# Handbook of Research on Perception-Driven Approaches to Urban Assessment and Design

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# Chapter 14
# Towards a Virtual Soundwalk

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## ABSTRACT

*This chapter presents the debate on the conceptual framework for the virtual soundwalk as a tool for soundscape assessment for use within urban design tasks and the management of urban open spaces. A hybrid model between a soundwalk in situ and a listening test in laboratory conditions is needed to gain benefits from both methods by simulating links between spatial relations and soundscape changes in actual urban open spaces. This link is vital due to the widely accepted architectural theory background on the urban open space experience. A prototype of a virtual soundwalk tool is described. It was used by the authors during laboratory research conducted in 2014 and 2015 and developed further in 2017. The prototype was based on partial virtual reality reconstruction of visual and aural field recordings. Its potential use is illustrated using a case study of the waterfront promenade in the historical centre of Zadar, Croatia. The future prospects for the method described are debated according to the most recent developments within the field of soundscape research.*

## INTRODUCTION

Urban open spaces are always experienced in context. Whether a set of open spaces, or a series of interiors and open spaces, the inescapable fact of the urban pedestrian experience when moving from one point to another is that each space is experienced through a certain spatial sequence. It is like music, where each note or chord has a relative function within the tonality of the entire piece, alongside its absolute characteristics, such as pitch, or frequency. Each note and chord can be perceived quite differently, depending on what the listener hears immediately before, or the sounds that follow.

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For example, the chord of E major (E – G# – B) may be the tonic in one musical piece, but have a completely different musical meaning in another. The opening of Edward Grieg's Peer Gynt Suite (Morning) is in E major, and hearing it makes the listener feel content and steady. On the other hand, hearing the same chord in the next movement (Anitra's Dance), which is in A minor, induces drama, because its relative function has changed. So the meaning of each element can change drastically, depending on the context.

It can be argued that soundscape perception is affected by a similar principle. After all, this principle has been widely accepted within the field of soundscape research, as the concept of soundwalk dates from the same period as architectural theory on the experience of urban open space. The soundwalk is one of the main soundscape research tools, and includes inherently experiencing a sequence of places characterized by different atmospheres. In the broader sense, a soundwalk is the act of walking through a setting with a focus on critical listening to the sounds that can be heard there (Truax, 1999). In an urban environment, the aim is to collect audio data and grasp a mental representation of a city and its public space by combining soundscape with urban morphology (Venot & Sémidor, 2006). It is used for both quantitative and qualitative analyses (Jeon, Hong, & Lee, 2013), by conducting soundscape assessment questionnaires and collecting objective data, i.e. measurements and recordings, for further analysis (Aletta, Kang, & Axelsson, 2016).

However, critical listening within a soundwalk *in situ* ensures the most comprehensive, relevant research environment but rarely offers the opportunity to observe key design factors closely, such as the precise distance from the sound sources simultaneously with the exact vista. Another widely-used tool for soundscape assessment is based on laboratory experiment, which in most cases does not include the contextual principle already described, but eliminates many potential biasing factors which are unpredictable *in situ*. The virtual soundwalk was proposed to combine the benefits of both approaches.

The prototype of a virtual soundwalk tool described in this chapter was created in 2014 to research four acoustically specific urban open spaces. Three of them were examples of aural perception driven design; the waterfront promenade in Zadar which contains a wave-powered organ, a historical park in Zagreb which features an echo-generating pavilion, a museum plaza in Graz with an adjacent electro-acoustic sound art installation, and a sequence of equally sized squares in Zagreb characterized by different soundscapes (and reverberation times). Along with the detailed description of the prototype, the waterfront promenade in Zadar was described and compared with research conducted using a different method in 2011.

The proposed virtual soundwalk can serve as a tool to assess the congruence of visual and aural experiences of urban open space, which is major indicator of its quality. It enables the assessment of soundscapes in urban open spaces to be conducted so that the participant can understand the spatial relations between the analysed ambiences and experience their consistent representation (through the corresponding visual and aural recordings), while the benefits of standardization provided by laboratory conditions, are obtained and expanded by introducing selected key soundwalk elements, such as the spatial sensation of sequence of ambiences in the exact order in which they would be experienced *in situ*.

## THEORETICAL BACKGROUND IN ARCHITECTURE AND SOUNDSCAPE RESEARCH

Walking down the stone steps descending from a busy Parisian street to the quay of the River Seine probably inspired Christopher Alexander (or one of his co-authors) to write of aural sequences in *A Pattern Language* (1977). During an ordinary walk through a city centre, a square may have the quiet, almost intimate acoustic quality of a room. In a nearby lane, each footstep may be clearly heard. Yet the next square might be a market-place. While a quiet square may be monotonous, a market-place can be chaotic. Yet the former can be calming and the latter exciting. Whether they are perceived positively (calming and exciting) or not (monotonous and chaotic) depends on their spatial context – their position within a sequence experienced, among other factors. Similarly, To, Cho and Schulte-Fortkamp (2017) considered that the same soundscape could be assessed positively or negatively depending on the context implied by the expected activities in certain places. The descriptors for soundscape assessment defined by Axelsson, Nilsson and Berglund (2010), such as eventfulness, sense of chaos, calmness and sense of excitement, are among recent advances in soundscape research, along with the standardized soundscape assessment protocol and the adoption of the ISO soundscape standard (Kang & Schulte-Fortkamp, 2016).

The soundscape concept itself dates from the latter half of the 20th century. It implies a positive approach to the holistically understood sonic environment, instead of focusing solely on noise as a negative element. It is an interdisciplinary concept which has enabled interdisciplinary research, including the quantitative and qualitative approaches, environmental noise control and artistic practices.

For the purpose of this chapter, the theoretical background dating of the late 1950s, 1960s and 1970s is important from the soundscape and architectural viewpoints. The former focuses on understanding the aural experience of the environment, and the latter on understanding the experience of space. The pedestrian experience of urban open space is a starting point for both, as they have been influenced by the same movement that started as a reaction to the ‘dehumanized modernist city and alienated society’. The work of Rasmussen (1964), Southworth (1969), Alexander (1977), Murray Schafer (1991), Truax (1977), Westerkamp (1974), Augoyard (1978) and Amphoux (2003) has been recognized as the most significant for this issue.

In terms of understanding the aural experience of the environment, the authors (2014) have suggested the systematization of soundscape theory and research, in three non-exclusive phases, while trying to include both architectural and soundscape approaches: the pre-theoretical phase, the phase of establishing a comprehensive theory, and the ongoing phase of scientific research. The third depends on the second, and focuses on soundscapes in general and the methodology of implementing research results in environmental planning and design. The pre-theoretical phase recognizes the fundamental problem from the viewpoint of architecture and urban planning, but instead of offering systematic comprehensive approach to the sonic environment, which is characteristic of the theoretical stage, it introduces a set of comments and expert advice. The theoretical stage provides a comprehensive interdisciplinary theory on soundscape.

The pre-theoretical phase and phase of scientific research are most significant for this chapter, since they are more closely related to the aspects of architecture, urban design and landscape architecture than the phase of establishing a comprehensive theory.

