Abstract: The harmonization of noise indicators, noise mapping, and action plans delivers basic administrative information not only for noise abatement in highly noise-polluted areas, but also for comparisons across built environments regionally and internationally. However, such activities do not provide any tools or essential knowledge for the more demanding tasks required in designing and planning sustainable built environments that are supportive to wellbeing and health. Without knowing the determining factors behind dose-response curves [1, 2], the decision process for developing action plans is unnecessarily restricted. Optional courses of action for handling a noise problem cannot be sufficiently considered without understanding the full context—physical, cultural, emotional—of noise’s effect on people. Therefore, an approach for considering these many angles must involve diverse fields of practice and interdisciplinary approaches. One such methodology is the multidimensional Soundscape Approach, which emphasizes how the acoustic environment is perceived, experienced, and/or understood by a person or people in context. Relying on principles of the Soundscape Approach, two urban green spaces will be examined regarding noise abatement strategies in relation to visitors’ experiential expectations. It will be shown how and why soundscape is an invaluable tool in detecting and analyzing needs for an adequate acoustic environment, accounting for people’s concerns and integrating their local expertise to guide the process of planning, designing and maintaining sites.

Keywords: soundscape; architecture; local experts; built environment; historic environment

1 Introduction

An understanding of the soundscape offers the ability to unlock a community’s complex response to noise beyond the data from technical measurements. R. Murray Schafer recognized the vital influence of the sonic environment when he first developed the term “soundscape” in the 1960s, a concept introduced as a method for rethinking the evaluation of “noise” and its effects on people. The challenge was to consider the limits of acoustic measurements and account for its cultural dimension, an idea introduced by Schafer’s neologism and continued research. His first field studies, which coalesced into the World Soundscape Project, involved sound pressure level measurements (see Figure 2), soundscape recordings, and the description of a wide range of sonic features [3, 4].

About 40 years later, noise mapping is a major issue in noise control, while the Soundscape Approach is used in a wide range of noise control and sound design initiatives: from the evaluation of residential areas to vehicle...
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interiors. Over the years, the development of the Soundscape Approach has been supported by countless research studies all over the world. The European COST Action TD 0804 [5] created a network among European “soundscaping” efforts by integrating soundscape experts from all over the world. Meanwhile the ISO/TC 43/SC 1/WG 54 is advancing the standardization of soundscape in order to enable a broad international consensus and to provide a foundation for communication across disciplines and professions with an interest in soundscape [1, 6]. With regard to application, soundscape is being used in city planning in collaboration with “local experts” and in the sound design of different products ranging from transportation to household appliances. Understanding this level of information can enable informed design interventions in the built environment towards the sustained health of a community as much as a particular space [7, 8].

Today, the Soundscape Approach combines perceptual and physical evaluations towards a holistic study of the sonic environment. Beyond merely the physical conditions at a particular location—what has previously been termed the “shallow soundscape” [9]—a soundscape also necessarily includes any contributions by an individual, incorporating physical inputs (e.g. footsteps) as well as perceptual ones (e.g. how one experiences a condition based on previous experience, social conditioning, etc.). One’s ‘acoustic biography’ of past experience, which can include questions of aesthetics, semantic values and identities, symbolism, and psychology at individual and societal levels, plays a significant role in one’s interpretation of the physical world. Sound sources thus can have complex associated meanings to the individual exposed to them, and can therewith block or enable one’s activities, thoughts, and feelings [10]. Moreover, how people react to or handle sounds depends on the “acoustic coloration” of the larger environment from aspects such as geography, climate, wind, water, people, buildings, and animals [11].

Because of this surfeit of influences on any soundscape, evaluation must be dedicated to a combination of acoustical factors and other sensory, aesthetic, geographic, social, psychological and cultural modalities relevant to human activity across space, time, and society. Taken together, these factors comprise a “deep soundscape” that poses quite a challenge to comprehensive
study; the continued refinement of investigative soundscape procedures is critical to advancing our understanding of sound and noise in our built environment.

