described following a sound source taxonomy (e.g. Annex C);

— the acoustic environment shall be described using a combination of appropriate acoustic indicators (e.g. see ISO 1996-1) and psychoacoustic indicators (see Annex B).

c) **context:**

— information on the context shall be reported in detail in accordance with Annex A.

This document specifies the data collection and reporting method(s) for each of these key components in turn. The annexes provide further details of recommended (and any alternative) approaches for each component.

The main requirements and some of the associated questions for descriptors and indicators shall support:

— acoustical assessment: acoustic distinction of the variety of soundscapes (Why does this place sound different? What is unique?);

— psycho-physiological assessment: assessment of the grade and type of neurophysiologic stimulation (Is the soundscape stressing, supporting or relaxing? Which emotions are linked to it?);

— context assessment: assessment of the person-environment fit [Are there sounds or sound components that interfere with the intentions/expectations of the meaning or support these? Are there other sensory factors (visual, vibration, olfactory) that interact with the sounds in a supporting or distorting way? Is the meaning of this place or the attachment to this place distorted, undermined or supported?];

— design or remedial action: assessment of the holistic potential of the place (Are control/coping options available/implementable? Can new meaning/emotions/attachment and social interaction be created to support adaptation and meet expectations?).

4.2 Acoustic and psychoacoustic indicators

In order to describe the acoustic environment as the sound from all sound sources modified by the environment and auditory sensations evoked by the sound, a set of acoustic and psychoacoustic indicators shall be measured and reported as a minimum. Classical acoustic indicators shall be measured and reported to be in conformance with ISO 1996-1. This includes equivalent continuous sound pressure level $L_{\mathrm{Aeq},T}$ and $L_{\mathrm{Ceq},T}$ as well as percentage exceedance levels $L_{\mathrm{AF5},T}$ and $L_{\mathrm{AF95},T}$.

Psychoacoustic parameters play an important role with respect to auditory sensations. Such parameters are functions of the time structure and spectral distribution and lead to results which yield information with greater differentiation than the consideration of the sound pressure alone. Psychoacoustic loudness indicators shall be reported in conformance with ISO 532-1, since acoustic environments are time-variant sounds.

The consideration of further psychoacoustic parameters, like sharpness, tonality, roughness and fluctuation strength, is recommended. If calculated and reported, the used calculation method shall be reported. Some standards exist that can be applied to determine further psychoacoustic indicators, such as DIN 45692[6] for sharpness calculation or ECMA-74[7] for quantifying the tonality of discrete tones.

In general, the application of psychoacoustic parameters allows for an enhanced description of acoustical environments (see Annex B). It has been shown that psychoacoustic parameters, like

loudness and sharpness, correlate with the perception and assessment of environmental noise sources, e.g. road traffic noise[25]. However, acoustic and psychoacoustic indicators describe only the sound and evoked auditory sensations; for example, whether the sound is perceived as loud, sharp or tonal. These indicators are not intended to explain the level of pleasantness or appropriateness of sound in its entirety.

5 Data collection

5.1 General

In practice there is still a significant gap between soundscape descriptors and indicators, which are used in some standardized way in the "measurement by persons" and those applied in the "measurement by instruments". Psychoacoustic, ecological and landscape acoustics require techniques to be more tightly integrated in such studies to mediate between personal experience and group-area-society requirements and needs. Only through the proper integration of these techniques can the potential of the soundscape approach be implemented in planning and design. The soundscape approach relies by definition on this strategy. In this strict sense it can be said that any study that does not consider people, acoustic environment and context in a combination of several differing investigative methods cannot be seen as a full-featured soundscape study. So it is necessary to investigate each soundscape situation from several viewpoints. This requires performing a soundwalk (see 5.2) and/or a questionnaire (see 5.3) and/or a guided interview (see 5.4) in addition to the binaural measurements (see 5.6).

Soundscape data collection tools and methods can be applied in situ and in situations where sound is reproduced by headphones or loudspeakers. In the case of the reproduction of sound (e.g. for the performance of listening experiments) an appropriate test design shall be applied.

5.2 Soundwalk

Over the past few decades, the focus of soundwalks has shifted from noting the researcher's view to determining the people's understanding of places. The experiences and expectations of people, when they are listening and observing during a soundwalk, are accessed primarily through the evaluation of the rating scales and the annotation of the participants' comments.

Soundwalk is a method to obtain human sensations/responses/outcomes (see ISO 12913-1). Soundwalks are participatory group sound and listening walks through the environment. Soundscape analysts observe and measure the perceptual responses of the participants to the acoustical, visual, aesthetic, geographic, social and cultural differences. The participation of local experts and members of relevant communities of interest in soundwalks enables researchers, practitioners, policy makers and local authorities to collect and analyse ecologically valid acoustical as well as perceptual data. This enhances the investigator's sensitivity to the unique features of the examined areas.

Human sensations, responses and outcomes cannot be easily reduced to singular values of physical units. The response to sound depends on the listener's mental, social and geographical relation with the sound source.

5.3 Questionnaire

When gathering data on human perception, the investigator should not interfere with the participants' experience. Such data collection shall capture the general mood, restoration, appreciation, preferences and overt behaviour to create an accurate representation of a specific location. Moreover, this type of evaluation shall respect the way people are experiencing their environment. Data gathering via questioning participants is a possible way to assess the whole path from acoustic environment to soundscape, including the processes of individuals assessing and giving meaning to sound(s) and/or demonstrating their responses to the acoustic environment. The final assessment shall be holistic, covering all auditory sensations as well as all other context variables such as visual stimuli and personal expectations.

5.4 Guided interview

Data collection on human perception puts very strict requirements on managing attention processes. Guided interviews shall be performed with the respective participants to explore associations, feelings and emotions concerning the acoustic environment more deeply. The soundscape investigation demands a holistic approach for the analysis of environments. This is why perceptual data (interviews, questionnaires, non-participatory methods), psychoacoustic indicators (e.g. loudness, roughness, sharpness) and physical parameters (sound levels) shall be used. Moreover, perceptual data collection is particularly constructive because the context and information content of a soundscape can be assessed as a result. It is important to use guidelines for narrative interviews to guarantee compatible data collection related to the participant's individual perception. Currently guidelines are available in different formats. An example is provided in C.3.3.

5.5 Sound source taxonomy

To assist in source reporting for researches, a classification for all sound sources in any acoustic environment in accordance with a common framework or checklist, is recommended[17], see Figure C.1. The taxonomy shown in C.1 has been constructed on three levels: types of places, types of sound sources and sound sources.