## Soundwalks Before Soundscape

Walking up the Spanish Steps and then down to the Quirinal Hill in Rome made Steen Eiler Rasmussen think of the concept of rhythm in architecture and city life, as described in Experiencing Architecture in 1959. He used the contrast between the 'chaotic medieval city' 'downstairs' and the rigid rhythm of the Quirinal Palace facades 'upstairs' (some 500m south of the Spanish Steps) to elaborate the complexity and richness of architectural rhythms (Rasmussen, 1964). Interestingly though, Rasmussen conducted a debate on the aural perception of interiors instead of open spaces. He tried to relativize the hierarchy of the senses and the dominance of visual stimuli by discussing the importance of the acoustic properties of architecture in an integral spatial experience, by stating that principles of visual and aural perception are based on the refraction and reflection of waves, in which particles depict space (Rasmussen, 1964). In the tenth chapter (Hearing Architecture) Rasmussen further explained the potential for designing an acoustic experience of the built environment by articulating the acoustic properties of materials according to the main function of certain spaces, with a focus on basic acoustic effects such as reverberations or echoes. He also observed their influence on the stylistic features of individual music epochs, as musical characteristics change according to the reverberation length of the space where they are mainly performed, to attain the optimal articulation of melodies and harmonies (Rasmussen, 1964). His work, first published in 1959, despite its focus on the experience of interior space, became the forerunner of systematic study of this issue, as he was cited by many followers (Ripley, 2007; Hedfors, 2008; Labelle, 2010; Sherif Mourad, Shafik, Noaman, & Kandil, 2013; Oberman, Bojanić Obad Šćitaroci, & Jambrošić, 2014).

Besides Rasmussen's work at the end of the 1950s, in the pre-theoretical phase in the 1970s, the group of authors gathered around the architect and theoretician Christopher Alexander at the Center for Environmental Structure, Berkeley, California, already mentioned at the beginning of this subchapter, also stands out. As part of their comprehensive architectural and urban theory, based on systems theory, *A Pattern Language* presents a series of reviews and practical advices related to acoustics and urban sound planning. While Rasmussen approached acoustics by mainly focusing on interiors (which, as mentioned earlier, was not the case with other aspects of experiencing city and architecture), Alexander, Ishikawa, Silverstein, Jacobson, Fiksdahl-King and Angel (1977) analysed the aural experience of urban spaces. They recognized the need to create a quiet urban space in which to escape the roar of traffic, placed in the city centre, but less exposed to noise. They called those spaces 'quiet backs'. To illustrate, they mentioned the Parisian quays located in the city centre, unevenly in relation to the road along the banks of the River Seine, which shielded them from traffic noise. This stressed again the importance of analysing the spatial sequence of adjacent spaces characterized by different soundscape experiences. The focus is on the effect that is a result of a change in soundscape properties - the contrast between the rush of a busy street, characterized by traffic noise and human sounds, and the calmness of a riverside promenade, characterized by more pronounced water sounds.

Possibly the first use of a soundwalk as a soundscape research tool, prior to establishing the theory was the study performed by Michael Southworth in Boston, USA and published as a paper called *The Sonic Environment of Cities* in *Environment and Behaviour* in 1969. Southworth (1969) relied on soundwalks as a method to produce the first soundmaps. He was inspired by his teacher, Kevin Lynch, who established a key approach in architectural theory and urban analysis - the method for analysing the image of the city based on interviews conducted *in situ,* in 1960. Lynch's method included 'sensewalking' in New York City to establish a relation between 'sensuous urban experience and the capacity of individuals to use the public spaces' (Radicchi, 2017). Southworth (1969) adjusted it to analyse the sonic environment of the city of Boston. He determined principles for creating the sound identity of the urban environment. Although he was not actually referring to the discourse that was at the time developing in Canada within the World Soundscape Project, Southworth used the self-explanatory term 'soundscape'. His research was based on qualitative methods such as Lynch's. He concluded that quieter, spatially specific areas, such as the Beacon Hill quarter on the hill in the centre of Boston, or the quarter by Boston Common public city park, were acoustically recognizable, and both visually and aurally distinguishable from spaces filled with the noise of traffic and construction work (Southworth, 1969). He conducted his experiment by leading groups of participants in wheelchairs, wearing either blindfolds, ear plugs and ear muffs, or no sensory deprivation accessories, to distinguish the stimuli investigated (Southworth, 1969). Based on the test results of separate visual, aural and usual audio-visual experiences of the same parts of the central Boston area, Southworth defined goals for the potential planning and design of the urban sound environment: increasing the recognisability of soundscapes, the possibility of experiencing desirable sounds and adjusting the congruence between aural and visual spaces and their use (the correlation between sound, visible space and activity) (Southworth, 1969).

The soundscape theory established at Simon Fraser University in Vancouver, Canada within the World Soundscape Project, included the urban planning aspect, but did not provide clear opportunities for practical application (Oberman, Bojanić Obad Šćitaroci, & Jambrošić, 2014). It advocated the prevalence of the qualitative approach to soundscape analysis, especially regarding soundscape content, i.e. the information and emotions it contains. The significance of the theory for acoustics mostly lay in the principle of including soundscape content in the research. Amongst its many dissemination activities, a series of soundwalks which could be experienced in Europe was described by Hildegard Westerkamp in 1974, and this is in a sense complementary to this chapter (judging by the illustration from the *European Sound Diary*, World Soundscape Project, Music of the Environment Series, no.3, 1977 (Truax, 1999)).

The theory established in the 1970s and 1980s resulted in the 1990s in scientific research from the standpoint of environmental acoustics, and is accepted today as the starting point of scientific research on soundscapes. In recent times, it has encouraged debate on the possibilities for full implementation in the practice of planning and designing the built environment, based on results collected using a wide range of tools, such as field measurements and recordings, laboratory experiments, questionnaires, protocols, software for psycho-acoustic analyses and soundwalks.

Recent implementations of soundwalk in soundscape research have questioned data collection methods, optimal soundwalk duration, individual versus group soundwalking, defining evaluation positions (Jeon, Hong, & Lee, 2013), classification of soundwalks (Radicchi, 2017), and the possibility of using the soundwalk concept in simulated environments (Ming, Chung, & Schulte-Fortkamp, 2017; Echevarria Sanchez, Van Renterghem, Sun, De Coensel, & Botteldooren, 2017; Puyana-Romero, Lopez-Segura, Maffei, Hernández-Molina, & Masullo, 2017).

## The Soundwalk Effect

As the listener passes a narrow street in a densely-built city centre, he becomes part of that street's atmosphere - for just a moment. The parallel theory of sonic effects describes that experience as the cut-off effect. It was coined in 1995 to explain every aspect of the aural experience and practically every sound we experience during our lives, as a combination of sonic effects, by researchers gathered at the Cresson Institute in Grenoble, France (Augoyard & Torigoe, 2011). It is part of the parallel comprehensive theory describing our sonic environment, called the theory of sonic effects, developed in France in the same period. Interestingly though, this theory does not explicitly consider the soundwalk as an analytical tool, or as a sonic effect, although, Augoyard's research was based on 'a rhetoric of walking' (McCartney, 2014; as quoted by Radicchi, 2017).

Besides arguing that the soundwalk is an essential tool for analysing urban open spaces, used even before it acquired a name, another conclusion is presented. Contrasting experiences within a spatial sequence as a part of one spatial sensation may be the most important concept derived from this overview. Perhaps, we learn something most effectively when we have just experienced the opposite. The most pleasing rhythm may be one containing a sequence of contrasting elements.