Soundscape has become a major tool in facilitating people’s involvement in decision processes about acoustical environments. Despite recent strides in standardizing research methodologies, it is important to keep in mind that the Soundscape Approach is not a one-size-fits-all methodology. Rather, it establishes a framework from which to draw tools, strategies, and starting points for customized work. This article calls for the precise crafting of soundscape research at a time when such studies are beginning to proliferate in a number of fields. Despite the similarities shared by Berlin’s Nauener Platz and the Berlin Wall Memorial, two urban green spaces with quite similar physical contexts and noise profiles, a comparison of these two built environments will underscore the limitations of noise mapping and a simple, universal soundscape application [12].

The discussion begins by reviewing the detailed soundscape methodologies implemented at Nauener Platz and highlighting key components of the results. The resulting design and rehabilitation strategies for Nauener Platz will be discussed as well. This site will then be compared to the Berlin Wall Memorial with respect to recent preliminary research in soundscape and noise. The successful research model implemented at the Nauener Platz will be shown to be merely a starting point for similar research at the seemingly very analogous Memorial. The reasons for this will be addressed and contextualized, particularly with respect to the Memorial’s history and current functions as an historic site, and suggestions for potential modifications in research strategy will be suggested to aid future researchers in crafting their own studies in similar conditions. The main purpose here is to clarify how the Soundscape Approach can evaluate acoustic environments with unique structures and purposes by drawing from the expertise of affected people.

2 Methods

2.1 Soundscape research methodology

Evaluating the acoustic environment calls for interdisciplinary measures. While A-weighted sound pressure level (SPL) has dominated measurement practices, there is common agreement that additional parameters are necessary to accurately capture the complexity of a sonic environment. But psychoacoustic parameters such as loudness, roughness, sharpness, and tonality provide an immense contribution towards more accurately measuring and assessing environmental sound perception [13]. The physical conditions of any particular soundscape can be measured using binaural recording devices according to standardized metrics [14, 15]. Recordings using microphone arrays are a further possibility and potential alternative. These are primarily derived from standardized procedures of measurement and analysis [16], and they make it possible to explain annoyance from and acceptance of environmental noise more in detail.

Subjective conditions are measured through a combination of evaluations usually involving residents, who are termed ‘local experts’. Local expertise in a soundscape is a combination of meaningful knowledge about an area with which an individual interacts directly over time. In soundscape work, local experts generally live in the study area and provide their knowledge through evaluation processes such as soundwalks¹ and various kinds of open interviews. Local expert participation sharply focuses the subsequent analysis of acoustical and perceptual data, as the information provided often enhances the investigator’s sensitivity to the subtle particularities of the examined areas.

Once primary data has been collected, physical noise criteria can be matched to perceptual descriptors in order to generate comparative data between individuals. Without question, the multidimensionality of human perception cannot easily be simplified to singular numbers. The listener’s attitude, expectations, and experiences are all significant parameters that must be considered when performing a full perceptive evaluation of specific stimuli; perhaps the only factor of more significance in such data collection is the knowledge people have about the area in which they live. Combining these collection priorities and strategies enables a more meaningful phenomenological examination of a particular place, supported by multiple disciplines as well as personal perspectives [17].

It should be noted that, with so many strategies of research at work, interdisciplinarity is considered a necessity in the Soundscape Approach. Research tasks are directly related to local individual needs and take into consideration those who are noise-sensitive and other vulnerable groups. Research should also account for cultural aspects and the relevance of natural soundscapes, sometimes referred to as quiet areas. These factors can be the

¹ Soundwalks are participatory sound and listening walks with respect to the acoustical, visual, aesthetic, geographic, social and cultural modalities. See also [1].
most essential issues for the people impacted by a soundscape, and their comprehensive study should require tools developed through various fields of study. The Nauener Platz project, for instance, required the direct collaboration of architects, acoustics engineers, environmental health specialists, psychologists, social scientists, and urban developers.

