



Developing a taxonomy of soundscape interventions from a catalogue of real-world examples

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Abstract – In recent decades, there has been a growing interest in urban soundscapes and a shift towards a user-focused approach in urban sound environments. Despite this interest, there is no comprehensive taxonomy for soundscape design available. The Catalogue of Soundscape Interventions (CSI) project aims to fill this gap by creating a tool to collect and share data on real soundscape practices, with the goal of developing a design toolkit and brief to facilitate communication between local authorities, consultants, and researchers. An online platform has been launched to gather instances of soundscape interventions. This paper proposes eight dimensions of soundscape interventions and presents a taxonomy that categorizes these interventions based on recurring strategies and goals observed in 43 practice cases collected. These dimensions include stages, contributors, scale, period of time, intervention types, public involvement, aims and purposes, and approaches. As soundscape practices increase in complexity and variety, the taxonomy can be revised and expanded. Nevertheless, the provided taxonomy serves as an orientation aid for understanding, analyzing, and designing soundscapes, leading to the development of more harmonious and contextually appropriate acoustic environments.

Keywords: Soundscape design, Interventions, Taxonomy, Acoustic environment, Classification, Soundscape practices

1 Introduction

Our daily lives are profoundly impacted by the acoustic environment in which we live, which has an impact on our emotions, cognitive function, and general well-being. In order to improve the human experience and quality of life, the interdisciplinary field of soundscape design aims to comprehend, modify, and optimize the acoustic environment [1–4]. By employing a holistic approach that considers both natural and human-generated sounds, as well as positive mechanical/artificial sounds, soundscape design holds the potential to create more harmonious and pleasant sonic environments, positively impacting various domains, including urban planning, architecture, health, and education. Over the past few decades, the amount of research on soundscapes has increased substantially, particularly with regard to urban environments [5, 6]. Numerous environmental noise studies have consistently highlighted the detrimental effects of excessive noise levels on human well-being, such as those generated by transportation, industrial activities, and urban settings. These studies have

established a clear link between noise pollution and a range of negative outcomes, including stress, sleep disturbances, cognitive impairments, and a diminished quality of life [7]. In contrast, emerging soundscape research emphasizes the potential benefits of carefully designed acoustic environments. Pleasant and well-constructed soundscapes have been shown to enhance relaxation, concentration, and productivity, contributing significantly to the sense of place and identity within a specific location [8–10].

In spite of the growing recognition of the importance of soundscape design and the attention it has garnered from practitioners in the built environment and policymakers [11–13], there is still a lack of evidence of the benefits of soundscape approaches in practical contexts and applications. While some studies have explored specific aspects of soundscape, there is still a lack of a holistic framework based on real soundscape practice cases to capture the multifaceted nature of soundscape interventions in the existing literature. To this end, the Catalogue of Soundscape Interventions (CSI) project was initiated to collect comprehensive information on soundscape practice projects worldwide. The aim is to identify and collect recurring design approaches and effective intervention strategies

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and compile them as a tool to enhance communication between local authorities, soundscape consultants, and researchers [14]. In this context, “soundscape intervention” refers to a site-specific design that improves or preserves a soundscape.

The CSI project has published an online repository and is open to receiving additional examples of soundscape intervention practices. A comparable repository is SoundscapeDesign.info, initiated in 2010 as a joint effort between Gunnar Cerwén and the think tank Movium (<https://soundscapedesign.info>, retrieved August 2023). This database aggregates various sound-related practical projects and, starting from 2018, offers summaries of frequently employed actions in soundscape design, serving as a useful tool for practitioners. While there are similarities with other repositories, the CSI database adopts a systematic approach to collecting relevant information, which allows the development of a comprehensive taxonomy, identifies common strategies, and potentially uncovers drawbacks. This approach requires users to fill out a detailed submission form about interventions, guaranteeing clear and comprehensive documentation. Based on this database, in this paper, we propose 8 dimensions for describing soundscape interventions, including stages, contributors, scale, period of time, intervention types, public involvement, aims and purpose, and approaches, and provide a taxonomy of existing intervention practices.

2 Literature review

Decades of research have shed light on the direct and cumulative negative impacts of environmental noise on health, socio-economics, and the living environment [15, 16]. In urban environments, effectively controlling unwanted noise has always been a focal point of research and practical attention. However, this approach does not always result in improved quality of life, as people’s auditory comfort is not solely related to sound pressure levels, but also correlates with the type of sound, listener characteristics, context, and a variety of other factors [1]. The concept of “soundscape” was first popularized by Schafer in 1977, and the subsequent evolution of soundscape research over the past few decades represents a shift in paradigm for environmental sound studies. It has moved away from the conventional focus on noise control towards a more holistic understanding and utilization of sound in our environment [17]. According to the ISO 12913-1 standard, the term “soundscape” is defined as “the acoustic environment as perceived or experienced and/or understood by an individual or group of individuals, in context” [18]. While the soundscape can not be accurately designed in a deterministic way as it is considered a perceptual construct, the environmental conditions that influence this perception can be changed. Through thoughtful design of these conditions, it’s possible to indirectly shape the soundscape in ways that aim to enhance people’s comfort, enjoyment, or functionality of a space.

Soundscape research is not only limited to exploring the interaction between the sound environment and people, but from a practical point of view, in recent years, there has been a growing interest in the proactive creation of better sound environments. This is reflected in the definition and consideration of the concept of soundscape design. Schafer perceives the world’s soundscape as a vast musical composition in which everyone can partake in both performance and composition, and he believes that acoustic design is not exclusively the domain of sound engineers [19]. While the term “acoustic design” may suggest a purely technical and quantitative process, the concept of “soundscape design” is considerably broader [20, 21]. Soundscape design integrates various sounds in artistic and therapeutic ways, aiming to improve the acoustic environment and enhance the social, psychological, and aesthetic qualities of the soundscape [21, 22]. This approach also includes disciplines such as garden design, urban planning, and other forms of environmental design [21].

The conceptualization of soundscape design in this research is consistent with the definition provided in the “Handbook for Acoustic Ecology” [23], recognizing it as an innovative inter-discipline that integrates the expertise of scientists, social scientists, and artists, particularly musicians, with the goal of improving the social, psychological, and aesthetic dimensions of our acoustic environments or soundscapes through collaborative efforts. However, this study focuses on the practical aspect of soundscape design, referring specifically to the practice of designing itself rather than the interdisciplinary field as a whole. Soundscape design can be seen as a proactive approach that goes beyond simple noise mitigation. It implies the thoughtful and intentional construction of soundscapes, drawing from various fields like acoustics, ecology, psychology, and design to create or enhance sound environments [17]. In essence, noise mitigation is about decreasing undesirable noise, often with a clear quantitative target. While acoustic design also focuses on sound, it considers a variety of sounds rather than solely noise. However, the scope of soundscape design is broader, aiming to enhance the overall acoustic environment. It emphasizes how the soundscape influences human experience and perception.

Meanwhile, beyond focusing on the acoustic environment, the concept of soundscape design often includes human-centered participatory design methods and involves non-acoustic factors that affect people’s acoustic perception [4, 24]. In addition, many real-world construction projects take sound into account as a significant factor and implement measures to create a more favorable acoustic environment. Under this conception, what distinguishes ‘soundscape design’ from classic environmental acoustics design or noise mitigation is its central focus on multi-dimensional human perception as the design outcome and the holistic inclusion of context, especially the potential for positive impacts of the soundscape. Soundscape design also generally considers a broader array of sources and strategies, as noted explicitly in the above definition from the “Handbook for Acoustic Ecology”.