Categories of places are broadly considered either indoor or outdoor; within the outdoor environment, they are divided between urban, rural and wilderness conditions. One can thus refer, for example, to the acoustic environment of a wilderness place, or the acoustic environment of an urban place. Having broadly characterized the type of the place, the taxonomy then categorises all sources of sound that can be present. Most importantly, the nomenclature of sound sources has been carefully chosen to avoid value judgements or connotations regarding these sound sources, irrespective of the type of the place (for example, "motorized transport" is preferred to "intruding traffic noise" or "the passage of lorries"). In some places, various sounds of human activities, say footsteps, can be present with only infrequent sounds from roadway traffic; but in another location, roadway traffic can constitute the only sound source. In each of these examples, the taxonomy of sources is applicable and encourages the description of sources using a common terminology. The distinctiveness of particular acoustic environments lies, amongst other things, in the presence or absence of these different sources and their relative intensities. However, the framework for sound source identification assists in comparing the reporting of sound sources across places and make other labels, value judgements and definitions more transparent, and thus portable, across different studies.

5.6 Binaural measurements

Acoustical measurements related to a soundscape shall consider the way human beings perceive the acoustic environment. For this purpose calibrated binaural measurement systems (artificial head) shall be used to record an acoustic environment. Measurement conditions shall be chosen to measure the acoustic environment as close as possible to the human auditory sensation. Binaural acoustical measurements shall be performed in accordance with Annex D.

Each binaural measurement shall be described in a soundscape binaural measurement protocol. The measurement protocol includes information about measurement time and interval, description of measurement locations, measurement equipment, atmospheric conditions, notation of the influence of topographical features, local shielding effects and description of sound sources. Reporting shall be made in accordance with Annex A.

NOTE Further recording technology such as microphone arrays are frequently used in soundscape investigations. It is acknowledged that those recording technologies can offer some advantages. In particular, such technologies strive for a latter playback based on multi-loudspeaker arrays providing a certain level of immersion. However, in contrast to binaural measurement technology these technological approaches lack standardization and make it difficult to perform aurally accurate analyses to compute psychoacoustic parameters and indicators.

Binaural recordings are used for aurally adequate analyses, for the reproduction of acoustic environments (e.g. in laboratory-based listening experiments) or for the purpose of preservation and archiving.

6 Reporting requirements

The minimum reporting requirements that shall be adopted are given in Annex A.

Annex A
(normative)

Minimum reporting requirements

A.1 General

The minimum reporting requirements in soundscape studies comprise the following:

a) the selection and classification of the participants;

b) a characterization of the studied acoustic environment;

c) the data collection with regard to human perception of the acoustic environment (including context).

A.2 Participants

Soundscape studies are primarily conducted as field studies. However, sometimes laboratory studies are also carried out. An example of a field study is a case study of a residential area where the acoustic environment is redeveloped. In such a case it is common to select residents as participants in order to learn how they perceive the acoustic environment and how they would like it to sound (indoors as well as outdoors). Other examples of field studies are evaluations of parks or green areas. In these cases it is common to select visitors in order to learn how they perceive the park and its acoustic environment. It is also possible to select a panel of participants who are brought to the field study site to evaluate its acoustic environment. Panels of participants are common in laboratory studies, which typically are used to assess audio recordings of the acoustic environment from one or several sites.

As in any study design, the participants shall be identified and the following information recorded:

a) how they were selected;

b) whether the participants were residents at or visitors to the study site;

c) whether the participants were lay people, or experts in a field that is relevant to the study (e.g. environmental noise or urban planning);

d) age and gender distribution;

e) other relevant information (e.g. hearing ability).

A.3 Acoustic environment

An acoustic environment can be real, recorded or virtual. A real acoustic environment is evaluated in situ by means of a field study. A recorded or virtual acoustic environment is evaluated in a laboratory.

The two most common recording techniques in soundscape studies are binaural and ambisonics. The former is typically reproduced by headphones and the latter by a multi-loudspeaker array. A virtual acoustic environment can be based on recorded or synthesized sound sources that are mixed together into an acoustic environment.

With regards to the characterization of the studied acoustic environment, the following aspects shall be reported:

a) what type of acoustic environment the study concerns (real, recorded or virtual);

b) the sound sources and the composition of the acoustic environment, including the total sound, the background and foreground sounds;

c) weather and wind conditions;

d) time of the year and time of the day;

e) the measurement points (including height and orientation of the binaural measurement system) and what acoustic measurements were taken;

f) the results of the measurements for the following:

— A-weighted equivalent continuous sound pressure level $L_{Aeq,T}$; C-weighted equivalent continuous sound pressure level $L_{Ceq,T}$ as well as percentage exceedance levels $L_{AF5,T}$ and $L_{AF95,T}$;

NOTE A-weighting and C-weighting are specified in IEC 61672-1. Equivalent continuous sound pressure level and percentage exceedance level are defined in ISO 1996-1.

— loudness exceeded in 5 % of the time interval N_5 in accordance with ISO 532-1;

— loudness exceeded in 95 % of the time interval N_{95} in accordance with ISO 532-1;

— root mean cubed loudness N_{rmc} in accordance with ISO 532-1;

NOTE The root mean cubed loudness (cubic mean), Nrmc, is computed by determining the mean of all loudness values raised to the power of 3 with a subsequent application of the exponent 3 as shown in the following formula:

$$N_{rmc} = \sqrt[3]{\frac{1}{n}\sum_{i=1}^{n} N_i^3}$$

where

N is the single measurement value of the loudness;

n is the number of measured loudness values.

g) for a field study or a study based on audio recordings, a description of the study site, including the type of site (e.g. indoors or outdoors; residential, plaza or a park);

h) for a recorded or virtual acoustic environment, how it was recorded or created and how it was reproduced.

A.4 Data collection

Data on how a person or people perceive or experience and/or understand the acoustic environment shall be collected by interviews or questionnaires or rating scales, or by observations of behaviour or combinations of those. The following shall be reported:

a) the methods used;

b) the questions asked, how they were formulated and how the responses were documented;

c) for a study based on rating scales, how the questions, response alternatives and response format were constructed and formulated;

d) what language was used in the study and examples of questions written in the original language as well as in translation;

e) for observations of behaviour, how they were conducted and documented.

A copy of the data collection instrument (e.g. questionnaire or scales) shall be included in the report.

Annex B
(informative)

Psychoacoustic indicators

According to ISO 532-1 and ISO 532-2[8], loudness and loudness level are two perceptual attributes of a sound describing absolute and relative sensations of sound strength perceived by a listener with otologically normal hearing under specific listening conditions. Since the loudness parameter considers human signal processing effects like spectral sensitivity (frequency weighting), masking, critical bands and nonlinearities, it shows a higher correspondence with the sensation of volume (loudness) than any sound pressure level based indicators[23]. For example, the psychoacoustic parameter loudness indicates a loudness difference between a narrow-band noise compared to a broad-band noise, even if both sounds have the same A-weighted sound pressure level. The broad-band noise is clearly perceived as louder, which is indicated by the respective loudness value.