With so much varied information being collected, an appropriate evaluation procedure is needed to integrate contextual and subjective variables and fully account for people's expertise. A standardized procedure is currently under development as Part II of the ISO standard [6], though it is also necessary to develop tailored evaluation procedures that prioritize different points of view [18, 19]. This was no less true at Nauener Platz, where a list of concerns that needed to be addressed started with the following:

- Visual aesthetics
- Social
- Economic
- Environmental
- Transport mobility
- Safety
- Sustainability

Figure 3: Map of neighborhood around Nauener Platz (park highlighted in blue; image: Rudi Volz, André Jakob).
2.2 Nauener Platz

Earlier publications introduced the redevelopment project of Nauener Platz in Berlin², a path-breaking example (and winner of the 2012 European Soundscape Award) of a collaborative Soundscape Approach. As a fundamental component of the redevelopment, the objective was not merely to develop a methodology for soundscape measurements; rather by understanding sound as a resource, the aim was to integrate all relevant opinions in creating a cohesive new design strategy for a neglected space. Nauener Platz itself is an urban park approximately 5000 m² in area located in the Mitte neighborhood of Berlin (see Figure 3). It is situated at the corner of two main roads, Reinickenstraße and Schulstraße, with a traffic volume of 18,444 cars/24 hours on Reinickenstraße and 14,756 cars/24 hours on Schulstraße. The land is divided into two distinct parts by a building containing a family support facility as well as a children’s radio station. While a predominantly residential area, the U-Bahn station located across Reinickenstraße results in interspersed businesses and constant street activity.

Surveying the social structure of the Nauener Platz at the outset of the project, approximately 12,000 inhabitants included a high proportion of children and residents over 65, as well as a high quota of various cultures with foreigners constituting 42.5% of the population (a particularly high number in Berlin)³. There was also high overall unemployment, lower incomes for the employed, and alcohol and drug abuse problems throughout the community. The challenges being faced were a strong factor in the initial government selection of this site for redevelopment and enhancement. From the beginning, the aim of the project was to improve the quality of life for residents by rebuilding the park into a meeting point over which the entire community could feel an increased sense of custody.

The research process included a number of parallel efforts, including soundwalks, acoustic measurements and recordings, and expert interviews. Each of these strategies affords its own strength; unifying them was a priority to involve residents in the research and decision making process at every stage of development [20]. The first essential step was the recruitment of local experts to participate in these various measures. Outreach began with a party and flea market to introduce the project. Soon after, a public hearing was held on the rehabilitation of the park, where the people concerned were introduced to the concept and process of evaluation through soundwalks. For over a year, well-defined workshops were held every few weeks with 64 residents to access different social groups and their respective opinions. Particular attention was paid to including perspectives from multiple genders and age brackets. People were also informed of the need for narrative interviews; these were scheduled by phone with interested people after their participation in a soundwalk and then conducted in person.

Each evaluation with a soundwalk was carried out in a group of at least eight local experts. The tasks were to define the listening position for the evaluation, to rank the road traffic noise using the Rohrmann scale, and to comment on those rankings. Noise and comments were binaurally recorded simultaneously. Based on the recommendations of the local experts while soundwalking, the marked eight points for subjective evaluation were chosen for comments, rankings, and further binaural measurements (see locations in Figure 4).

These approaches and methods make it possible to learn about the process of perception and evaluation sufficiently as they take into account the context, ambiance, the usual interaction between noise and listener as well as the multidimensionality of noise perception. By contrast, conventional methods often reduce the complexity of reality into controllable variables, which supposedly represent the scrutinized object. Furthermore, traditional tests frequently neglect the context-dependency of human perception; they only provide artificial realities and diminish the complexity of perception on merely predetermined values, which do not completely correspond with perceptual authenticity. However, perception and evaluations entirely depend on the respective influences of the acoustic and non-acoustic modifiers.

3 Results

3.1 Results from Soundwalks, measurements, recordings, and interviews

The information gathered through recordings and communication with local experts provided physical and perceptual data about the soundscape of Nauener Platz (see ex-
Figure 4: Map of Nauener Platz with locations of study highlighted (as established with community) (Image: Barbara Willicke). 1 – Cross road; 2 – New entrance; 3 – Café Naumi; 4 – Kindergarten; 5 – Pedestrian underpass; 6 – Entrance from Reinickendorfer St.; 7 – Playground; 8 – Projected rest area.
ample in Figure 5). Combining the comments from soundwalk surveys, group discussions, and narrative interviews, it was possible to trace common threads between people’s preferences in the park and begin to formulate some shared desires for potential interventions. One common theme was the dominant experience of noise from the street, even from the most remote end of the park. Issues related to social life and social control within the park (such as the inclusion of a playground and gardening space) were also mentioned or suggested frequently.