In this study, we describe soundscape practices linked to specific locations as “soundscape interventions”, which are site-specific designs aimed at preserving or improving the acoustic environment [25]. These interventions often involve modifications to the physical aspects or management of the site. This description is based on an early document from ISO Working Group 54 (ISO/AWI TS 12913-4), which is currently in progress [26].

Both the academic and practical fields have made substantial efforts to explore how to create better sound environments. Some scholars have proposed guidelines for soundscape design; for example, Brown and Muhar have identified certain spaces where there may be opportunities for soundscape planning and have suggested a design approach for soundscape planning and management [27]. Several studies have reported on and discussed the application of sound installations in public spaces, often associated with art [28–31]. In many instances, sound artists enhance urban environments through impartial listening, innovative solutions, and the introduction of new activities. They not only uncover the latent potential of sounds but also enrich the experiential and social dimensions of public spaces, closely aligning with the principles of soundscape approaches [32]. Additionally, research has contributed to understanding the quality of soundscapes [33], as well as the methods and evaluation of soundscape practices [34, 35].

Regarding soundscape intervention practices, the National Park Service (NPS) in the USA hosted a workshop in October 2012 to protect the natural soundscape of national parks. The workshop explored measures that park managers could take to control noise, focusing on aspects of transportation, facilities and maintenance, and construction. The workshop concluded with the identification of cost-effective measures to reduce noise in national parks, including equipment maintenance, policy amendments, education, monitoring, and partnerships aimed at preserving natural soundscapes and enhancing visitor experience [36]. A widely known soundscape intervention experiment in Montreal installed a sound device called Musikiosk in a park pavilion, which allows users to play audio content from their own devices. The study found that although this device led to an overall increase in sound pressure level, it did not affect people’s perception of tranquillity, but rather promoted more social interaction, sharing, and a more positive evaluation of the environment [37]. Similarly, other existing soundscape intervention practices also primarily focus on introducing, removing, or modifying sounds in a specific location to influence perception and behavior [38–40]. The employment of soundscape interventions can yield several beneficial outcomes, such as alleviating antisocial behavior, encouraging social interaction [41, 42], and leading to more positive evaluations of the environment [43–45]. However, it is worth noting that artificial interventions in the environment can have negative impacts and ethical issues, such as accusations of manipulation, displacement of marginalized groups, and interference with public space [45, 46].

Based on existing research and the variety of real-world projects, considerations of soundscape are not confined to a

specific stage of a project. Some projects conduct a comprehensive assessment of the sound environment of the site during the planning stage, considering ways to enhance the quality of the soundscape [47]. Some other soundscape interventions occur in already established sites and may involve the use of soundscape installations, such as sound sculptures and electroacoustic systems, to address existing issues or enhance environmental quality. For instance, a soundscape intervention might involve the placement of speakers in a park to deliver a diverse range of generative natural sounds or musical content, thus creating an immersive and interactive experience for visitors [48, 49]. This implies that soundscape interventions could involve various contributors besides local residents, including policymakers, planners, academics, acoustic engineers, and sound artists. In summary, soundscape interventions may vary significantly. These variations can be found in many aspects, including the contributors involved, the stage at which the soundscape is considered in the project, the duration of the intervention, its objectives, as well as the specific measures implemented. Consequently, there arises a necessity to establish an orientation guide that describes the key characteristics of soundscape intervention examples. Such an orientation aid would also facilitate the classification of both existing and future soundscape intervention practices.

3 Aims and objectives

Although scholars have explored frameworks or guidelines for soundscape installations and soundscape design, we find that these studies seldom focus on the characteristics and differences between various soundscape practices and interventions. Previous studies on soundscape design [17, 46, 50] provide several examples but do not provide frameworks or taxonomies incorporating data from numerous soundscape interventions realized worldwide. While Cerwén [48] and Oberman [51–53] have made certain attempts towards developing a classification system of soundscape interventions and the corresponding urban and landscape architecture tools, broad systematic approaches are still lacking. Therefore, this study aims to develop a classification system for categorizing and analyzing real-world soundscape practices, facilitating a structured comprehension of soundscape interventions. This will be instrumental in assessing the efficacy of various soundscape interventions and pinpointing impactful soundscape intervention strategies, which could prove beneficial for forthcoming design and planning. The objective of this study is to deduce and summarize those recurring and effective soundscape strategies from actual soundscape projects.

4 Method

The method for the data collection phase of this study primarily involved developing an online data collection platform. Through this platform, case submissions from different groups were received, and CSI project members

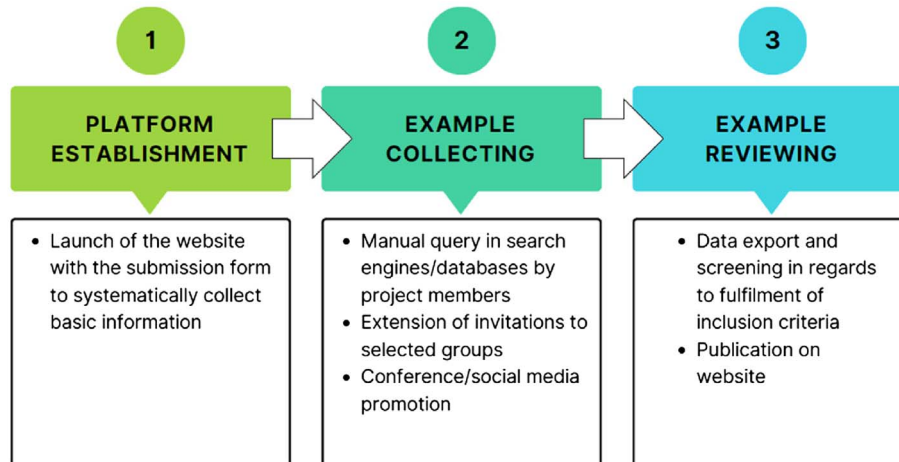


Figure 1. Three main steps of data collection regarding real-world examples of soundscape interventions (<https://soundscape-intervention.org/catalogue/>).

reviewed each project to ensure compliance with requirements. The method for the data analysis phase primarily employed Grounded theory. Grounded theory is a bottom-up approach that starts with data to build theories, making it a practical way to understand complex issues [54]. After collecting a significant number of soundscape intervention practices, a comprehensive review is conducted to propose potential dimensions for soundscape interventions, which are then refined through rounds of expert online discussions. Subsequently, this information served as a reference for analysis using the grounded theory method, facilitating the identification of soundscape practices and the development of a corresponding taxonomy.

4.1 Data collection

The collection of case studies for soundscape intervention practices involves three primary steps, as illustrated in Figure 1, including the development of data collection tools, example collecting, and example reviewing. The Catalogue of Soundscape Interventions (CSI) website (<https://soundscape-intervention.org/>) as a platform for data collection was established in 2022. The platform is divided into two main sections: a catalogue and a submission form. It features two soundscape intervention examples and provides basic information, such as the purpose of the project and our understanding of soundscape interventions, i.e., a soundscape intervention is a site-specific design to preserve or improve a soundscape. The platform was developed for the sake of clarity and accessibility. It aims to reach a diverse audience, including academia, professionals, and the general public, thereby promoting broader participation and networking opportunities.

Following the establishment of the platform, various methods were employed to accumulate practical cases of soundscape interventions. This included CSI project members actively seeking and gathering pertinent cases through online research and archival exploration. By searching for keywords such as “soundscape,” “sound,” “installation,” “practice,” “design,” and “intervention” and their

combinations in search engines, related soundscape intervention practices were documented. However, due to the asynchronous nature of searches conducted by different team members, and the direct inclusion of well-known cases, the precise figures for the total number of relevant findings or the specifics of excluded entries were not available. Additionally, invitations were extended to specific groups or individuals recognized for their expertise or experience in the field, encouraging them to submit cases they were involved in or had identified. Furthermore, the project was promoted at academic conferences [14, 20, 55], workshops, and on social media to attract attention, stimulate interest, and inspire submissions from a broad and diverse audience.