For calculating the psychoacoustic parameter loudness, different models and procedures have been developed with the aim to represent the human signal processing as closely as possible. In particular, procedures for computing the loudness of steady sounds are already established and have been in use for several years (DIN 45631[3], ISO 532[9], ANSI/ASA S 3.4[2]). However, almost all sounds in acoustic environments are time-variant in general and loudness computation models for time-variant sounds should be used. ISO 532-1 and DIN 45631/A1[4] allow for determining the loudness of steady as well as time-variant sounds.

Sharpness represents the sensations of timbre with emphasis on high frequency content. It is influenced by the spectral envelope of the sound and increases with increasing high frequency content[23]. The calculation of the psychoacoustic parameter sharpness as independent from total loudness is standardized in DIN 45692[6].

There is an alternative computation method for sharpness with a slightly different weighting function, but without any influence of the total loudness on sharpness as well[62]. Other computation methods for sharpness exist, which apply a certain total loudness dependent weighting[11]. For example, the noise of waterfalls produces a relative high sharpness sensation.

With respect to modulated sounds, different sensations exist and are modelled by different indicators. At very low modulation frequencies the loudness changes slowly up and down leading to a sensation of fluctuation. The parameter fluctuation strength describing this phenomenon has its maximum near a modulation frequency of 4 Hz. For example the sound of sirens possesses a high fluctuation strength. Fluctuating sounds usually attract attention. At higher modulation frequencies a sensation of roughness takes place. Roughness is related to relatively quick changes of sound with a maximum near a modulation frequency of 70 Hz[23]. Moreover, the parameter roughness is influenced besides the modulation frequency by the sound pressure level, carrier frequency and degree of modulation. For example, a motor scooter equipped with a two-stroke engine produces a relatively high roughness. Standardized computation methods of roughness or fluctuation strength are not available yet. However, different models for the computation of roughness exist[11][23][44][56].

Tonality[12] is another sensation of timbre, which indicates whether a sound consists mainly of tonal components or broadband sound[12][59]. Although standards for the determination of tonal content in sound exist (DIN 45681[5], ANSI/ASA S 1.13[1]), these standards do not model the psychoacoustic impression of tonality, but rather focus on the derivation of penalties. However, different approaches exist to compute the perceived amount of tonality of a sound[11][57][59]. Several publications have observed an increase of annoyance for technical sounds with increasing tonality[38].

Other hearing related parameters are available, e.g. impulsiveness[55], gravity centre of spectrum[21] or relative approach as an indicator of the perceived amount of noise patterns[27].

In general, it is important in the case of the determination of a single value representing an auditory sensation to consider the human cognitive processing of sound. For example, in case of a time-variant sound, the determination of a single value representing a “sensation magnitude in average” over a certain period should follow the typical human cognitive stimulus integration. Frequently, the arithmetic mean of the function of a parameter over time does not reflect the human cognitive processing of a sound. For example, surveys have shown with respect to loudness that the perceived overall loudness of a time-variant sound is well represented by the percentile loudness N_5[23]. This is the loudness, which is reached or exceeded in only 5 % of the measuring time interval. Prominent and loud sound events dominate the overall loudness and should be emphasized.

Since binaural measurements provide signals representing the left and right ear of a listener, any acoustic parameter can be calculated for both ears separately. Since an acknowledged model for combining dichotic situations causing inter-aural differences into one global sensation is missing, different strategies for determining a single value are reasonable. For example DIN 45631/A1[4] and ISO 532-1 recommend using the maximum value of both ears or in ISO 532-2[8] a binaural loudness model is proposed[43].

In general, if psychoacoustic parameters are analysed the applied computation method and potential post-processing steps should be indicated.

NOTE In psychoacoustics, the term "parameter" is commonly used for established psychoacoustic metrics instead of the term "indicator".

Annex C
(informative)

Data collection methods

C.1 Taxonomy

To assist in source reporting an information structure that is aligned with a classification for all sound sources in acoustic environments can be used. A proposed taxonomy is shown in Figure C.1 and is intended to be used only by investigators and is not intended to be used by participants.

C.2 Soundwalk procedures

C.2.1 General

The purpose of a soundwalk is to evaluate the soundscape in a given area. Usually a soundwalk should be led by a moderator who also conducts a narrative interview or discussion session after the soundwalk. The participants may be led along a predefined route or be asked to walk where they prefer within a predefined area. They may be asked to stop at predefined locations to listen or to select any place they like in order to listen more attentively. The moderator should instruct the participants to pay attention to what sounds are heard during the soundwalk, what they liked and disliked, why, and how they believe the acoustic environment could be improved. The participants are expected to report on these aspects in their personal narratives, comments or statements. For examples, see C.3.1 and C.3.2.

C.2.2 Soundwalk: Obtaining human sensations/responses/outcomes

C.2.2.1 Instructions to the participants about to undertake a soundwalk

a) Conduct the walk in silence in order to pay attention to surrounding sounds and to avoid disturbing the concentration of the other participants.

b) Try listening to "sound as sound", suspending any attempts at "source identification" and source-related value judgements in favour of listening to the innate qualities of the sound.

c) Alternatively, try to identify the maximum number of separate sounds audible at any one time.

d) Identify which sounds are entirely natural and which are man-made and by what or whom.

If attention should also be paid to the movement, body awareness and sensitization within a soundwalk, it is proposed to add the following instructions.

e) Listen to the sounds that your body creates while moving. These are the sources of sounds closest to you and establishing the first interaction between you and the environment.

f) Lead your attention away from your own sounds and listen to the sounds nearby.

g) Lead your attention away from the nearby sounds and listen beyond, into the distance.

h) Select a continuous moving sound (e.g. footsteps or a vehicle) and try to listen to it until it becomes inaudible. This can help "recalibrate" the ear to pick up detail.

i) Closing your eyes (when safe to do so) can help to improve listening.

j) Alternatively, try to train your hearing to focus on sounds which have positive associations for you, even if they are only just audible above sounds which normally have negative associations.

k) Assess how the changing environment alters sounds; for example, absorption by some surfaces, reflection from others, especially multiple reflections within narrow alleyways, tunnels, colonnades or below bridges. Judge where any of the sounds are coming from. Assess the effects of screening by buildings, walls, or changes in sound level.

C.2.2.2 Questions to the participants of a soundwalk

a) What was your favourite sound on the walk? Why and where was it?

b) What sound did you dislike the most? Why and where was it?

c) Where would you make improvements to the sounds you heard? which would be the most important and why?

d) Did the sounds you heard match your expectations of the area? why/why not?

C.2.3 Soundwalk: Obtaining quantitative data

A questionnaire with predefined questions and response scales should be used to describe the most essential aspects of the soundscape. At least twenty participants should assess the soundscape with the questionnaire at exactly the same sites in the area under scrutiny. The selection of the assessment sites depends on the purpose of the study. Sometimes the researcher or investigator selects the assessment sites alone, and sometimes the researcher or investigator selects them together with the participants, who can be stakeholders in the study.