A correlation was observed between how people reacted to low frequency noise and a desire for more natural sounds. In a clear example of experience and expectations informing each other, the desire to have natural sounds by so many individuals was actually rooted in wanting to escape the encroaching traffic noises rather than simply desiring an ecologically influenced acoustic setting.

### 3.2 Park redesign

The information gathered through recordings and the various local expert dialogues provided a range of physical and perceptual data with which to begin work. A num-

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**Figure 5:** Nauener Platz calculated noise map (with points of intensified study highlighted, image: B. Schulte-Fortkamp).
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Figure 6: Image of gabion wall dividing street (behind wall) from Nauener Platz playground (to the left), (Image: B. Willecke).

Figure 7: Ring seats with activated sound playback (Image: B. Willecke).

Figure 8: Bench seats with activated sound playback in side panels (Image: B. Willecke).

A number of strategies were developed to alter the soundscape of Nauener Park for the benefit of the people involved: in order to mitigate traffic sounds from the Schulstraße, a gabion wall to a height of 1.4 m was installed along edges of the playground for young children (located at the eastern portion of the park, see Figure 6). A lighting scheme was introduced throughout the park for nighttime visibility. Audio islands in the form of benches and immersive ring-shaped seats (see examples in Figures 7 and 8) were installed throughout the park to provide locations of optional distraction from the nearby traffic noise; these installations present sounds (such as city bird songs and ocean waves) that the local experts wished to hear when visiting (see Figure 9). It was important that these audio islands provide a localized intervention to the soundscape rather than a more pervasive “designed sound” introduced throughout the park, which would have been universally aggravating instead of helpful in masking traffic sounds. All ideas and discussion points emerged during the stakeholder workshops, and the decisions were made interactively with the people involved.

4 Discussion

Integrating the Soundscape Approach from the beginning of the Nauener Platz redevelopment project enabled a horizontal, long-term dialogue with the people in the area. The project that resulted was effectively guided by its many participants, resulting in a unique solution for mitigating noise and creating a much-needed ‘backyard’ for the local residents through an improved soundscape. Three masters
theses followed up on the studies and confirm the long-term positives effects of the project.

The temptation with this level of success is to apply the strategies from Nauener Platz wholesale to other locations and expect to replicate its achievements. However, this would be a false promise, even at seemingly very similar sites. The physical components of a location are simply not enough to base a soundscape study upon. An instructive example is the Berlin Wall Memorial, which shares many physical attributes to Nauener Platz. However its political and historical layers provide a very different set of social conditions that must be factored into any experiential analysis.

4.1 Application elsewhere: Berlin Wall Memorial

Located only 3 km away, the Berlin Wall Memorial (Gedenkstätte Berliner Mauer) stands as a testament to German division. It comprises a series of remnants from the original Berlin Wall, including the only original grounds on the Eastern side, as well as interpretive stations, new construction, and commemorative elements.

The entire site stretches approximately 1.4 km along the south side of Bernauer Straße in what was formally the border strip between East and West – now maintained as an open, grassy zone between residential neighborhoods.

4 There is also a popular Mauer Park (‘Wall Park’) situated across from the far northern end of the Memorial. While the park and memorial are intrinsically linked by their shared physical history, their settings and functions significantly differ today. This discussion will focus on the Memorial, which bears much stronger physical and functional resemblances to Nauener Platz.
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Transit along this street is constant, with regular vehicle, pedestrian, tour bus, bicycle, and tram traffic. Bahn (public rail service) stations also stand in the middle of the Memorial as well as its western edge, which provide ample points of entry for visitors as much as centers of gravity for local commuters. The site itself is extremely popular as a national and international tourist attraction, receiving approximately 938,000 visitors in 2015 alone.