Submitted cases undergo a two-stage review process: initial screening and criteria identification [14]. Submissions with incomplete information, poor metadata quality, or unclear authorship are returned for resubmission. Entries containing false information, duplications of existing cases, invalid contact details, or unverifiable addresses are excluded. Those that pass the screening phase move to criteria identification. The screening checklist served to preprocess data and eliminate unsuitable entries, while the criteria identification checklist aided in analyzing qualitative data. Cases that can be included in the database, in addition to having basic project-related information such as name, construction time, location, etc., also need to include a specific elaboration of the goals and methods of the soundscape intervention. Ultimately, approved soundscape interventions are featured on the CSI website, with each case granted a specific subpage to offer detailed insights, including the project’s background, implementation date, observations, and supplementary materials like audio, photos, and publications. As a result, the data for this study was based on a database containing 43 real-world examples of soundscape interventions across the world (Fig. 2). These examples were gathered from various sources, including government reports, academic publications, online articles, public submissions, and non-governmental organization (NGO) reports.

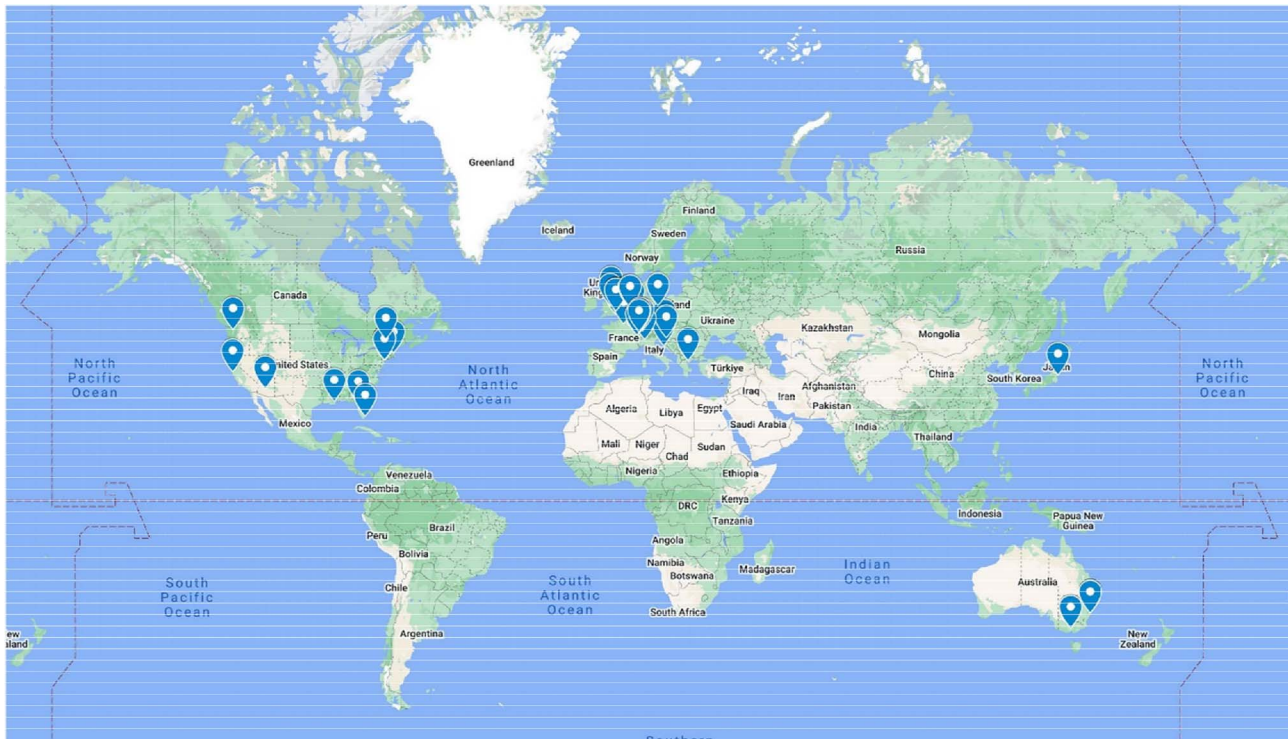


Figure 2. An overview of the locations on the world map of the 43 sites presently included in the Catalogue of Soundscape Interventions, as of November 2023 (<https://soundscape-intervention.org/catalogue/>).

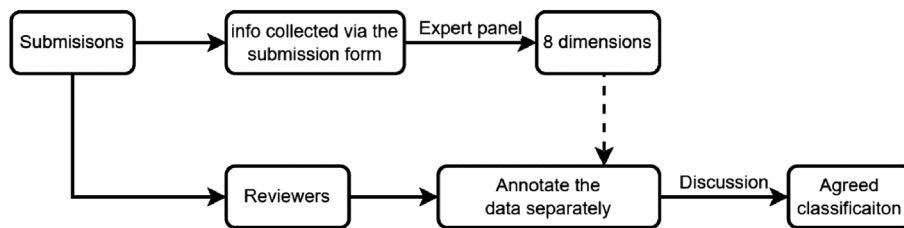


Figure 3. The process of the data analysis of real-world examples of soundscape interventions (<https://soundscape-intervention.org/catalogue/>).

The contributors of these cases are recorded in the database entries, with 37 cases contributed by members of the CSI project and another 6 cases submitted by individuals outside of the project. Throughout the process of case collection, we consistently engaged in the identification and summarization of intervention measures that emerged. With the incremental increase in the volume of cases, it was observed that intervention measures employed in newer instances frequently had precedents in earlier cases, indicating a diminishing occurrence of novel intervention strategies. Despite this, the conclusions obtained at present are more related to the nature and scope of the database. As more cases are incorporated into the database, these conclusions may evolve.

4.2 Data analysis

The process of data analysis can be divided into two main phases (Fig. 3), the first phase identified eight dimensions of soundscape interventions based on case reviewing

and expert panel discussions, while the second phase categorized all the collected cases into each category utilizing Grounded Theory. In determining the key aspects of soundscape practices, an extensive initial assessment is first conducted to fully understand the various facets of soundscape interventions. The first step involves listing potential dimensions that could characterize soundscape intervention practices by reviewing existing literature and case studies. Subsequently, an expert panel consisting of project members with rich experience in soundscapes and environmental psychology is convened, and through online meetings, these dimensions are evaluated and discussed. The main considerations for selecting dimensions are, on the one hand, to have a clear description of these intervention practices, including aspects such as time, space, and participants; on the other hand, to incorporate considerations and detailed approaches related to soundscapes in practice. The expert panel, some members of which are also authors of this article, conducted multiple rounds of review to discuss the strengths and applicability of each potential

dimension. After thorough deliberation and refinement, eight dimensions were identified as essential for capturing the essence and variability of soundscape interventions.

In the second phase of the data analysis, encoding techniques, including open coding, axial coding, and selective coding based on grounded theory, were applied, see [56] for more detail. For this purpose, two researchers independently conducted a thorough review and annotated and encoded cases of soundscape interventions. These interventions were classified from eight dimensions. To ensure the consistency and accuracy of coding, the two researchers engaged in extensive communication and discussion until a consensus was reached. Subsequently, these encoded data were compiled, aiding not only in comprehensively understanding soundscape intervention practices around the globe but also in summarizing common soundscape intervention strategies.

5 Results

5.1 The eight dimensions of describing soundscape intervention practices

The analysis of the 43 real-world soundscape interventions revealed eight distinct but interrelated dimensions that comprehensively characterize these interventions. The following items (1) to (8) provide an overview of the classification of each dimension, which will be elaborated upon in detail subsequently. Specifically, these dimensions were:

(1) Stages: Classification as “Planning” or “Implementation” based on the time and way of incorporation into the site design, inspired by different stages of green infrastructure in urban settings [57].