## THE VIRTUAL SOUNDWALK PROTOTYPE

Moving a fingertip over the tablet's interactive screen, which showed a black and white sketch on a light red background, changed the sounds reproduced from splashing waves to bird cries. The iOS application in question was *Sound Map Hailuoto*, created to experience sounds recorded during a workshop on the Finnish island of Hailuoto. The workshop was part of the 2013 artist-in-residency project performed by the Hai Art arts organization and the media artist Juan Duarte, involving the local elementary school (Hai Art, 2013). It showed an artist's interpretation of a map of Hailuoto, and changed the sound reproduced according to the island area touched. This experience of seamless movement between the recorded ambiences, instead of clicking on points as with a sound map, such as Radio Aporee or similar web-based platforms, immediately inspired the authors to use a tablet depicting a map to control a virtual soundwalk in an ambisonics-equipped laboratory. As a result, bearing in mind the four main methods for soundscape assessment (soundwalks, laboratory experiments, narrative interviews and behavioural observations) defined by Aletta, Kang and Axelsson (2016), the creation of a hybrid prototype was imminent.

The virtual soundwalk prototype was designed in 2014 to enable the assessment of urban open spaces containing several different ambiences. The completely immersive experience of moving smoothly through space was not considered essential, due to the findings of previous researchers (Jeon, Lee, & Hong, 2011; Jeon, Hong, & Lee, 2013), but created an overview of the key distinguishable ambiences within a soundwalk. It was based on the following conceptual framework (as shown in Figure 1):

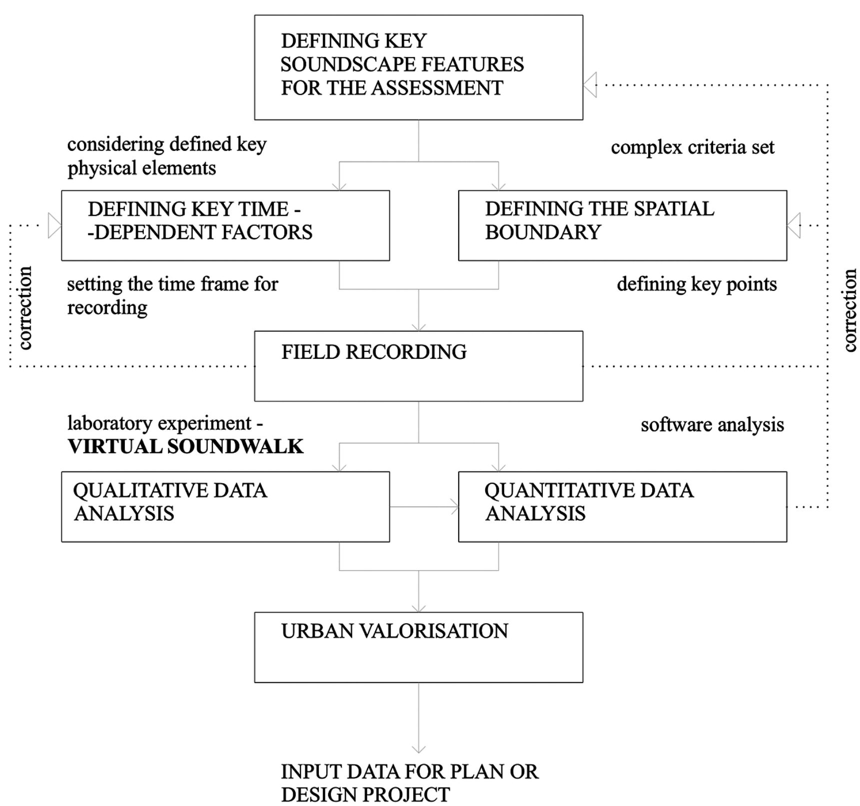
- Defining the boundary of the analysed area by using non-exclusive criteria which include analyses of physical, property, urban design commission and town plan boundaries, or even the specific sound propagation properties of the area, and applying intuitive spatial logic. The boundary can be defined either by the researcher or the client, but expertise in the field of planning and design of the built environment is suggested to optimize these set criteria.
- Defining key physical elements for both aural and visual experience, specific for urban open spaces, i.e. a sound art installation, another specific sound source or sonic effect (the most common would be the echo and masking effect, a specifically designed vista (a view along the city axis, towards a landmark), an area that people use most, or another specific spatial sensation.
- Defining key points which represent the defined key physical elements to be included in the virtual soundwalk. Later, the 'key points' may also be referred to as 'measurement points' since they overlap physically. They correspond to the term 'evaluation positions' used by Jeon, Hong and Lee (2013) or 'evaluation point' used by Radicchi (2017). The number of points influences the smoothness of the soundwalk. It is argued that for most purposes, the choice of key points is more

important for design issues than the smooth, almost realistic experience of movement, so the use of static recordings is satisfactory, if not preferred.

- Field monitoring and recording audio-visual material at defined key points, by using a technique that corresponds to the technical requirements for a virtual soundwalk, expected spatial complexity of relevant sound sources and assessment purpose (the possibilities are vast and discussed later in this chapter).
- Choosing the most consistent recordings for the research purpose.
- Creating the virtual soundwalk by the technique most suited to the specific research.
- The participant can experience simultaneously the visual and aural stimuli of the recorded key points, understand their spatial relations, and assess them using a selected questionnaire (behavioural observation during the experiment would also be possible).

This enables tests with questionnaires, or behavioural observations in laboratory conditions to be conducted, while following the soundwalk concept, which was considered essential from the architectural point of view in the early stages of soundscape research in the late 1950s, 1960s and 1970s. Therefore,

*Figure 1. The conceptual framework for the assessment of urban open spaces containing elements of perception-driven design, or other pronounced acoustic features, complementary with the conceptual virtual soundwalk framework described.*
*Source: (Oberman, 2015)*



it was hoped that the results produced would be graphical and self-explanatory to design and planning professionals. More specifically, it was driven by the following questions:

- What would be the result of a soundscape-quality protocol conducted for an acoustically specific urban space, i.e. a public space containing a sound art installation?
- What would be possible advantages of a soundscape assessment of sequence of places in the laboratory?
- What is the 'soundscape identity' of an urban open space, and how can it be transferred to a sound map?

## The Control Interface for the Virtual Soundwalk Prototype

The crucial element of the virtual soundwalk prototype was the tablet used as a control interface, simulating the previously described experience of the *Sound Map Hailuoto* application. As the authors did not have the opportunity to design a dedicated iOS or Android application, they came up with a system which relied on a set of several applications. It was based on the specific version of the *DAWOSC* application, developed by Derrico (2015), available in 2014, that was used to transmit continuous controller / control change (CC) MIDI messages via the Wi-Fi network to trigger audio excerpts prepared in a sequencer-type application on a computer for ambisonic playback. The key factor which enabled this prototype was the option to customize the layout of the *DAWOSC* application so that it resembled the map of the urban open space, while the CC playback triggers were hidden at the positions of the selected measurement points. This design of the control interface layout allowed intuitive understanding of the spatial distribution of the analysed ambiences. An example of the layout is shown in Figure 2. The smoothness of the soundwalk depended on the number of measurement points inserted.