For each soundwalk a group of up to five participants walks together along a predefined route. Therefore, the procedure should be repeated a number of times to reach at least twenty independent observations of each assessment site under similar conditions (e.g. time of the day, weather, ambient conditions). The participants should not discuss their assessments or experiences with each other during the soundwalk. In order to reduce a systematic influence of order effects on the assessments it is necessary to bring the different groups of participants to the assessment sites in different orders, if possible.

A soundwalk with predefined assessment sites should have the following aspects.

— The soundwalk area, including assessment sites, is predefined.

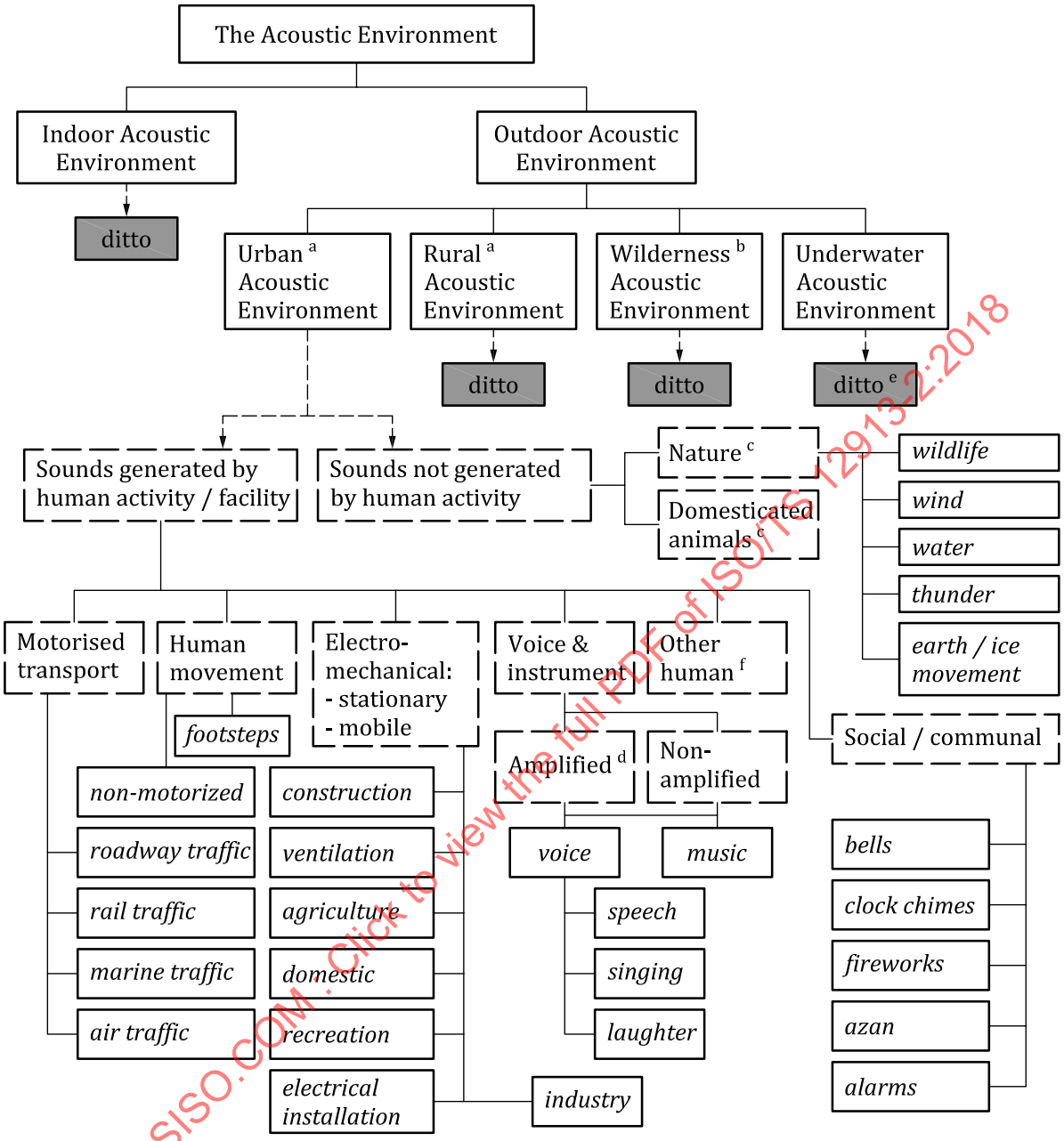
— The soundwalk is led by a moderator.

— A questionnaire with predefined questions and scales is used.

— The participants walk in silence and listen freely for the duration of the soundwalk.

— All participants fill in the questionnaire at the predefined assessment sites.

— At least twenty independent observations are collected at each assessment site.



a The urban/rural distinction is not always readily defined, but remains useful.

b The wilderness category includes national parks, undeveloped natural and coastal zones and large recreation areas for example, though the wilderness/rural divide is not always clear-cut.

c While "nature" and "domesticated animals" sources are shown as being "not generated by human activity" there are many areas of overlap, e.g. the sounds of running water in constructed water features or the sounds of wind on buildings. Domesticated animal sounds are generally from animals associated with a human activity/facility.

d Recording, replay and amplification can occur for any type of sound, e.g. in installations playing nature/wildlife sounds.

e Because of the different acoustic impedances in air and water, many of the terrestrial sound sources would not normally be observed under water, but overall the same classification system is still applicable.

f Coughing, for example.

NOTE 1 Bold boxes = types of places; dashed boxes = types of sound sources; italics = sound sources.

NOTE 2 See Reference [17].

Figure C.1 — A taxonomy of the acoustic environment for soundscape studies

C.2.4 Local expertise

Local experts are those people — e.g. the daily inhabitants of an environment or the stakeholders in the investigation area — who provide their expertise to researchers, investigators and project designers through such processes as soundwalks and open interviews. The listener's attitude, expectations and experiences are significant parameters which can be used to comprehend the different perceptions and evaluations of the acoustic environment of a place due to specific stimuli. People unconsciously gather the most important key features of the acoustic environment by experiencing this area in daily life. That experience considers all conscious and unconscious influences sound makes in peoples' mind, as they judge the appropriateness of sounds, sound sources, places or situations. Expanding the evaluation through a situational discourse in an ad hoc interview on the noted perception reveals additional layers of the description.

C.3 Examples of data collection

C.3.1 Questionnaire (Method A)

C.3.1.1 General

This questionnaire presents questions for collecting data on how people perceive an acoustic environment in situ, e.g. in a soundwalk. The questions may be included in the questionnaire in any order, used alone or together with other complementary questions, depending on the purpose of the study.