(2) Contributors: Categorization of contributors into five distinct groups (i.e., policymakers, etc.) based on the individuals or groups that took part in the soundscape intervention practices.

(3) Scale: Depending on the urban scale, Soundscape interventions can be categorized into three scales: micro-scale, mesoscale, and macroscale [53].

(4) Period of time: Classification of the soundscape intervention practice as “Short-term” or “Permanent”, depending on if it is established as a temporary installation or a permanent facility, following the work by Oberman [53].

(5) Intervention types: Classification of soundscape intervention types into Source, Path/Infrastructure, Integral/Design, and Receiver, grounded in the framework of the World Health Organization (WHO) guidelines for environmental noise and based on acoustic design approaches from prior work [14, 58].

(6) Public involvement: Classification of public involvement into Formal application, Design and Management, Implementation, Assessment, and Dissemination [25].

(7) Aims and purposes: Classification of the objectives of the projects into Preservation, Enhancement, Mitigation,

Design Integration, and Education, building on Cerwén’s concept of ‘The three categories of soundscape actions’ [48].

(8) Approaches: Classification of intervention approaches into four types: Architectural, Mechanical, Electroacoustic, and Biological/Natural, determined in previous work [20, 53] (Fig. 4).

Each dimension, while distinct, intersects and influences the others, contributing to a holistic understanding of the soundscape interventions. It should be noted that some of the dimensional classifications are mutually exclusive, including stage, scale, and period of time. For instance, a soundscape intervention can only be considered either permanent or short-term. However, the different types within the other five dimensions can coexist in the same soundscape intervention. For example, a soundscape intervention project may involve various contributors or approaches.

The **STAGE** in the site design at which soundscape interventions are considered is a crucial dimension that distinguishes different practices. This is because soundscape interventions conceptualized at different stages often have their own unique manifestations. In some planning projects for site design, considerations of the soundscape are already included. Such interventions are often more on a broader planning level and might not be directly reflected in the specific design and facilities. For example, the plan might encompass quiet areas or buffering zones for traffic noise. However, some soundscape interventions involve tangible modifications to the site, becoming part of the site’s construction. For example, designing a fountain waterfall that also serves as a sound barrier (e.g., Sheaf Square in Sheffield, UK). Some soundscape interventions are implemented after the site has been built, which is often the case with sound art installations in public spaces. Considering that these soundscape interventions all make tangible modifications to the site, they are therefore classified under the Implementation category. These kinds of interventions are often associated with specific facilities and real conditions, aimed at addressing certain issues within the site or enhancing the overall environmental quality through a carefully designed sound environment. Thus, we categorize the collected soundscape practices based on whether they are considered during the ‘planning’ stage or the ‘implementation’ stage.

The **CONTRIBUTORS** dimension identifies the main participants involved in soundscape interventions. These contributors include urban planners and architects, acoustic engineers, musicians and artists, academics, and policymakers. Understanding the contributors involved in a soundscape intervention project is important because it not only facilitates the project to be found by the appropriate audience, but also demonstrates that soundscape interventions can benefit from multidisciplinary perspectives, and that innovative approaches can be formed through the collaboration of different professionals.

SCALE refers to the spatial extent of soundscape interventions. It is categorized into three levels: Microscale (e.g., pocket garden), Mesoscale (e.g., city block), and Macroscale (e.g., city) [53]. Understanding the Scale dimension is

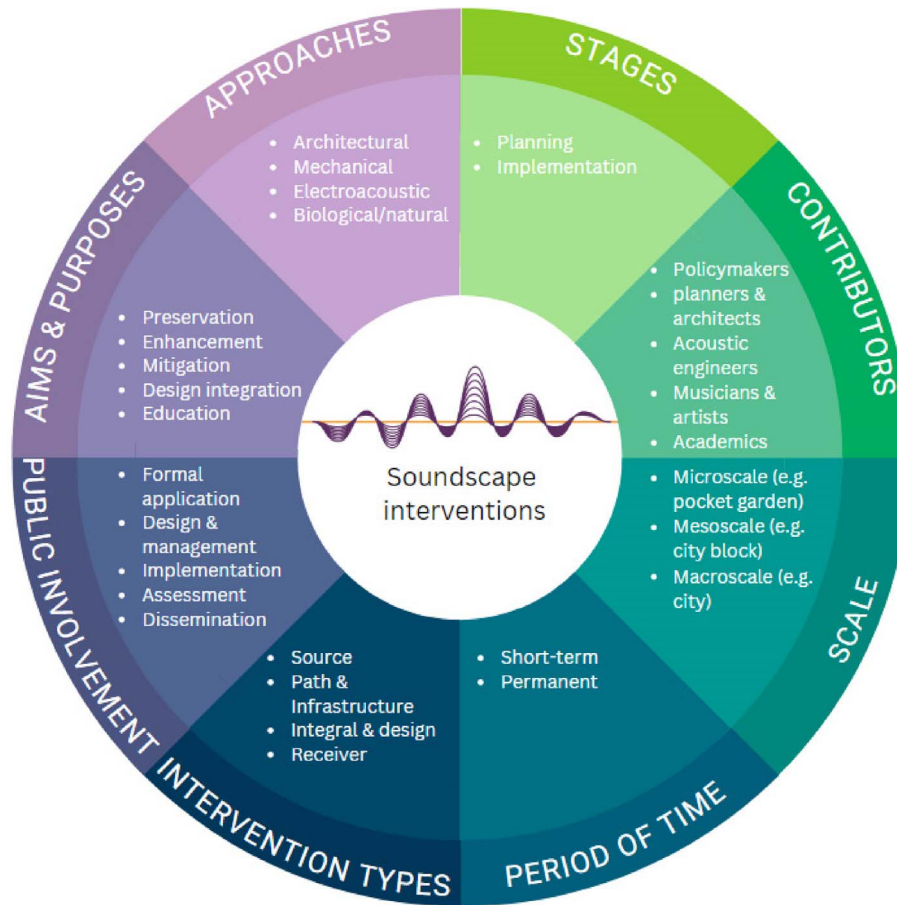


Figure 4. The eight dimensions of soundscape interventions (<https://soundscape-intervention.org/catalogue/>).

crucial as it allows us to analyze the impact of soundscape interventions at different spatial levels.

The **PERIOD OF TIME** dimension distinguishes between short-term and permanent soundscape interventions. Short-term interventions may be temporary installations or events, while permanent interventions involve long-lasting modifications to the built environment.

INTERVENTION TYPES are categorized into four main areas: Source, Path/Infrastructure, Integral/Design, and Receiver [20, 58]. The classification of types of soundscape interventions mainly refers to the stages of sound generation, transmission, and reception, divided into three categories: source, path/infrastructure, and receiver. Since interventions in the soundscape might not always focus solely on one of these stages, and other aspects, including space, visuals, etc., can also affect people’s acoustic experiences, a sub-category named Integral/design was added.