The virtual soundwalk prototype was designed for use in a laboratory for auralisation, shown in Figure 3, with the following equipment: an ambisonic speaker system, a dedicated Wi-Fi network with

*Figure 2. The touch-sensitive interface made for the location in Zadar*
*Source: (Google, 2013; Oberman, 2015)*

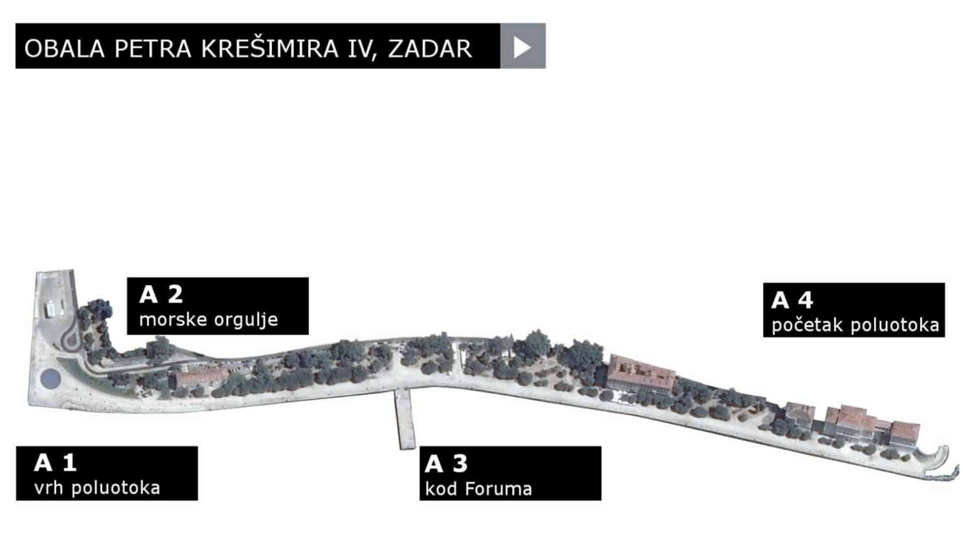


*Figure 3. A participant in test conditions in the listening room of the auralisation laboratory at the Faculty of Electrical Engineering an Computing, University of Zagreb*
*Source: (photograph by Oberman, T.)*

internet access (to enable remote playback control and completion of the questionnaire), a computer for ambisonic playback with a large display placed in the listening room, and two tablets – one for remote playback control, and the other for the questionnaire (at least one using an Android operating system, due to the limitations of the *DAWOSC* application).

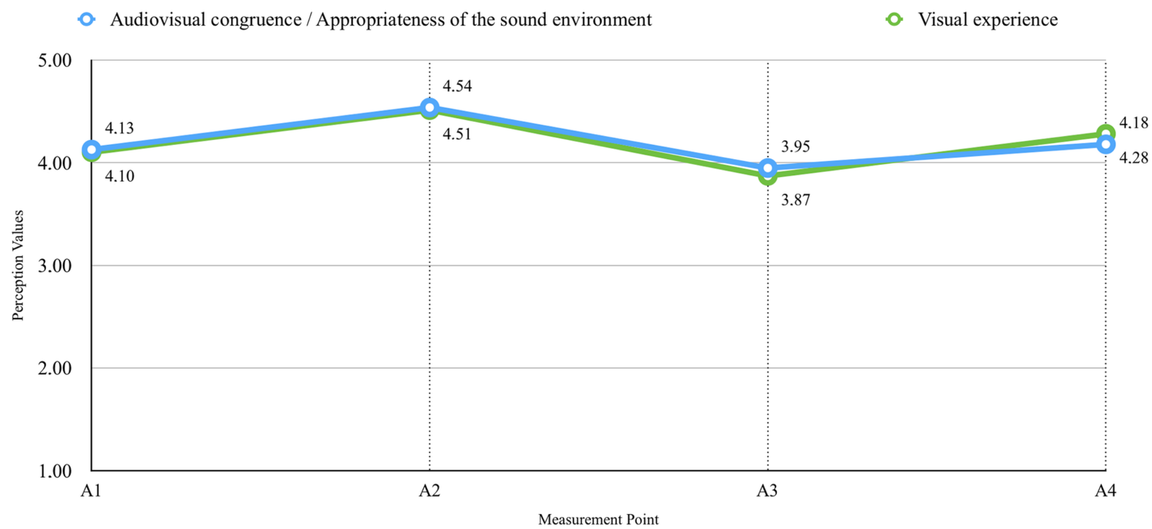
The laboratory for auralisation was chosen because the ambiences analysed were spatially complex and contained many sound sources around the measurement points, including 'beneath' and 'above'. To further strengthen the spatial aspect of the assessment, inherent to design and planning practices, the direction of the designed sound source was also considered important, along with the spatial relations between the static and dynamic sound sources. Therefore, the soundscapes were recorded using a sound field microphone, to capture these relations in three dimensions. An additional monaural recording using a microphone with an omnidirectional pattern was conducted in parallel to enable quantitative analyses.

The aural simulation was realistically three-dimensional, thanks to the recording and reproduction techniques, while the visual simulation was limited to a sequence of static panoramic photographs, since it was impossible to record and reproduce a video sphere at the time of the experiment. Simultaneous playback of video (panoramic photos) and audio recordings was achieved by playing both from the same sequencer application (Reaper Digital Audio Workstation).

## The Zadar Experiment

As mentioned in the introduction, the wider research which included the virtual soundwalk prototype included the assessment of four urban open spaces considered to be aurally specific, or examples of aural perception driven design. They differed in scale and morphological properties. *Obala Petra Krešimira IV* waterfront promenade in Zadar (Croatia), containing a wave-powered organ installation, was described to illustrate the application of the prototype in a listening experiment. The experiment showed a very high audio-visual congruence of the key points analysed, based on contrasting ambience located within an elongated urban open space, and was therefore a useful example to elaborate this topic, as shown in Figure 4.

*Figure 4. The relation between the assessment of audio-visual congruence and visual experience at four measurement points along Obala Petra Krešimira IV in Zadar.1 = very bad, 5 = very good*
*Source: (Oberman, 2015)*




The sequence of these ambiences occurs in a public space in the historical centre of Zadar. It occupies approximately 4.7 hectares along the southwestern waterfront of the Zadar peninsula (approximately 1 km) where the historic city centre is located. The linear sequence of the key points was defined according to the elongated shape of the promenade. For morphologically different urban open spaces, a different layout of key points, such as a network pattern, may be more appropriate.

The promenade leads continuously along the shoreline. The paved pedestrian area and gravel path are approximately 15 metres wide. A one-way road also follows the shoreline, approximately 30 metres from the pedestrian path. In the area between the road and the pedestrian path, green areas with tall trees and elongated three- to five-storey buildings alternate, as can be seen in Figure 5.

The social presence can be interpreted as almost linearly scaled along the promenade – starting from the calm forecourt of the university buildings at the southwest end, and culminating at the tip of the peninsula, where tourists and locals come to experience the specially designed public space featuring the sound installation of the Sea Organ, the light installation known as *Pozdrav Suncu* (Salute to the Sun; not visible on Figure 5) and the view of Zadar's archipelago.

Four characteristic measurement points were chosen, using both aural and visual criteria. Regarding their visual features and presumed role in the city centre, they were:

- **The Northeast End of the Promenade (Key Points A1 and A2):** This is the site of the promenade's main tourist attractions – the sound and light installations. The open view is approximately 270 degrees, with trees and a residential building blocking it to the east. Church spires can be seen in this direction.
- **The Mid-Point of the Promenade (Key Point A3):** This point was considered important according to urban design and planning criteria, since the *cardo maximus*, the main street in the Ancient Roman city of Iader, was located there. This ancient road is still part of Zadar's street network

*Figure 5. The vistas recorded at the four measurement points (A1 - A4) along Obala Petra Krešimira IV in Zadar. All four photographs show the view south-east along the promenade and south/south-west out to sea.*
*Source: (photographs by Oberman, T.)*


today, marked on Figure 8. Geometrically, it divides the peninsula in half, as it is at right angles to the coastline and points toward the mountain peak on the island of Ugljan. The view is approximately 180 degrees to the southwest, with tall trees blocking it to the northeast and towards the Forum. Church spires and some buildings overlooking the trees can be seen in this direction.