NOTE Details of Method A can be found in references [13], [14], [15], and [16].

Participants should be informed in advance of participating how their data will be used/processed/stored. Upon agreeing to participate they should sign a relevant consent/release form to this effect. Furthermore, interviewees should be told that all of the questions are optional and they are free to answer any of them or not as they choose. This applies to all three methods (Method A, B, and C).

C.3.1.2 Questionnaire part 1: Sound source identification

The investigated acoustic environment should be characterized by identifying what sound sources can be heard in the area and how dominant they are. In general, sound sources can be divided into three main types:

— sounds of technology;

— sounds of nature;

— sounds of human beings.

Examples of technological sounds include those from transportation, like the sounds of cars, buses, trains and air planes, as well as those from industry including warning signals and sounds from constructions, plants and machineries. Examples of natural sounds are singing birds, flowing water and wind in vegetation. Examples of the sounds of human beings are mainly voices, footsteps and children at play.

Figure C.2 presents a version of the sound source identification scale. It consists of a question and an additional instruction. Thereafter follows a list of four response scales. The heading of each response scale in the list presents a type of sound sources, or part thereof, including some examples to guide the respondent.

To what extend do you presently hear the following four types of sounds?
Please tick off one reponse alternative per type of sound

	Not at all	A little	Moderately	A lot	Dominates completely
Traffic noise (e.g., cars, buses, trains, air planes)	☐	☐	☐	☐	☐
Other noise (e.g., sirens, construction, industry, loading of goods)	☐	☐	☐	☐	☐
Sounds from human beings (e.g., conversation, laughter, children at play, footsteps)	☐	☐	☐	☐	☐
Natural sounds (e.g., singing birds, flowing water, wind in vegetation)	☐	☐	☐	☐	☐

NOTE The first scale has the heading "traffic noise" and the second completes the category with the heading "other noise." The term "noise" is used instead of "technological sounds". The term "noise" is not intended as a value judgement.

Figure C.2 — Questionnaire part 1 related to the sound source identification

Figure C.3 presents an alternative. It includes one response scale for each of the three main types of sound sources.

To what extend do you presently hear the following three types of sounds?
Please tick off one reponse alternative per type of sound

	Not at all	A little	Moderately	A lot	Dominates completely
Noise (e.g., traffic, construction, industry)	☐	☐	☐	☐	☐
Sounds from human beings (e.g., conversation, laughter, children at play, footsteps)	☐	☐	☐	☐	☐
Natural sounds (e.g., singing birds, flowing water, wind in vegetation)	☐	☐	☐	☐	☐

Figure C.3 — Questionnaire part 1 related to the sound source identification (alternative to Figure C.2)

C.3.1.3 Questionnaire part 2: Perceived affective quality

Figure C.4 presents the second part of the questionnaire and is related to the perceived affective quality. It consists of a question and an additional instruction. Thereafter follows a list of eight response scales with an affective attribute in the heading.

For each of the 8 scales below, to what extend do you agree or disagree that the present surrounding sound environment is...
Please tick off one reponse alternative per scale

	Strongly agree	Agree	Neither agree, nor disagree	Disagree	Strongly disagree
- pleasant	☐	☐	☐	☐	☐
- chaotic	☐	☐	☐	☐	☐
- vibrant	☐	☐	☐	☐	☐
- uneventful	☐	☐	☐	☐	☐
- calm	☐	☐	☐	☐	☐
- annoying	☐	☐	☐	☐	☐
- eventful	☐	☐	☐	☐	☐
- monotonous	☐	☐	☐	☐	☐

Figure C.4 — Questionnaire part 2 related to the perceived affective quality

C.3.1.4 Questionnaire part 3: assessment of the surrounding sound environment

Figure C.5 presents a five-point ordinal-category scale related to the assessment of the surrounding sound environment.

Overall, how would you describe the present surrounding sound environment?

Very good	Good	Neither good, nor bad	Bad	Very bad
☐	☐	☐	☐	☐

Figure C.5 — Questionnaire part 3 related to the assessment of the surrounding sound environment

C.3.1.5 Questionnaire part 4: Appropriateness of the surrounding sound environment

Figure C.6 presents a five-point ordinal-category scale related to the appropriateness of the surrounding sound environment.

Overall, to what extent is the present surrounding sound environment appropriate to the present place?

Not at all	Slightly	Moderately	Very	Perfectly
☐	☐	☐	☐	☐

Figure C.6 — Questionnaire part 4 related to the assessment of the appropriateness of the surrounding sound environment

C.3.2 Soundwalk data collection (Method B)

C.3.2.1 General

A soundwalk should be conducted to learn about an existing acoustic environment but also to provide information about a proposed environment. Such information can be used for the classification of areas but also for planning requirements.

Method B was developed in the TUD COST Action TD0804[19] It presents questions for collecting data on how people perceive an acoustic environment in situ. The questions should be included in the order presented in the following clauses. It is designed to deepen current understandings of the acoustic environment. A soundwalk should be led by a person familiar with the requirements concerning the procedure of a soundwalk to guarantee a proper data collection.

C.3.2.2 Instructions

C.3.2.2.1 For the person leading the soundwalk

The person leading the soundwalk should stop at the defined site and should provide standardized instructions, including the participants' viewing direction. Prior to the soundwalk, local experts should be consulted to identify locations for study during the soundwalk.

The participants are requested to listen in silence for a certain period to be reported (e.g. 3 min) and to use all of their senses to perceive the site.

After listening the participants are requested to fill out the assessment (a Method B specific questionnaire). The moderator of the soundwalk should not rush this process and allow the participants time to process their thoughts and complete the form as long as needed.

All details of the soundwalk, such as the direction faced during observation and the period of listening, should be reported. The relevant time period of the assessment, which is the time the participants listen to the sounds of a study site before completing the assessment sheet, should be defined in the preparation of the soundwalk measurements and should be communicated to the participants by the person leading the soundwalk.

C.3.2.2.2 For the person performing the binaural measurements

The person responsible for the binaural measurement system should direct the orientation of the measurement system in the position according to the participants' view. While measuring, the measurement system should not be moved. The person supervising the measurement system should be as quiet as possible.

NOTE The person leading the soundwalk and the person performing the binaural measurements can be two different persons or one and the same person.

C.3.2.2.3 For the participants

The participants should not eat or drink while listening to a study site. They should not walk during the evaluation phase, which is the defined period of time when the participants are requested to consciously listen to a study site. The participants should use all of their senses. The participants are requested to rate their experience on the provided scales (these can be marked at any location on the scale) after listening for the defined period of time. Moreover, they should list noticed sound sources in descending order starting with the most noticeable one. Finally, the participants should note any thoughts running through their mind after listening the defined period of time. After completing the assessment sheet, the participants should move to the next defined site.