Source interventions aim to modify or manage sound sources directly, like controlling emissions. Path/Infrastructure interventions focus on the transmission process of sounds, such as rerouting traffic to gain a larger buffer zone to minimize noise, rather than merely reducing it through speed limits. Integral/Design interventions may involve aspects of all other categories and go beyond noise reduction and start from a holistic perspective, such as improving

the acoustic and visual quality of the environment. Receiver interventions aim to enhance the perception, understanding, and experience of individuals within the soundscape. In some cases, distinguishing interventions between the source and receiver categories can be challenging as interventions aimed at enhancing the acoustic experience often involve modifications to the sound source. Therefore, we categorize soundscape interventions that involve human participation or interaction under the ‘receiver’ category, while those that only involve changes to the sound environment are considered to be in the ‘source’ category. Certain interventions are solely concentrated on modifications to the acoustic environment (e.g., Parco Sempione), whereas others may go beyond the sound perspective, usually being interactive and including human participation (e.g., PS244 primary school in Brooklyn, Musikiosk in Montreal, Ellen Reid Soundwalk). For example, some sound art installations require human participation to generate sound; hence, we consider these interventions as targeting the receiver aspect of the soundscape. It should be noted that in this article, we classify the type of intervention for the sound installation in Birrarung Marr Park as ‘receiver’, but because people can only remotely control the sound installations, the person who curates the sound and the person who receives is usually not the same person in the same time. Analyzing the dimension of the intervention type

helps in classifying and understanding the diverse strategies employed in soundscape design.

The **PUBLIC INVOLVEMENT** dimension captures the different stages of public participation throughout the soundscape intervention process. It includes Formal application, Design and Management, Implementation, Assessment, and Dissemination [25]. The five stages of public participation in soundscape design start with the Formal Application, where initial public feedback and expectations are gathered. This is followed by the Design and Management stage, where this input is integrated into the planning and design. During the Implementation phase, the design is executed with opportunities for public feedback. The Assessment stage involves evaluating the soundscape's impact and effectiveness using community input. Finally, the Dissemination stage shares the project's outcomes and learnings with the wider community and beyond. By involving the public in soundscape design, decision-making processes become more democratic, and designs become more responsive to the needs and preferences of the community. This dimension emphasizes the importance of engaging stakeholders and the public to identify the most appropriate soundscape interventions.

The **AIMS AND PURPOSE** dimension includes Preservation, Enhancement, Mitigation, Design integration, and Education. Preservation aims to protect and conserve valuable acoustic environments. Enhancement focuses on introducing sound sources and improving the quality and positive attributes of the soundscape. Mitigation addresses the reduction or elimination of unwanted noise. Design integration focuses on creating new atmospheres. Education aims to raise awareness and understanding of the importance of soundscape. By considering the Aims and purpose dimension, we gain insights into the intended outcomes and motivations behind soundscape interventions.

APPROACHES refer to the different methodologies and techniques employed in soundscape design. The four identified approaches are Architectural, Mechanical, Electroacoustic, and Biological/Natural [25]. Architectural approaches involve the design and construction of physical structures and spaces to achieve specific acoustic qualities. These methods include the strategic design of spaces and the use of materials to control sound propagation, such as building noise barriers or modifying landforms to influence sound waves. Mechanical methods, on the other hand, take advantage of physical and natural forces to create or alter the sound experience. This includes utilizing resonance, as well as using the power of natural elements such as wind, water, and solar energy to produce sound or alter the acoustic environment of a location. Electroacoustic approaches employ technology and audio systems to shape and enhance the soundscape. The biological/natural approach emphasizes natural environmental transformations that introduce biophonic sounds like birds and insects, and non-biophonic natural sounds like water and wind. For example, creating a natural pond that attracts animal and water sounds. In contrast, using sound installations powered by natural

elements, or using facilities that amplify natural sounds are seen as a mechanical approach because they do not involve natural environmental modifications. The approaches dimension sheds light on the diverse tools and techniques available for soundscape design practitioners.

5.2 Overview of the existing soundscape interventions

The soundscape intervention examples in the CSI database were classified across eight dimensions (see Appendix 1). Figure 5 shows the distribution of cases in the database across three dimensions: stage, scale, and period of time. The categories within these three dimensions are mutually exclusive. Figure 6 presents the frequency of each category within the five dimensions of Contributors, Intervention types, Public involvement, Aims and purpose, and Approaches in the database.

STAGE: The majority of examples are classified as being conceived in the implementation stage of site design (39 out of 43), indicating a strong focus on practical application rather than planning.

CONTRIBUTORS: Those involved in these interventions were mainly acoustic engineers (36), musicians/artists (23), urban planners/architects (15), and academics (9). The involvement of policymakers in soundscape practice was relatively low and usually occurred at the planning stage and for larger-scale projects. It can be noticed that soundscape practices usually have the involvement of different contributors, by which soundscape practices become more inclusive and multidisciplinary, allowing for a holistic exploration and understanding of the sonic environment.

SCALE: The scale of the interventions varies, with the most common being mesoscale (e.g., city block, 24), followed by microscale (e.g., pocket garden, 16) and macroscale (e.g., city, 3). This distribution suggests a greater emphasis on improving soundscapes at the neighborhood or district level, potentially due to the immediate impact on local communities and the feasibility of implementing changes within smaller areas.

PERIOD OF TIME: Regarding the duration of interventions, the majority of examples are categorized as permanent (34), indicating a long-term commitment to improving soundscapes rather than short-term solutions (9).

INTERVENTION TYPES: The integral/design interventions (36) are the most prevalent, followed by receiver interventions (25), path/infrastructure interventions (14), and source interventions (7). This distribution suggests a focus on shaping the overall soundscape through design and interventions that target the receivers' experience.

PUBLIC INVOLVEMENT: Because limited cases of public participation were precisely reported and documented, it was difficult to assess public participation in these projects overall. The examples of documented public participation revealed that public participation was primarily related to design and management (6), implementation (5), evaluation (3), and dissemination (3).

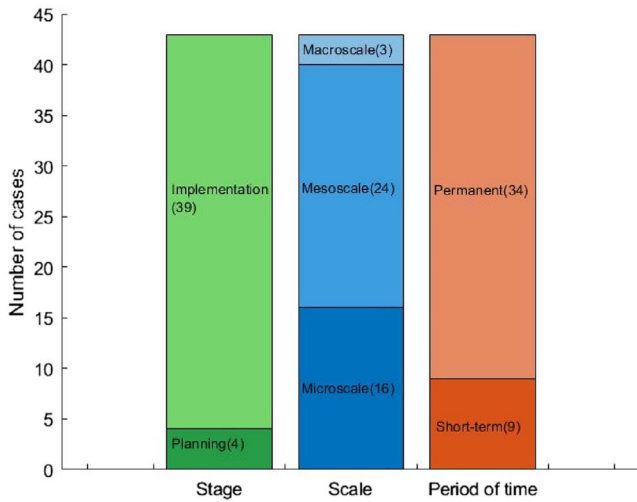


Figure 5. Stacked bar graphs representing the number of cases and categories of Stage, Scale and Period of time dimensions (<https://soundscape-intervention.org/catalogue/>).

AIMS AND PURPOSE: The aims and purposes of the interventions are diverse, with enhancement (36) being the most frequently targeted goal. This indicates a strong focus on improving the acoustic environment by adding positive elements or modifying existing ones. Education (17), mitigation (17), and design integration (14) are also important goals, and the goals of soundscape design are often multifaceted. Notably, preservation (6) was mentioned relatively less often than the other goals.

APPROACHES: Different approaches are employed in soundscape design, with electroacoustic (21), architectural (19), and Mechanical (17) approaches being the most commonly used. The prominence of electroacoustic and architectural approaches may be attributed to their applicability in designing and controlling soundscapes. However, biological/natural (6) approaches are less prevalent in the database so far.

5.3 Common strategies used in soundscape interventions

In the framework consisting of eight dimensions that we propose, these dimensions are not strictly independent but are interrelated and complementary. For example, the ‘stage’ at which an intervention occurs typically determines the ‘scale’ of its implementation and influences the ‘period of time’ of the intervention. ‘Contributors’ play an important role as they provide diverse expertise, which impacts the ‘approaches’ employed and the ‘types of intervention’ chosen. Furthermore, the extent of ‘public involvement’ helps to define the ‘aims and purpose’ of the project, ensuring that interventions are tailored to meet local needs and expectations. Although these dimensions are distinct, they interact dynamically, each one influencing and enhancing the others to provide a more comprehensive and profound explanation of soundscape intervention practices.