- **The Southwest End of the Promenade (Key Point A4):** The open view at this point is approximately 180 degrees to the southwest, with a five-storey building blocking it to the north east.

Aurally, the key points were chosen according to the key soundscape identity features. At each key point, they were considered to be achieved in a different way:

- Additional sound via the permanent art installation (key points A1 and A2).
- People using the space – commerce, walking and shopping (key point A3).
- Sounds of nature, as this key point is shielded from traffic and city noise by a building (key point A4).

Points A1 and A2 were selected to illustrate further the spatial effect of the permanent musical installation of the Sea Organ. They share very similar audio-visual features. The main difference is their position in relation to the Sea Organ installation. Point A1 is in the immediate vicinity of the installation, where the organ pipes are located to the left and in front, and point A2 is within the space of the Sea Organ, surrounded by the organ pipe openings on all sides, below the listening plane.

During monitoring, a larger number of measurement points was documented and tested. The sound field microphone was placed so that it was directed towards the sea and the island of Ugljan, i.e. to the southwest, at all the measurement points.

The experiment included 44 participants with an average age of 27.6. Only one participant said that they used the space regularly, and only three participants had never visited it before. None said that they had never heard of it. Most (21) had been there occasionally, while 19 had been there once or twice in their lives.

The experiment was performed in Auralab, the laboratory for auralisation at the Faculty of Electrical Engineering and Computing, University of Zagreb. The laboratory consisted of a control room and a listening room equipped with an ambisonic system. The experiment was conducted with one participant at a time, due to the limitations of the ambisonics (there is only one ‘sweet spot’ where the illusion of aural space is accurate) and the requirement of critical listening (more than one listener at a time would have interfered with optimal perception). At the beginning of the test, the listeners in the listening room were given two tablet devices - one as a previously described control interface to control remotely the reproduction of audio and video simultaneously, and the other showing written instructions and the questionnaire in the online Google Form application. For more information on the auralisation laboratory at the Faculty of Electrical Engineering and Computing at the University of Zagreb please see Rychtáriková, Horvat, Jambrošić and Domitrović (2013).

The questionnaire was organized key-point by key-point, in actual order, so listeners were deliberately guided to listen to sound excerpts in a spatially logical, rather than random order. However, they were free to go back and forth between the recorded ambiences for comparison. The focus of the research was the effect of the designed sequence experienced while walking through the specific urban open spaces, reduced to the selected key points. The same set of questions based on the Swedish Soundscape-Quality Protocol was repeated for each key point.

The Swedish Soundscape-Quality Protocol, developed by Axelsson, Nilsson and Berglund (2012), was chosen because of its clear structure and the connection between descriptors for soundscape perception and sound source types (Axelsson, Nilsson, & Berglund, 2010). It provides results for the recognition of sound source types, evaluation of soundscape perception, the most general evaluation of visual features and evaluation of congruence between aural and visual stimuli, which were considered crucial, given the theoretical background and the fact that the urban open space analysed contains a specific sound source – the wave-powered organ. Therefore, the recognition of sound source types within the questionnaire was expanded to include architecturally designed or public-sound-art sounds. The questionnaire included the note that the ‘designed sounds may seem alien’.

As previously stated and shown in Figure 4, the assessment of the entire promenade was extremely positive. Figure 6, showing the results of the audio-visual congruence assessment in detail, supports this, as 87.8% of the participants rated it as either 'completely congruent' or 'mostly congruent'. The difference in the assessment of key points at the promenade's tip (A1 and A2) proves the need for exact measurement points and experiments conducted in laboratory conditions, as the actual distance between them of approximately 30m could be tolerated within a soundwalk, and they could be considered the same position.

Despite these extremely positive results gathered from assessments of the Sea Organ and the surrounding urban open space, some controversial issues regarding the position of the adjacent port and the neighbouring residential building arose. The position of the dock for cruise ships is considered discordant with the position of the Sea Organ (Oberman, Bojanić Obad Šćitaroci, & Jambrošić, 2015). The constant engine noise of docked passenger ships congests the soundscape characterized by the sound art installation, sounds of nature and people. It is turning the sound art installation into a device for noise-masking, instead of being the attraction it was before the completion of the project. As can be seen on the spectrograms in Figure 7, sound recordings made on 1 July 2014 from 6:56 to 8:00 a.m. show that the noise of ships' engines was audible along the whole promenade (the low frequency of up to approx. 100 Hz overlapped with bursts resulting from the wind gusts). The harbour construction was the driving force behind the design of the peninsula tip and the revitalization of the neighbourhood in 2003. Its function in terms of soundscape has negatively affected all the benefits derived from the new design of public space, especially the Sea Organ. Moreover, the tenants of the neighbouring building do not share the extremely positive opinion of the sound installation because their experience of the Sea

*Figure 6 The results of the assessment of audio-visual congruence for four measurement points along Obala Petra Krešimira IV in Zadar. Given the planned extension of the whole urban area on the peninsula and possible construction in the gaps along the promenade created during the bombing in World War II, this study may provide guidance for future plans that would sustain the analysed experience qualities along the southern shore of the peninsula.*
*Source: (Oberman, 2015)*