4.2 Comparison of key experiential qualities

A number of similarities between sites can already be observed; both sites are public open spaces in the midst of busy residential neighborhoods and are situated along roadways with permanent traffic flow. Each sits directly adjacent to transit station entrances, ensuring pedestrian traffic day and night. Each is maintained to offer full accessibility and points of relaxation (easily navigable paths, benches, lawns) and visibility at night (lighting schemes, open sightlines throughout). And notably, both employ active sound installations for visitors (birdsong and water at Nauener Platz and historical sound-clips and interviews at interpretive stations throughout the Memorial – see Figure 11).

4.3 Differences in architectural intent

Despite the superficial physical similarities, however, it is critical to realize the distinct difference in purpose and message embodied by each site – a park setting is not just

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5 Personal communication with Dr. Axel Klausmeier.
Data collection considerations

When structuring a soundscape investigation, therefore, it is vital to understand the overlapping functions that a site can serve. Stakeholder involvement at Nauener Platz revealed the different expectations people held about the space. This is no less true at the Memorial, and the same process could be applied here. However, the stakeholder landscape is quite a bit more intricate due to its local, national, and international participation. Local individuals might include long-term residents who bore witness to the Wall throughout active use (during its historic period of significance, 1961–1989) or individuals relocating from other countries with little awareness of the locality’s past. Equally complex, visitors to the memorial can vary widely in awareness and motivation, including historically informed persons, casual tourists to the city at large, or local school children on a field trip. Due to its profound historic and iconographic significance, there are vast numbers of people around the world who have at least a visual association with the Wall [21]. There are also additional groups to consider, such as caretakers of the site and technical enthusiasts (individuals interested in past concrete construction, for instance). Each group brings its own variation of prior knowledge, what can be considered pre-conditioning [22, 23], that informs the perceptions and activities of visitors.

This is both the burden and opportunity of historic places in particular – there are many degrees of prior exposure that can influence one’s experience on-site. Currently soundscapes are often studied identically across all urban environments irrespective of their current or historical roles. The focus of measurements and perceptive data gathering is almost always on present conditions: how a place feels at this moment. But this focus misses the relevant changes of a soundscape over time and what meanings these changes might embody for different users. Equally, such a narrow focus does not capture the effect that historic context can have on one’s perception. For instance, the traffic density at Bernauer Straße is such that conversation can be difficult at times. Guided tours most often must be conducted elsewhere. Yet once one enters the Eastern border strip (what appears as park lands today), the immediacy of the traffic recedes behind the sober impressions of the site and adjacent Sophien parish cemetery grounds. The open expanse, with historical information and fragments peppered throughout, conspire for one’s attentiveness. One’s attention is designed to be

for amusement. Nauener Platz was redesigned specifically to be a functional park, a place of relaxation and recreation primarily for those living and working in the immediate vicinity. The redesign included areas for play and sport, for leisure, and it posited interventions to increase residents’ feelings of security in the area. Sounds were introduced that connected to the natural elements of the space. The message overall was one of welcome, of reclamation by the neighborhood, and of openness.

The Memorial, on the other hand, is fundamentally an educational facility. The features that are similarly present in park settings (open lawns, paths, bench seating, ample lighting, absence of boundary walls) in this case are employed towards commemorative and educational purposes. The grounds are maintained to preserve the Wall and ground fragments as much as for easy access to large crowds learning about the site’s history. So while the park character of Nauener Platz and the Memorial may appear similarly inviting, the purpose of that invitation differs. At the Memorial, one is invited to learn and collectively remember—to participate, not simply to relax.

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6 Personal communication with Dr. Axel Klausmeier.
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Figure 12: Berlin Wall Memorial site (Chapel of Reconciliation at top left, preserved border strip with west and hinter walls at center, preserved Wall ruins and sound stations at right; image: P.Jordan).

Figure 13: Berlin Wall Memorial – east side of preserved border strip; location of recording 1 (Image: P.Jordan).

Figure 14: Berlin Wall Memorial – west side of preserved border strip, along Bernauer Straße; location of recording 2 (Image: P.Jordan).

focused at the memorial – at Nauener Platz, it is quite the opposite. Whether or not everyone’s concentration is equally harnessed is a question of preconditioning, of age, and myriad other factors that soundwalks, interviews, and other experiential data collecting can capture. Approaching a site like the Memorial requires developing new forms of multi-tiered psychoacoustic soundscape studies to ascertain links between the site’s interpretation as an historical place and the sonic experience of visitors.