Practices of soundscape intervention are complex when viewed from the perspective of entire projects, necessitating

descriptions across various dimensions. However, the strategies employed in these cases can be universal and may serve as references for future soundscape intervention practices. Therefore, an important goal of this study is to summarize frequently encountered strategies in soundscape intervention practices and to compile these strategies into a design toolkit. The eight dimensions proposed in this study for describing soundscape interventions can serve as a framework for categorizing these strategies. However, some dimensions, such as contributors and period of time, are not suitable for categorizing these common strategies. This is because the soundscape strategies involved do not expect to show significant differences due to variations in contributors or periods of time. Therefore, this study chose the intervention type dimension as a classification of common soundscape strategies because it allows for better differentiation of these strategies. Based on the analysis and categorization of 43 soundscape intervention instances in our database, we distilled common strategies inherent to four types of soundscape interventions (Fig. 7).

Source:

Strategies on sound sources interventions aim at directly manipulating the sound at its origin. This includes amplifying desirable sounds to enhance the site’s characteristics by identifying and preserving inherent sound resources. Adding preferable sounds not originally present through sound-emitting devices powered by natural forces or electroacoustic systems enriches the sound environment. Conversely, mitigating unwanted sounds at the source involves either planning to exclude noise sources from the site or employing sound masking techniques to reduce the impact of undesired noise.

Path/Infrastructure:

Strategies on path/infrastructure interventions focus on the trajectory of sound from its source to the receivers, emphasizing the control and management of sound as it travels. Employing noise buffer zones allows for broader environmental noise management. The deployment of noise barriers, both hard (such as terrain modifications and constructed sound barriers) and soft (using vegetation as noise-blocking elements), alongside the use of sound-absorbing materials, are key strategies to reduce noise impact and enhance sound quality across a site.

Integral/Design:

Strategies on integral or design-focused interventions consider the entire site’s sound environment, aiming for holistic improvement through careful spatial planning. This involves an initial assessment of the existing soundscape, followed by strategic design choices like creating quiet areas, integrating water sounds for environmental quality, and amplifying specific intriguing sounds. The application of electroacoustic systems to improve acoustic quality and biodiversity design, which attracts wildlife and promotes a harmonious soundscape, is also central to this category.

Receiver:

Strategies on receiver interventions focus on the experiences and interactions of individuals within the soundscape. This

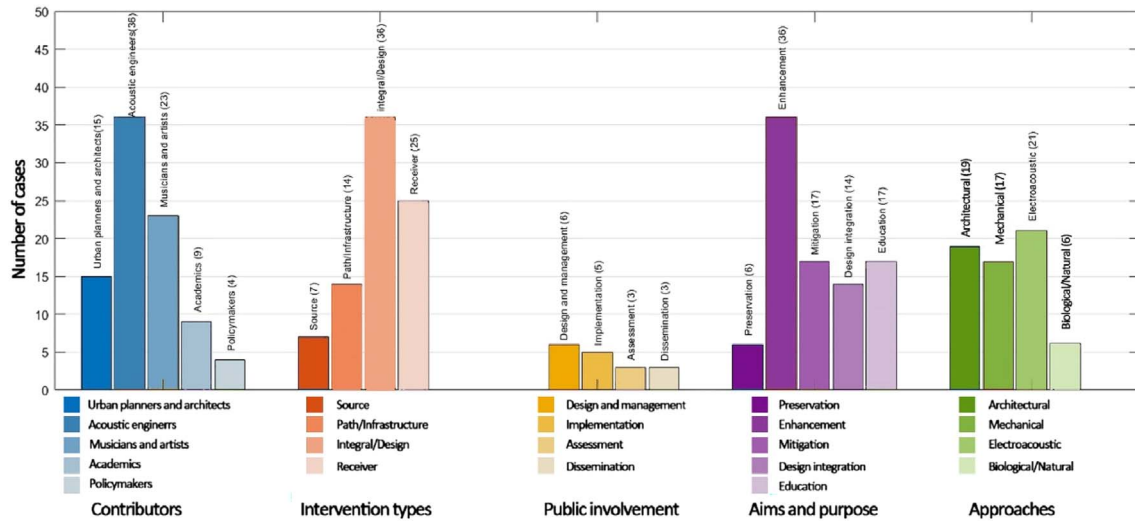


Figure 6. Distribution bar graphs representing the number of cases and categories of Contributors, Intervention types, Public involvement, Aims and purpose, and Approach dimensions (<https://soundscape-intervention.org/catalogue/>).

includes the deliberate placement of sound devices to enhance human engagement with site-specific sounds and offering immersive sound experiences to individuals, thereby enriching their connection to the environment. It should be emphasized that the focus of these strategies is on the human aspect, aiming specifically at altering individuals' behaviors and perceptions. As a result, they fall under the category of receiver-oriented strategies. While these approaches also entail adjustments to the sources of sound, the strategies classified under the 'Source' category concentrate on physical alterations to the sound environment.

Soundscape interventions share many strategies with traditional noise mitigation and acoustic design, like adding musical or ambient/environmental sounds, a measure even before the proposal of the soundscape concept [59]. However, unlike classical methods focusing on decibel reduction, soundscapes aim for a holistic acoustic environment that balances and enriches auditory experiences, considering the emotional, psychological, and social impact of both positive and negative sounds. Moreover, soundscape considers added musical or ambient sounds within their auditory and non-auditory context. Furthermore, soundscape interventions are often characterized by their participatory aspect, involving community input and feedback to tailor solutions that reflect the desires and needs of the affected populace, as the quality of the soundscape is not simply determined by the decibel.

6 Discussion

6.1 Rationale behind the eight-dimensional taxonomy

The eight-dimensional taxonomy established in this study is pivotal in offering an in-depth, multi-faceted analysis of soundscape interventions across various global contexts. We strategically selected these dimensions to encapsulate the nature and diverse characteristics of

soundscape interventions, derived from available data and informed by a comprehensive literature review and analysis. The eight dimensions proposed in this study are a mix of both established and novel categories.

The 'contributors' dimension has been widely documented in planning and architecture design projects. Therefore, this factor has been adopted in identifying the key stakeholders involved in any intervention. The dimensions 'stage,' 'scale,' and 'period of time' introduce a more holistic perspective into soundscape interventions. While traditional noise control approaches often focus on immediate solutions [60], we argue for a broader consideration of temporal and spatial aspects, reflecting the dynamic and evolving nature of soundscapes. In modern urban planning theory and practice, public participation is regarded as a critical method and is extensively applied in urban planning [61]. Taking a cue from this, the concept of 'public involvement' is extended to soundscape interventions, examining the diverse levels of public engagement.