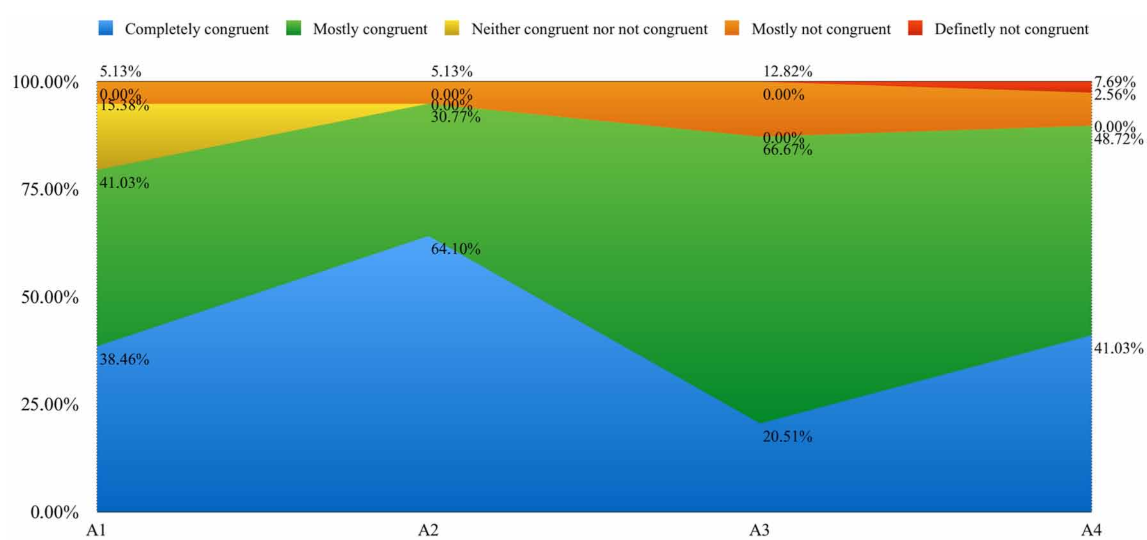
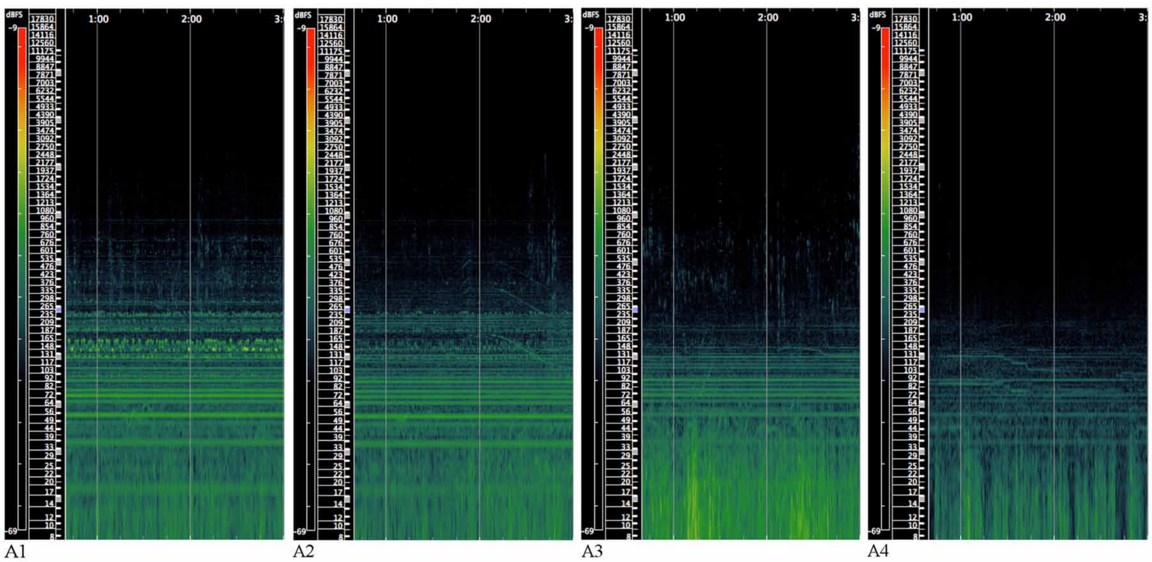


*Figure 7. Excerpts from spectrograms of recordings at measurement points A1 – A4. The following sounds were noticed by the authors: the Sea Organ, a ferry passing by, people shouting in the distance during rowing training, distant church bells, terns calling, gulls calling, a dog barking, automatic lawn sprinklers, a roadsweeper and a cruise ship engine humming at A1 and A2; people walking on the gravel, the splashing of sea waves, gulls calling, a distant cruise ship engine humming, the distant sound of the Sea Organ and occasional passing cars at A3; the splashing of sea waves, distant conversation, gulls calling, people walking on the stone pavement and a distant cruise ship engine humming at A4.*
*Source: (Recorded by Oberman, T., spectrograms created using the Sonic Visualiser v 12.4, application)*

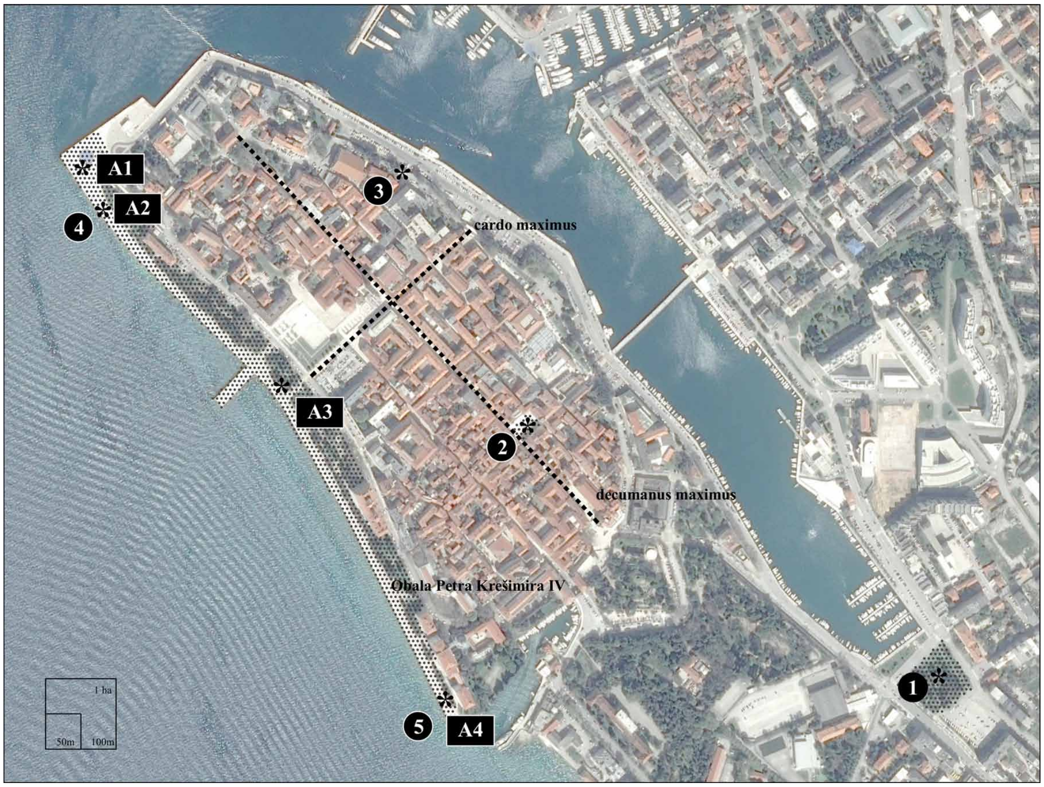



Organ is permanent, in contrast to visitors, for whom it is unique. The Sea Organ is a rare example of a permanent installation with musical content located in the historical centre near residential buildings, so it should be monitored in relation to the dynamics of economic and cultural life in Zadar as a whole (Oberman, 2015). Clearly, there is need for both qualitative and quantitative analyses, as well as planning expertise to assess the soundscape quality of this urban open space.

## Comparison with Previous Research at the Same Two Key Points

Previous research performed in 2011 (Jambrošić, Horvat, & Domitrović, 2013) in the historical centre of Zadar included five separate urban open spaces located in different parts of the peninsula, including measurement points A2 (Sea Organ) and A4 (also called the Boardwalk) from the 2014 study. It relied on the Swedish Soundscape-Quality Protocol conducted *in situ* and included 167 participants with an average age of 36.5. It aimed to prove the positive effect of the architectural installation with musical features, despite the high sound pressure level, by comparing it to morphologically and sonically different public spaces, shown in Figure 8, through parallel qualitative and quantitative analyses. On the other hand, the 2014 study aimed to prove the positive effect of different ambiences within one public space. This research also resulted in the extremely positive assessment of the measurement point at the Sea Organ. As Jambrošić, Horvat and Domitrović (2013) suggested, it was based on the uniqueness of the urban area, and probably on the uniqueness of the aural experience itself.