C.3.2.3 Soundwalk data collection part 1: Assessment of the sound environment

The participants should assess a site on three different five-point unipolar continuous-category scales with additional verbal labelling ranging from "not at all" to "extremely". The participants are requested to listen in silence for a defined period of time (e.g. 3 min) and to use all of their senses to perceive the respective surrounding. The participants should assess their experiences on the scales shown in Figure C.7. They can provide an assessment at any location on the scale.

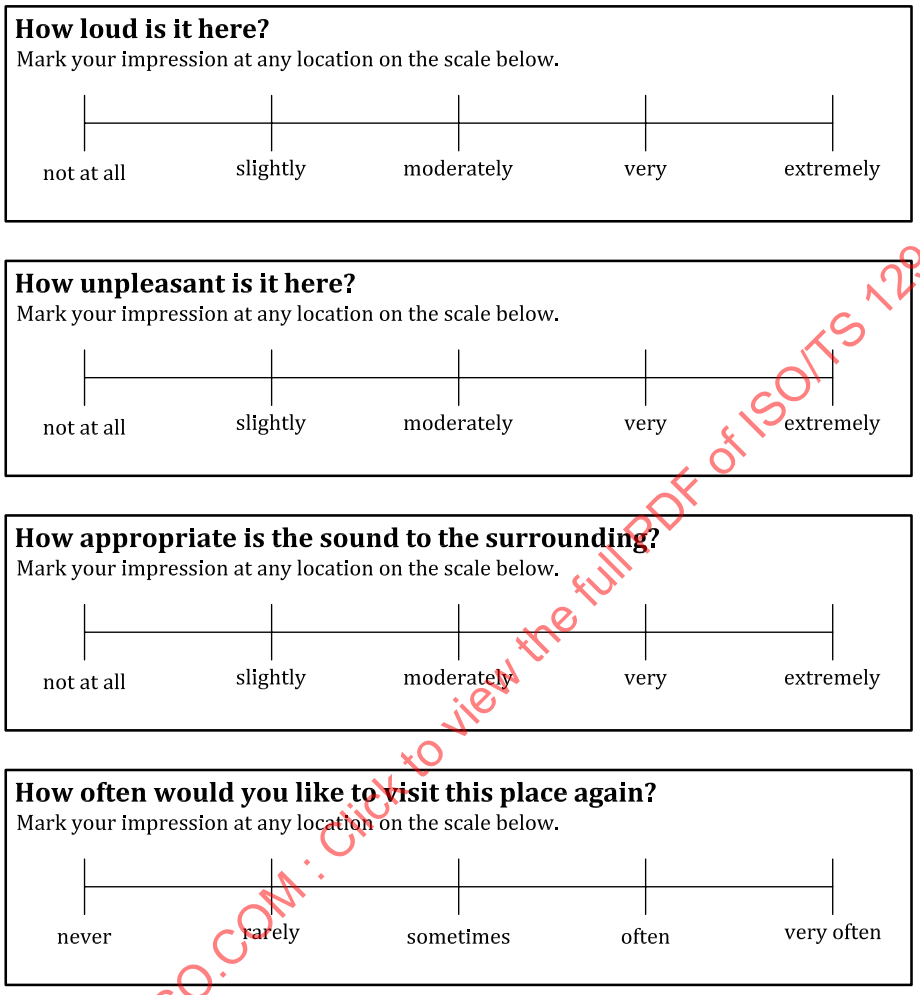


Figure C.7 — Soundwalk data collection part 1 related to the assessment of the sound environment

C.3.2.4 Soundwalk data collection part 2: Sound source recognition and ranking

The soundwalk participants are requested to list all of the sound sources they have noticed while actively listening in descending order starting with the most noticeable sound source, see Figure C.8. The number of sound sources is not predefined but limited to eight. The participants answer this question after they have listened in silence for the defined period to the environment.

NOTE The list of noticed sound sources can provide information about attention and sound source focus processes, which can influence the assessments of the environment.

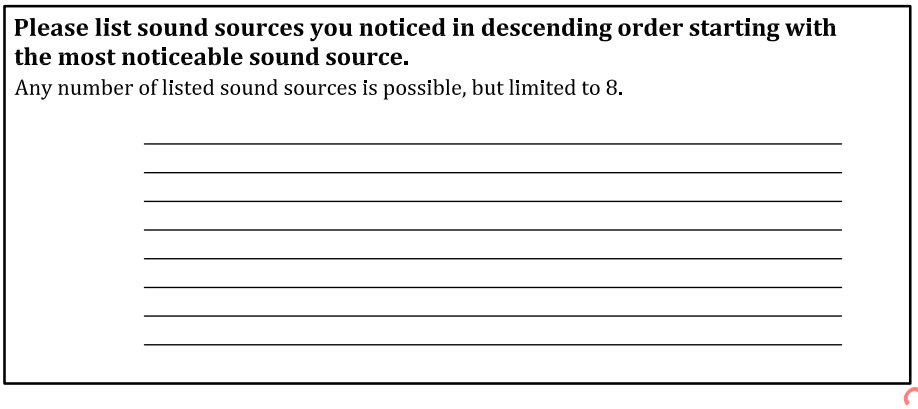


Figure C.8 — Soundwalk data collection part 2 related to the sound source recognition including ranking

C.3.2.5 Soundwalk data collection part 3: Subsequent comments

After listening, the soundwalk participants are requested to write down their thoughts and feelings while still at the specific location (see Figure C.9). The moderator of the soundwalk should not rush this process and should allow the participants time to write down their thoughts and feelings as long as needed.

NOTE Narrative reports provide a valuable source of information for the understanding of the underlying mechanism behind the perception of the acoustic environment by local experts. Moreover, this procedure provides site specific data that are directly related to the participants' mood and assessment strategies[50].

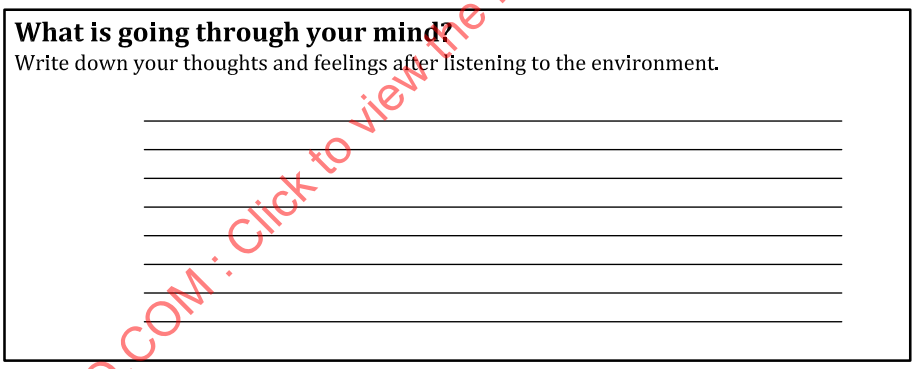


Figure C.9 — Soundwalk data collection part 3 related to the subsequent comments

C.3.3 Interview guideline (Method C)

This guideline for narrative interviews in residential contexts is based on COST TD0804 STSM[42] [20]. It follows the definition of soundscape in ISO 12913-1 to deepen current understandings of the acoustic environment from people important to understanding the local context, including citizens, policy makers, local authorities, designers, special interest groups and other relevant members of the community of interest. This guideline demonstrates the breadth of possible lines of inquiry. However, not all portions are necessarily applicable to the specific scenario under study and interviewers should remain open to spontaneous questions arising from the conversation.