At the same time, acoustic measurements can provide an informational backbone that can be contextualized, sometimes counter-intuitively, by the above experiential data [24]. For instance, the Memorial hosts a preserved section of the Berlin wall that includes the western concrete border wall (directly adjacent to Bernauer Straße), an empty expanse and patrol road immediately east, and a further hinter wall (directly adjacent to the Sophien parish cemetery – see Figures 12 – 14). Visitors can access the outside face of both walls, but the empty expanse within remains off-limits. A-weighted SPL measurements taken on a typical weekday afternoon show approximately a 23 dB difference between west and east side⁷ (see Figures 15 and 16).

Measurements were taken for one-minute durations using an XL2 Sound Level Meter.

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⁷ Measurements were taken for one-minute durations using an XL2 Sound Level Meter.
4.5 Historic considerations in context

Such data would initially suggest a problematic condition for the Memorial to contend with. However, a look at the historic context can offer a much different interpretation. Between 1961-1989, the border strip was dominated by one acoustic character: imposed silence by GDR patrols. Approaching the walls was forbidden. Naturally, this intimidation-through-silence extended beyond the wall into the bordering neighborhoods, though the portent of this silence varied on each side. Life could carry on directly adjacent to the west wall, including pedestrian and vehicle traffic, while a restrictive zone effectively extended for blocks into the east through restricted access, neighborhood monitoring, and direct intimidation. Today, the preservation of this silence within the memorial is a rare fragment of this earlier soundscape. What is more, the different intensities of sound measured on the east and west sides continues a dichotomy between east and west experience stretching back to the 1960s. Whether they realize it or not, visitors are able to access a key experiential quality of the site as it originally functioned through the soundscape. At the Berlin Wall Memorial, and likely many other historic sites, acoustic analysis opens the possibility of a soundscape being the most intact remnant of a site. It also throws into question whether a soundscape should be considered a static or evolving element of the built environment. If indeed one might posit the presence of ‘historic soundscapes’, much more work is required to solidify the terms and research methods for identifying them. The Soundscape Approach allows a key window into these questions and a framework in which to commence, combining place-specific contextual and experiential investigations with standardized physical measurements.

4.6 Next steps for the architecture of soundscapes

According to the ISO 12913-1 standard [1], there is a distinction made between “the perceptual construct (soundscape) from the physical phenomenon (acoustic environment), and clarifies that soundscape exists through human perception of the acoustic environment.” The success of Nauener Platz offers many lessons for future soundscape work in facilitating a community-driven shaping of the built environment, what we understand as the architecture of a soundscape. But it is vital to recognize that the physical and experiential data collection methods used are not prescriptive standards. The built environment, after all, is not a monolithic construction; questions of com-

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Figure 15: XL2 recordings from Berlin Wall Memorial, taken on eastern side of border strip (recording 1, left) and the western side (recording 2, right) (Image: P. Jordan).
Figure 16: Strategic Noise Map and legend (L_{DEN}, Day-Evening-Night-Noise Index) of Road Traffic along Bernauer Strasse from 2012; area of preserved border strip highlighted in black, left circle shows recording location 1, right circle shows recording location 2 (Base image courtesy of the Digital Environmental Atlas, Strategical noise maps 15.07, 2013 edition).
fort, engagement, and connection depend on the history and current purpose of a place. An acoustic environment is constructed in its entirety by the people who use it and their interactions with the space. Thus the strategies used to understand any particular location must be adapted to these singularities. Using the Soundscape Approach for the Nauener Platz redesign, for instance, provided a feedback loop between 1) physical measurements and 2) stakeholder communication based on mutual respect, trust and cooperation. Investigations here focused on current conditions; soundscape investigations at the Berlin Wall Memorial, on the other hand, would require a diversified focus on both the continuum of political and historic meanings in addition to present conditions for visitors. From these two examples, the Soundscape Approach clearly offers a flexible framework for assessing and maintaining many different kinds of sites.

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References


[18] B. Schulte-Fortkamp, and D. Dubois (Guest eds.), Special Issue on Soundscrapes – Recent advances in Soundscape research, Acta Acustica Vol. 92(6), (2006)