Similar to various other construction projects, soundscape interventions are designed with specific aims. However, they diverge from traditional noise control in their core purpose. While the latter primarily aims to suppress and mitigate harmful sounds, soundscape interventions focus on using beneficial sounds as well. Oberman [52] has distinguished the promotion of sound art and auditory perception as the main aim of several intervention projects. This aim has been covered by the type of dimension (integral intervention and receiver types) and the aim dimension (enhancement, education and integral categories). Building upon the three types of soundscape actions proposed by Cerwén [48], we further delineate the five types of the 'aims and purposes' of soundscape interventions. Given that there are distinct stages from the generation to the reception of sound [58], we classify soundscape interventions into four types [25]. Additionally, guided by prior research and an extensive analysis of existing soundscape interventions

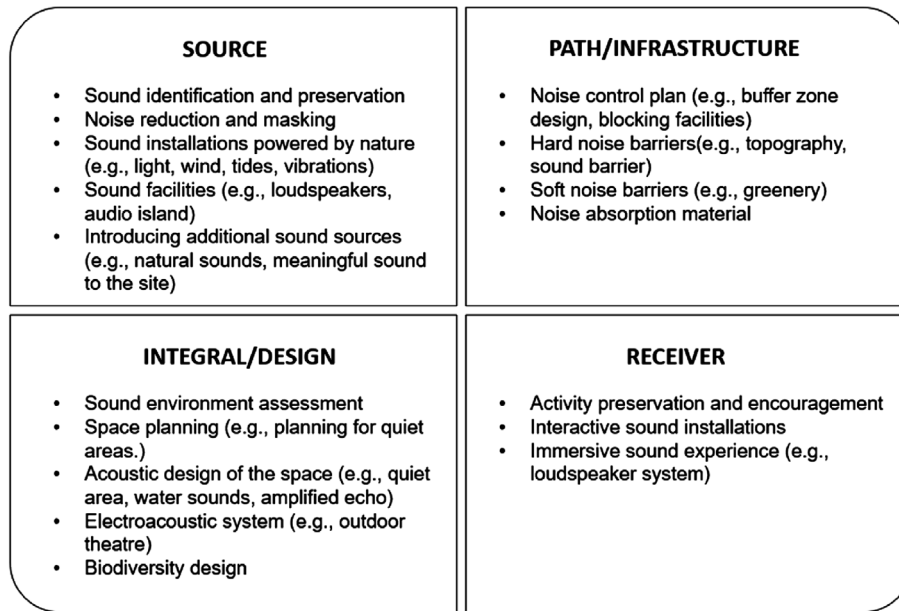


Figure 7. Common strategies used in soundscape interventions based on real-world examples (<https://soundscape-intervention.org/catalogue/>).

[25], we have now tested and confirmed the categorization of specific intervention methods into four distinct types: architectural, mechanical, electroacoustic, and biological/natural.

In exploring the intricate dynamics of soundscape interventions, the interplay among the eight dimensions provides crucial insights into the multifaceted nature of these practices. The “stages” of intervention are inherently influenced by the “contributors” involved, as diverse stakeholders bring varied perspectives, skills, and expectations. The “scale” and “period of time” are often interdependent, with larger-scale interventions necessitating extended time frames to realize tangible impacts. “Intervention types” are intricately linked to “aims and purposes,” wherein the chosen strategies are tailored to fulfil specific objectives. Thus, each dimension does not exist in isolation. Recognizing these interconnections offers a holistic perspective, fostering a better understanding that can inform both theory and practice in soundscape studies and environmental design.

6.2 Current state of the existing soundscape interventions

At present, only a few soundscape interventions in the catalogue are classified as being considered during the planning stage of a site. This may be because soundscape intervention is still a relatively new field, and there are few projects that incorporate soundscape planning at the initial stage. To explore how professionals of the built environment (PBE) approach the sonic dimension, Steele [35] conducted semi-structured interviews with different PBEs, active in six European and North American countries, and ultimately outlined three approaches: policy, public health, and urban user experience. Despite urban

practitioners gradually recognizing the importance of the soundscape in urban environments, they employ methods such as sound mapping, public participation, and technical simulation, incorporating sound factors into urban design to improve the acoustic quality of spaces [62]. However, a gap still exists between academia and practice. This issue is partly due to the lack of acceptance of soundscape research by urban developers and partly because researchers seldom directly participate in urban construction work [5]. This situation is more evident in policy-level soundscape interventions. In Steele’s study, policy-level control of the sound environment remains focused on controlling certain physical quantities, lacking a more comprehensive evaluation system. Therefore, soundscape interventions should not only be considered during the specific construction process of sites but should also be regarded as an important aspect of overall urban planning and design to avoid the permanence of poor sound outcomes [35]. The Ministry of the Environment of Japan launched the “100 Soundscapes of Japan” project in 1996 to reduce noise pollution and promote environmental protection by identifying and protecting important soundscapes throughout the country. The Government encourages public participation, supports local conservation initiatives, and raises awareness of environmental sensory awareness. This policy has been effective in promoting the protection of local soundscapes while emphasizing the importance of soundscape interventions at the policy level [63]. In the future, as the efficacy of soundscape interventions in shaping spaces is further substantiated by a greater number of practical cases, soundscape interventions are expected to become increasingly incorporated during the planning stage of sites. Most of the individuals involved in soundscape intervention projects are practitioners in environmental design and sound-related fields, such as architects, urban planners, and sound

engineers, with relatively fewer policymakers involved. This is also reflected in the fact that many soundscape intervention projects only reflect the considerations of environmental designers on smaller spatial scales. The formulation of soundscape-related policies requires a wealth of successful soundscape practice experiences, while practical projects require guidance from relevant policies. Hence, close collaboration between policymakers and practitioners is crucial.

Due to the complexity and various types of interventions involved in soundscape projects, it is challenging to differentiate between different soundscape intervention projects clearly. In terms of intervention types, apart from some planning-stage interventions, almost all intervention practices involve comprehensive transformation and design of the environment. The second most common type is interventions targeting receivers, such as facilitating their interaction with the environment. These two types of interventions seem to be the most prevalent. Out of the 43 cases, only 8 have been categorized as soundscape interventions targeting the noise source. It's important to note that we consider interventions at the source to involve reducing existing noise at its origin, such as planning car-free zones or introducing sounds that were not originally present. However, a majority of soundscape interventions appear to emphasize the overall environmental design and affirmative approach, as enhancement is the most common aim in soundscape interventions (36 out of the 43 projects). This might also be due to the widely set criteria for defining membership in that category.

Regarding specific approaches of soundscape intervention, electroacoustic methods appear to be the most popular, which is foreseeable as this approach can bring the most direct and effective noticeable changes to the acoustic environment and is likely the easiest to control and manipulate. Conversely, biological/natural methods have not been widely used, which prompts further consideration. From a long-term perspective, the changes to the acoustic environment caused by electroacoustic systems require higher maintenance costs and energy consumption, which may not be the most sustainable way to facilitate the sound environment [25]. Considering that most soundscape intervention projects recorded in the database are permanent, aiming for long-lasting environmental enhancement is also advisable in order to exploit ecological synergies, such as improving climate, thermal comfort, and air quality. This vision can be better achieved through natural methods, which offer the greatest sustainability [25]. Furthermore, the positive effects of natural methods in attention restoration, stress relief, health, and well-being have been demonstrated in research [64–66]. Therefore, natural methods of soundscape intervention are worth further exploration and utilization.

In addition, there is limited information regarding public participation in these soundscape intervention practices. Many soundscape interventions seem to lack public involvement, which does not fully reflect the user-centered and inclusive design approach of soundscape methods [25]. Furthermore, there is currently limited assessment and documentation of the management, maintenance, and

(long-term) impact of current soundscape practices on people. However, these aspects are crucial for the evaluation of soundscape interventions and can provide support for the formulation of soundscape policies [25].

The collection and classification of soundscape intervention case studies prompted a categorization of soundscape interventions. A previous study distinguished them based on intention and adherence to formalized standards into four types: sonic intervention, sonic installation, soundscape intervention, and soundscape design intervention [56]. While soundscape intervention broadly aims to improve or preserve the acoustic environment through various practical measures, soundscape design intervention involves a formal, standardized process with systematic evaluation and adherence to specific guidelines like ISO/TS 12913 [56].