*Figure 8. The positions of public spaces included in studies conducted in 2011 and 2014 on the satellite image taken on 3 April 2016. The 2011 positions are: 1 – "the park" Trg kneza Višeslava (Višeslav Square), 2 – "the square" Narodni trg (People's Square), 3 – "the harbour" Liburnska obala (Liburnian Shore), 4 – The Sea Organ on Obala Petra Krešimira IV, 5 – "the Boardwalk" on Obala Petra Krešimira IV. The 2014 positions are as previously described. The positions of the Ancient Roman cardo and decumanus in ancient Iader are also marked.*
*Sources: (Google, 2013; Jambrošić, Horvat and Domitrović, 2013; Oberman, 2015)*




There was no construction work along the promenade or in the immediate area, so no physical changes occurred in the analysed space between 2011 and 2014, apart from maintenance work. The traffic organisation in the area remained unchanged within the observed period and there were no organised events, nor temporary urban interventions at the locations during the measurements, so results can be compared despite differences in methodology. This comparison was intended to further illustrate the argument in this chapter. Naturally, it does not prove that one approach is better than another, nor was that intended. Moreover, the soundscape itself is subject to constant change and influenced by many external factors which are impossible to record, which makes differences in the assessments the subject of best guesses.

Some results from the studies conducted in 2011 and 2014 are shown in Table 1. Further, Jambrošić, Horvat and Domitrović (2013) compared the assessments of a small number of participants who participated in the survey as a soundwalk through the city centre with the rest, and concluded that this fact did not influence the results. Obviously, the soundwalk in 2011 did not cover the same route as that used in the soundwalk prototype, due to the different aims previously mentioned.

*Table 1. Comparison of results from the study conducted in 2011, using a spatially non-sequential sample of urban open spaces, and that conducted in 2014, focusing on a sequence of ambiences (Data source: Jambrošić, Horvat, & Domitrović, 2013; Oberman, 2015)*

| | | ***Spatially Non-Sequential Sample, 2011*** | | ***Sequence of Ambiences, 2014*** | |
|---|---|---|---|---|---|
| | | Sea Organ | Boardwalk | Sea Organ (A2) | South end of the promenade (A4) |
| Perception of the sound environment | Pleasant | 4.7 | 4.6 | 4.3 | 4 |
| | Eventful | 4.2 | 3.6 | 3.6 | 1.9 |
| | Exciting | 3.9 | 2.7 | 3.7 | 2.1 |
| | Chaotic | 1.4 | 1.9 | 2.9 | 1.7 |
| | Calm | 4.1 | 4.0 | 3.4 | 3.8 |
| | Uneventful | 2.3 | 2.1 | 1.9 | 2.9 |
| | Annoying | 1.5 | 1.4 | 1.9 | 1.8 |
| | Monotonous | 1.8 | 2.2 | 2.4 | 3.4 |
| Perception of the visual environment | | 4.7 | 4.6 | 4.5 | 4.3 |
| Measured sound pressure level / dB(A) | | 63.0 | 55.6 | 76.9 | 48.0 |

Surprisingly, the values for pleasantness, excitement, uneventfulness and annoyingness for the Sea Organ location differ by less than 0.5 points, leading to the conclusion that the location was very pleasant, exciting, not uneventful, and not annoying, in both assessments. This is probably due to the fact that the Sea Organ emits an audible, dominant sound, regardless of the changes caused by the wind intensity and sea traffic.

The values for the south end of the promenade, on the other hand, show greater differences. Nonetheless, they concur to a great extent in describing this point as calm and not chaotic. However, there is a greater difference in the assessment of eventfulness and monotony – it was considered less eventful (1.7 points) and more monotonous (1.2 points) when analysed within a sequence. It is hard to tell whether the more direct comparison with the contrasting part of this elongated urban open space benefitted this location by enabling participants to appreciate better its calm character, as well as the more pronounced difference between the two points, which can be seen in the sound pressure levels measured. Moreover, a 7.6 dB(A) difference between the two studies suggests the soundscape being more eventful during the measurement in 2011.

The difference in the measured SPL in 2014 along the promenade was 28.9 dB(A), which shows a remarkable aural contrast in ambiences within the analysed public space. The 13.9 dB(A) difference in the measured SPL at the Sea Organ in 2011 and 2014 possibly indicates the diapason of the levels which the installation can produce depending on the sea activity.

Visually, it can be noticed that both key points were assessed as equally attractive, with a slight preference for the Sea Organ in both assessments.

Regarding the validation of the virtual soundwalk method and this comparison, the results of the laboratory assessment were similar, which proves the usefulness of the method and its capacity to surpass the limitations of the laboratory environment.

## IMMERSIVE VIRTUAL REALITY AND BIASING FACTORS

Would an experiment using an immersive virtually real experience and smooth movement in virtually real space necessarily lead to a better assessment than one reduced to key ambiences? Using smooth movement in virtually real space for the assessment of existing situations is limited, among other reasons, by the inevitable bias made during recording 'in one take'– the moving speed of the recording gear, sounds (and shadows) produced by the movement and physical features of the person conducting the recording, e.g. height, and the subsequent inability of excluding irrelevant sonic events, e.g. gusts of wind which occurred during the soundwalk. Venot and Sémidor (2006) observed a significant bias resulted from these factors. This speaks in favour of focusing on a fixed number of key points instead of simulating smooth movement, although it inevitably causes researcher-induced bias in the case of preselected key points.

The following biasing factors were considered in relation to the experiments conducted:

- The effect of unusual technological experience.
- The effect of laboratory experiments.
- The effect of misunderstanding questionnaire questions.
- The effect of the researcher's bias – predefined evaluation positions and soundwalk duration.

Perhaps the unusual experience of technology such as immersive virtual reality or ambisonics biased the participants and led them to filling in the questionnaire in a rather overexcited frame of mind. This was also noticed by Echevarria Sanchez, Van Renterghem, Sun, De Coensel and Botteldooren in a lecture (2016). To minimize this effect, tests were repeated with the same group of participants to gain more coherent results, after they had adapted to the simulation experience (Echevarria Sanchez, Van Renterghem, Sun, De Coensel, & Botteldooren, 2016). For pragmatic reasons, this is not always feasible. The argument would lead to using a more common environment for the experiment – perhaps with only headphones and a tablet, as was done by the authors in 2016. This could be investigated in the future and the effect could be expected to decline as accessible virtual reality simulators continue to appear on the market.

During the Zadar experiment, on average, 14.4% of the participants per measurement point commented on the experience of participating in the experiment. All the comments were positive. Some comments addressed the experience of the ambisonic system, like this one:

*You can feel the openness of space – you can hear the horizon.*

After the experiment, several participants commented that all the sounds in the laboratory appeared much louder than in the actual outdoor space, because they were focusing on them, although the listening level was set to match the measured sound pressure level. This may be explained by the state mentioned earlier, which is induced by the unusual experience of the auralisation laboratory.

In conversations with some participants after the experiment, the possible advantage of using static images instead of video came up. In fact, the assessment of congruence can be confusing, so that participants begin to wonder if they can recognize visually the sound sources of all the sounds they perceive – they begin to assess the simulation itself, instead of deciding whether the soundscape and landscape are congruent. In the case of static images, it goes without saying that not each sound source is necessarily present, so participants are perhaps better able to focus on the real issue.