The guideline refers to satisfaction with the living space, residential experience, experiences with/ relation to sounds in life, daily routines, co-inhabitants, neighbours, spatial identification of sound effects within residences, effects of various kinds of sounds, assessment of the effect that varying

sounds have upon overall sound exposure, actions to improve residences with regard to sound exposure and to personal data.

a) Satisfaction with the living space

   1) How much do you like living in this house and in this neighbourhood?

      Complementary question: How long have you been living here?

   2) Why do you like/not like living here?

      If it has not been part of the interview so far, inquire about the following details:

      — Do you feel a personal attachment to this neighbourhood?

      — Do you have relatives or friends living nearby?

   3) How do you feel about the overall physical environment in this area?

      To be asked only if not previously mentioned during the interview.

   4) How important is sound in this context?

   5) What has changed since you have moved in?

b) Residential experience (regarding sound conditions) prior to moving into one's present residence

   We are now interested in your sound experience in other places.

   1) What was your experience in your previous residence?

      Allow for individual expression first, then ask the following:

      — Can you still remember the sound environment in the residence and in the neighbourhood?

   2) Can you still remember a residence in which the sound experience was especially important? If yes, what was/were the sound(s)? Why and how did this/they affect you?

c) Experiences with/in relation to sounds in life

   1) Are there sounds that you like very little or not at all?

      — *Follow on question concerning development*: Have you always felt this way about that/those sound(s)?

   2) What sounds do you have to deal with in your present professional life?

   3) Do you have hobbies or leisure time activities which expose you to a high level and/or extended periods of sound? If so, what are they and how long/high is your exposure to sound?

      (Example: making music, doing handicraft, riding motorcycle, sportive shooting)

d) Running through the daily routine

   Now we would like ask about your daily routine a little more thoroughly. You can think of any given workday, the only thing that matters is that this day is representative or average with regards to the rest of your life. It is especially important at this point where you actually are at a given moment and which kinds of sound occur. Please start with getting up in the morning.

   Ask about a relative time frame.

   Supportive questions dealing with the situation at hand:

   — Where actually are you?

— What exactly are you doing there?

— What kind of sounds are you aware of in this environment?

— What is pleasant/unpleasant about these sounds?

— What kind of emotions do you experience when hearing these sounds?

— During which part of the day are you yourself determining the sounds around you and during which part are you exposed to them instead?

— Are there times during which you consciously perceive several sound sources at once?

— Are there conspicuous sounds which occur only on certain days?

— So far we have talked about one of your average workdays. What does your weekend look like? Is there a difference in sound exposure during a Saturday or Sunday in contrast to a regular weekday? If that is the case, please describe in detail.

— Now, if you look back at your week: are there quiet times during which you can take respite from sound exposure and if that is the case which are these?

e) Co-inhabitants

1) How do your co-inhabitants experience the sounds occurring both within and outside your home?

2) How do you think your neighbours experience the sounds originating outside their homes when they are inside of their homes?

3) What do you think is the impact of the sounds originating in your own residence on your neighbours?

f) Spatial identification of sound effects within the residence

1) Is the sound exposure the same in all the rooms of your residence or does it differ?

2) What are the reasons for that?

Optional follow-up topics: the configuration of the rooms, at the windows, walls, doors, ceilings, floors, appliances, etc.

3) Where do you prefer to stay in your residence?

4) Do you experience the sounds differently according to the season of the year, condition of the weather, time of the day, quantity of wind, etc.?

5) Are there sounds from outside or not within the residence which help you to identify certain events, happenings, times of day, etc.?

6) Are there sounds which you cannot identify?

7) During which times of the day and in which parts of the residence do different sounds interfere each other? This question refers to both outside sounds as well as sound sources inside the residence.

8) In this case, does one of the varying sound sources (from outside or inside) hide the others or are all the varying sound sources still distinctly audible?

9) Are you under the impression that this is a cumulative effect?

g) Effects of various kinds of sounds upon moods and experience

1) Are there sounds which stimulate or support you during certain activities and moods?

2) Are there sounds which you appreciate to divert your attention from a given activity?

3) When you find yourself reacting to unwanted sounds over a longer period of time, which emotions prevail?

Let the emotions be described first, then offer further descriptive terms:

Feelings of helplessness, weakness, wrath, anger with respect to the authorities, resignation.

4) Could it be possible that the sounds contribute to tensions and conflicts with your co-inhabitants and/or neighbours?

5) Do you feel that sound exposure could lead to health problems for you personally?

Ask the following only if specific statements regarding health impediments are being made:

— Do you believe that there is a relation between strong sound exposure and certain health impairments?

h) Assessment of the share that varying sounds have upon overall sound exposure

1) How important is the sound exposure in your residential experience in relation to other exposures?

2) Do you find that the sound exposure in your residential area with regards to living conditions here in general are common place or extraordinary?

3) Do you incur financial disadvantages through this sound exposure?

Optional follow-up topics: Investments into soundproofing, depreciation of an apartment or a house, loss of time, diminishing productivity.

4) Would you rather move if you were to find a comparable residence in a quieter residential area?

i) Actions to improve the residence with regards to sound exposure

1) Which actions are you taking to hide from or avoid unwanted sounds?

First allow for a description of the measures taken, then offer additional examples (such as those that follow) and ask about effectiveness and effects:

— Windows for sound protection; keeping windows closed; using music to mask other sounds; using rooms with strong sound exposure less during the times in question; not using the residence during periods of peak sound exposure; using portable music device; using earplugs; taking medicine; complaining to those responsible for the sound; moving out.

2) What actions for improving sound conditions do you expect from:

— your landlord;

— your neighbours;

— the municipal authorities;

— the government.

3) *If relevant ask:* Would you join with your neighbours to do something about the noise pollution?

j) Personal data

(Only to be asked if this data has not yet been collected.)

We now would like to ask you about your personal data:

1) How old are you?
2) What is your occupation/profession at the moment?
3) With how many in the household do you share your residence?
4) Do you ever have difficulty with hearing?
5) Have you ever been diagnosed with hearing loss and/or tinnitus?