6.3 Limitations

We have summarized and developed a taxonomy of soundscape intervention methods based on the 43 soundscape practices in the database. It is important to note that this taxonomy will continue to evolve as more soundscape practices from different countries and regions, as well as the latest soundscape intervention practices, are included in the database. When the number of cases in the database significantly increases, the taxonomy of soundscape intervention methods will be updated accordingly to ensure it consistently provides accurate and comprehensive information. However, the development of the taxonomy of soundscape intervention methods is bound by several limitations. Firstly, since it relies on an evolving database, the taxonomy will require ongoing updates to maintain its relevance and accuracy. Currently, there may be a limitation in geographic and cultural diversity, making the study potentially unrepresentative of global soundscape practices in particular in areas less related to the English language. The completeness of the database is another concern, with potential omissions of existing soundscape practices impacting the comprehensiveness of the taxonomy. For instance, the cases currently documented in the database predominantly report successful practices in soundscape interventions. However, interventions that have not significantly impacted the site might be overlooked. Additionally, the effects of soundscape interventions are not always beneficial to all people. Some interventions might intentionally or unintentionally deter certain populations through sound. Such instances have not been adequately reflected in the existing database. Therefore, sustained efforts are needed to expand the database.

7 Conclusion

The CSI project has taken pivotal steps towards bridging the gap in the literature and practice by offering a multifaceted approach to collecting, categorizing, and sharing data on real-world soundscape practices. In this study, we have analyzed 43 practice cases, unearthing eight distinct dimensions that underpin the nature of soundscape interventions. These dimensions – stages, contributors, scale,

period of time, intervention types, public involvement, aims and purposes, and approaches – are instrumental in navigating the intricate landscape of soundscape design.

The findings highlight several important aspects of soundscape interventions and provide insights for future research and practice. First, we observed that soundscape interventions that are conceived in the planning stage of the site are not prevalent. Additionally, most practitioners involved in soundscape interventions are from environmental design and sound-related fields, with limited involvement of policymakers. The comprehensive transformation and design of the environment, as well as interventions targeting receivers, are the most prevalent types of interventions. Furthermore, the emphasis in existing soundscape practice is often on enhancing the overall environment. In terms of specific approaches, electroacoustic methods are commonly used in soundscape interventions due to their direct and noticeable effects. However, we propose that natural methods should be further explored and utilized, as they offer sustainable long-term solutions and have demonstrated positive effects on well-being and health. Moreover, public participation and the assessment of management, maintenance, and impact of soundscape interventions require more attention.

The taxonomy proposed needs to be understood as a dynamic framework, amenable to refinement and expansion as more data accrues and the field evolves. When new projects are added to the database, the taxonomy will be updated to ensure its accuracy and completeness. We hope that this taxonomy will help stakeholders such as local governments, soundscape consultants, and researchers in communicating and cooperating to improve the sound environment.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Data availability statement

Data are available on request from the authors.

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Appendix 1. Eight dimensions of the 43 soundscape intervention practices in CSI database, adapted from the work of Moshona and her team [25].

Project name	Stages	Contributors	Scale	Period of time	Intervention type	Public involvement	Aims and purpose	Approach
Arizona Science Center	B	B, C	B	B	D	–	E	B
Bamboo Garden	B	A, B, C	A	B	B/C, D	–	B, D	A, C
Biophony: SoundGarden	B	B, C	A	A	D, E	–	B, E	C, D
Birrarung Marr Park	B	B, C	A	B	D, E	E	B, E	B, C
Blue Moon	B	B, C	B	B	D, E	–	B, C, E	C, B
Ellen Reid Soundwalk	B	B	C	B	E	–	B	C
Fontaine de Milan	B	B	A	B	A, B/C	–	B, C	B
Garden of Sound	B	A	B	B	D	–	B, D	A, D
Harmonic Bridge	B	B, C	B	A	D, E	–	B, E	B, C
Harmonic Conduit	B	B, C	B	A	D, E	–	B	B, C
Heaven's Cloth	B	C	A	A	D	–	B	C
Het Klankenbos Sound Forest	B	B, C	B	B	D, E	–	B	C, B, D
Imagination Playground	A	A, B	B	B	D	–	C, D	A
Jim Ellis Freeway Park	B	A, B	B	B	B/C, D	–	B, C	A
Lincoln Park	B	A, B	B	B	D, E	–	B	A, C
Musical Roads	B	B, C	B	B	A, E	–	B	B
Nauener Platz	B	A, B, D	B	B	B/C, D, E	B, C, D	B, C, D, E	A, C
Neville Stress Underpass	B	A, B, C	B	B	B/C, D, E	–	B, C	C
Pavilion of Echoes	B	A, B	A	B	D	–	A, B, E	A
Pedalling SeaSides	B	B, C	B	A	E	–	B,	C
PS 244 Primary School	B	B	A	B	D, E	–	E	A, B
Salesforce Transit Center	B	B, C	B	B	B/C, D	–	B, C	A, B
Sea Cat Tail – Umi Tsukushi	B	A, B	A	B	D, E	–	B, E	B
Schüssinselpark	B	A, E	B	B	D	–	A, D	D
Sea Organ	B	A, B	B	B	D, E	–	B, E	B
Sempione Park	B	B, D	B	A	A, D	–	B, E	C
Sheaf Square	B	A, B, D	B	B	B/C, D	–	B, C	A
Spritzbrunnen at the Dreirosenanlage	B	A, B	B	B	B/C, D	–	B, C	B
Suspended Sound Line	B	C	A	B	D, E	–	D	A, B
Sustainable Urban Village	A	A, D, E	C	B	A, B/C, D	B, C	A, B, C, D	A, D
Sydney Modern Project	B	B, C	A	B	B/C, D, E	–	D	A
The Music Box Village	B	A, B, C	B	B	D, E	B, C, E	B, D	A, B
The National September 11 Memorial	B	A	B	B	B/C, D	–	B, C	A
Thames Barrier Park	B	A	B	B	B/C, D	B, C, D	B, C, D	A
Time Piece	B	B, C	A	B	D, E	–	B, E	C
Urban Light Contacts	B	B, C	A	A	E	–	B, E	B, C
Urban Sound Planing – Brighton & Hove	A	A, B, D, E	C	B	A, B/C, D, E	B, C, D	A, B, C, D, E	A, C
Vertical Water	B	B, C	A	A	A, D	–	C	A, C
War Damaged Instrument	B	B, C	A	A	E	–	A, B, E	C
Warwick Bar Master Plan	A	A, B, C, D, E	B	B	D, E	–	A, B, C, D	C, D
Water Veil	B	B, C	A	A	B/C, D	–	B, C	B
Whispering Wind	B	B, D	A	B	D, E	–	B, D, E	A
The Musikiosk	B	B, D	B	A	A, E	B, D, E	B, C	C

The classification of the eight dimensions (including number of occurrences):

1. Stages – A: Planning (4), B: Implementation (39).
2. Contributors – A: Urban planners and architects (15), B: Acoustic engineers (36), C: Musicians and artists (23), D: Academics (9), E: Policymakers (4).
3. Scale – A: Microscale (e.g., pocket garden) (16), B: Mesoscale (e.g., city block) (24), C: Macroscale (e.g., city) (3).
4. Period of time – A: Short-term (9), B: Permanent (34).
5. Intervention types – A: Source (7), B/C: Path/Infrastructure (14), D: integral/design (36), E: Receiver (25).
6. Public involvement – A: Formal application (0), B: Design and management (6), C: Implementation (5), D: Assessment (3), E: Dissemination (3).
7. Aims and purpose – A: Preservation (6), B: Enhancement (36), C: Mitigation (17), D: Design integration (14), E: Education (17).
8. Approaches – A: Architectural (19), B: Mechanical (17), C: Electroacoustic (21), D: Biological/natural (6).

<https://soundscape-intervention.org/catalogue/>, retrieved August 2023.

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