Annex D
(normative)

Binaural measurement methods

D.1 General

This annex specifies how to perform binaural acoustical measurements by means of artificial head measurement systems. In contrast to recordings based on a monaural microphone, binaural acoustic measurements record sound as if a human listener is present in the original sound field, maintaining all spatial information.

NOTE In principle, recordings using microphone arrays are a potential alternative to binaural measurement technology in the context of soundscape studies. While binaural measurements are typically reproduced by headphones, multi-microphone array recordings can be played back using suitable multi-loudspeaker arrays. Certainly, multi-microphone array technologies are more complex with respect to recording, auralisation and reproduction. In contrast to the established and manageable binaural measurement technologies, array-based sound field techniques are currently less advanced and subject to greater technological changes. Standard techniques and best practices have not yet been established in this field. In particular, using a multitude of channel signals for analysis reflecting the human perception is still an open research topic. Therefore, preference is given to the well-established binaural measurement technology.

D.2 Position of the binaural measurement system

The height of the microphones of the artificial head measurement system shall be chosen in accordance with the expected height of a typical soundscape listener. The height of the microphones shall represent the typical height of an adult person ranging from 1,6 m ± 0,1 m above the ground. The ear canal entrance of the artificial head measurement system (position of the microphone) is the reference point. In the case of a typical listener position deviating from a standing adult person position, the height of the microphone position may be different (e.g. seated position on a park bench). A tripod or similar mounting device shall be used for artificial head measurement systems.

The orientation of the binaural measurement system is dependent on the expected typical listener position, whether facing or averted to the main sound sources.

Binaural measurements shall be performed in a stationary condition, since any movement of the binaural system and the person holding it can cause additional noise, which can be untypical for the soundscape under scrutiny.

To minimize the influence of reflections, a minimum distance of 1 m to reflecting structures should be kept. However, in special cases a closer distance to a reflecting structure is possible, if it represents a typical listener position.

The height of the microphones of the binaural measurement system as well as the orientation shall be reported. All measurement positions shall be indicated on a map.

D.3 Selection of the measurement time interval

The choice of an appropriate measurement time interval depends on the type of the investigated soundscape. The time of the day of the binaural measurement and the measurement time interval shall be chosen to cover significant and typical sound sources and sound events occurring in the acoustic environment under scrutiny.

If the acoustic environment shows a clear periodicity, where certain sounds recur regularly, then the measurement time interval shall cover at least one period of all regularly occurring sounds. Thus, the measurement time interval shall be sufficiently long to encompass all sound situations that are needed to obtain a representative picture of the soundscape. If a continuous measurement over this period is not possible, measurement time intervals shall be chosen so that each represents a relevant part of the period. As a minimum requirement, a measurement time interval shall not be shorter than 3 min.

NOTE 1 In COST Action TD0804[19][20], it was observed that a measurement interval of 3 min can capture typical sound properties of a location for a certain period (e.g. afternoon on working days). In case of shorter measurement intervals it was observed that less reliable acoustical data are achieved. However, locations having strong acoustical variability can require longer measurements. Therefore, preparatory examinations are reasonable to identify a measurement interval sufficient to grasp the properties of an acoustic environment reliably. Such preparatory examinations can be repeated measurements preceding a measurement campaign (such as a soundwalk with participants) to use a priori knowledge to define a reasonable measurement duration depending on the respective character of a location[26].

NOTE 2 The measurement time interval of 3 min as a minimum requirement or more is defined for obtaining psychoacoustic indicators and parameters only. The length of recordings used for playback in laboratory studies can vary depending on the purpose of the study.

D.4 Equalization of binaural measurements

A binaural recording has the advantage that, in addition to analysing the sound with human hearing, the sound data can be subjected to computer-based analyses. Using equalization interfaces, it is possible to analyse artificial head recordings in a way that is compatible with conventional measurement technologies. This requires that a binaural recording be properly equalized considering the type of sound field of the acoustic environment under scrutiny. Artificial head measurement systems provide different equalization types:

— equalization for standardized sound fields, free field (FF) and diffuse field (DF);

— an equalization, called independent of direction (ID)[31].

With the ID equalization only the direction-independent parts (resonances) of the outer ear's transfer function are compensated for. The ID equalization type is suitable where neither a diffuse field nor a free field exists. The equalization of the binaural measurement systems shall be chosen with respect to the sound field situation of the considered acoustic environment.

D.5 Use of wind shields

For outside recordings, the use of wind shields is mandatory.

D.6 Recording requirements

The sampling frequency shall be at least 44,1 kHz. The bit depth should be at least 24 bit.

The binaural measurement system shall offer a signal to noise ratio to be able to measure the acoustic environment without any audible distortions. The range of the binaural measurement system shall be chosen to avoid any overload.

Any binaural measurement shall be recorded in an uncompressed format.

Physical dimensions of the artificial head measurement system shall comply with ITU-T P.58:2013, 5.2 and ANSI/ASA S 3.36:2012, Table 1. The monaural frequency responses shall comply with ITU-T P.58:2013, Table 4 and those that can be derived from ANSI/ASA S 3.36:2012, Table 3.

Without a torso box, some dimensions in ITU-T P.58:2013, Table 1 are not applicable.

D.7 Information to be recorded in a soundscape binaural measurement protocol

The following information shall be recorded in a soundscape binaural measurement protocol:

a) measurement positions indicated on a map and, in terms of the height of the microphones, distance above the ground and the orientation of the binaural measurement system;

b) measurement equipment;

c) date and time, including the measurement time interval;

d) meteorological conditions described by

   1) qualitative data, such as rainy, dry, wet, humid etc., and

   2) quantitative data (temperature and, if possible, wind and humidity);

e) description of sound sources present during the measurement by qualitative data;

f) geographical parameters and topographical features described by qualitative data;

g) description of visual aspects by qualitative data.

The area under scrutiny shall be documented by means of photographs or videos.

D.8 Playback of binaural measurements

For the playback of binaural measurements, a calibrated playback system with the playback equalization corresponding to the recording equalization should be used. A playback via headphones is recommended. Since studies showed that for playback more immersive methods shall be considered, especially for urban soundscapes with low-frequency content, loudspeaker playback can be reasonable[33]. A loudspeaker arrangement based on four loudspeakers allows a binaural reproduction with comparable results when using headphones with regard to localization and distance localization. The loudspeakers should be positioned in a square formation around a central point equidistantly at 2 m. The two left-hand loudspeakers receive the same free-field equalized artificial head signal of the left channel only; the right-hand side is arranged similarly[28]. Other reproduction methods based on multi-loudspeaker arrays could be reasonable for soundscape research as well, such as higher-order ambisonics. However, even if the playback is performed correctly through binaural or ambisonics a number of environmental factors are not present or differ in the playback situation; the impressions during playback can differ to those received in the original context.