As complex approaches to the selection of evaluation positions is specific to soundwalks intended for use in urban planning and design (Radicchi, 2017), and bearing in mind the quantity of data collected from each measurement point, it would be pragmatic to reduce their number according to clear criteria, depending on the research goal. A smooth soundwalk would be more convenient if used to gather data from behavioural observations instead answering a questionnaire for each key point. For example, Echevarria Sanchez, Van Renterghem, Sun, De Coensel and Botteldooren (2017) observed the whole virtually real soundwalk via the simulated environment on a bridge in Antwerp as one evaluation position, since their focus was on variations of a single design element – a pedestrian area on the bridge. On the other hand, during a soundwalk in Seoul Jeon, Hong and Lee (2013) instructed participants to define the best evaluation positions themselves. That resulted in forming sixteen evaluation areas of 10 m radius (Jeon, Hong, & Lee, 2013), which would then correspond to the researcher-defined key points used. Within the experiment conducted in 2014 (which included other locations besides the one in Zadar), the maximum number of key points per participant was sixteen. It took about an hour and was considered tiresome. Jeon, Hong and Lee (2013) reported similar findings regarding the optimal duration of a soundwalk, and suggested dimensioning the number of evaluation points not to exceed this duration, while Radicchi (2017) suggests 30 minutes as the optimal soundwalk duration. The proposed method therefore relies strongly on researcher-selected site boundaries and measurement points, instead of using an approach which allows participants to determine evaluation positions in a manner similar to Jeon, Hong and Lee (2013) *in situ* and Jiang, Maffei and Masullo (2016) in an online virtual reality. This method relies on urbanists' expertise in the initial phase of designing the soundwalk to capture the most significant spatial sensation within the key points, as it is a major factor influencing perception of urban soundscapes (Jeon, Lee, & Hong, 2011), as well as the understanding of planned scenarios which are not usually visible *in situ*, nor part of common knowledge, but contained in urban plans which sometimes need 'deciphering'.

Although one of key advantages of the virtual soundwalk is standardization (each participant hears exactly the same soundscape recording), allowing participants to measure their pace/speed – progression between the key points freely during the soundwalk probably reduces the precision of the results, since the duration of exposure to each soundscape becomes another biasing factor. In addition, it would be possible to track the chosen duration of exposure to each ambience and draw conclusions by comparing the main values between sequential ambiences, comparing the results of equal exposure, or performing the experiment using behavioural observation.

## POTENTIAL USES FOR VIRTUAL SOUNDWALKS IN URBAN DESIGN, PLANNING AND MANAGEMENT PRACTICE

Brown (2011) wrote of the various sounds he experienced at the Plaça de Catalunya in Barcelona as an example of a loud, eventful public space, yet congruent and therefore of high-quality. He proposed a model for identifying soundscape quality (Brown, 2007) based on sound source preference priority, instead of perceived or measured loudness. The main goal of assessing a place using the virtual soundwalk method would be to acquire results regarding the audio-visual congruence experienced. This would indicate any problems in quality and the factors which should be enhanced to achieve more satisfactory results.

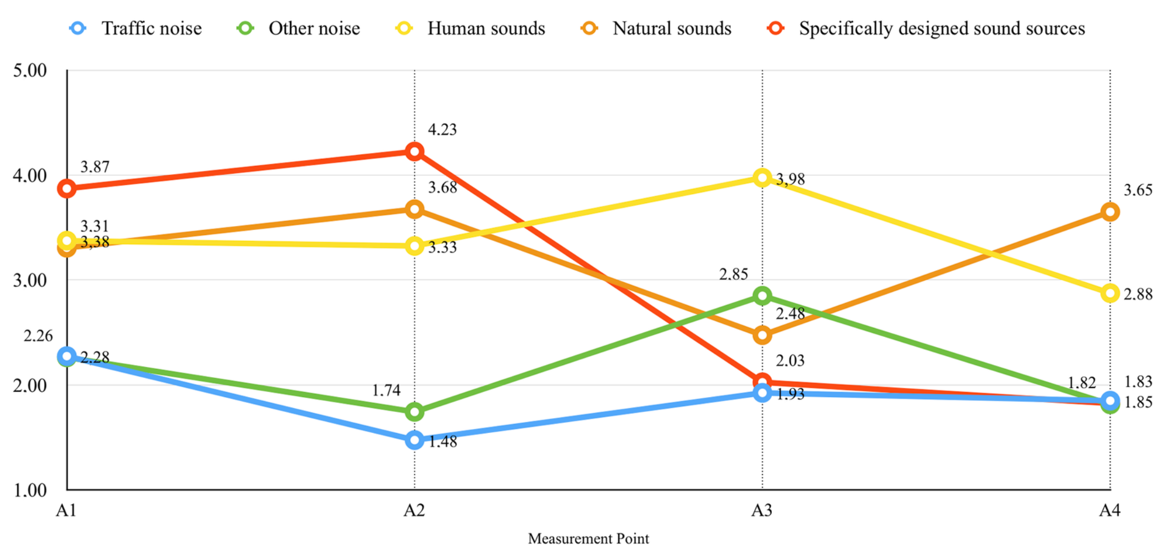
Depending on the difference in visual and aural assessment results, informed design, planning and/or management decisions can be made. In the case of congruent places, the recommendation would be to try to maintain a positive ambience. The prototype presented enables this, as the results shown in Figure 4 graphically indicate less congruent locations in relation to neighbouring ones.

For example, accordingly to Figures 4 and 9, the Zadar example suggests that minor interventions should be made at the *cardo maximus* point (A3) regarding both visual and aural features. The lower value at key point A3 is probably due to the ambience which has a less pronounced character than A1, A2 and A4. The musical content is generic (with songs playing on a radio and souvenir stands). The diagram in Figure 9 indicates that the problem of the overall quality at this measurement point lies in the perceived occurrence of 'other noise'. This probably refers to the generic music played at the stands, as one participant noted:

*Muzika nije u mom kodu (This music is not my mojo.)*

As Southworth (1969) stated, not only congruence between the aural and visual experiences is important, but their congruence with the use of the urban open space is also key. Acoustic comfort and excellent audio-visual congruence are priorities in sensitive places (due to their status, or the protection of natural or cultural heritage) and in places intended for residential stays. Further analysis, perhaps using space syntax software, could ensure soundscape evaluation which eliminates spaces where acoustic comfort and excellent sensory congruence are not important design or planning criteria. Again, this stresses the importance of urbanist expertise.

*Figure 9. Diagram showing the recognition of sound source types: traffic noise, other types of noise, human sounds, natural sounds, and specifically designed 'alien or artificial' sounds*
*Source: (Oberman, 2015.)*



## Implementation of the Virtual Soundwalk in Existing Planning Models

The topic of integrating soundscape simulation in design, planning and management processes has been widely discussed by many researchers. It is still being debated at conferences and there is still no firm, continuous practice validating this academic discourse, although isolated examples have been recognised. Two models were chosen to illustrate the potential use for the method: one proposed by De Coensel, Bockstael, Dekoninck, Botteldooren, Schulte-Fortkamp, Kang and Nilsson (2010) and the other by Adams, Davies and Bruce (2009).

Planning practice is strongly interdisciplinary, and besides the planning and design professions, it involves politics, economy and sociology, among others, and relies on research ranging from ecology to environmental psychology. However, both models focus on the process of planning and design in terms of the relationships between the individual participants: architects, planners, urban planning offices, experts in environmental acoustics and the public. They involve the application of two basic approaches, according to certain phases of project development, both relying on the soundwalk as a crucial tool in the stage of the initial analyses, as also recommended by Venot and Sémidor (2006):

- The soundwalk method for the analysis of the actual soundscape *in situ* in the initial phase of consultation, including architects, city/municipality representatives and experts in environmental acoustics, repeated at the early stage of design and acquiring building permits.
- The use of simulated soundscapes, i.e. the auralisation of the project proposal in the laboratory, in the early and final stages of design and issuing building permits.

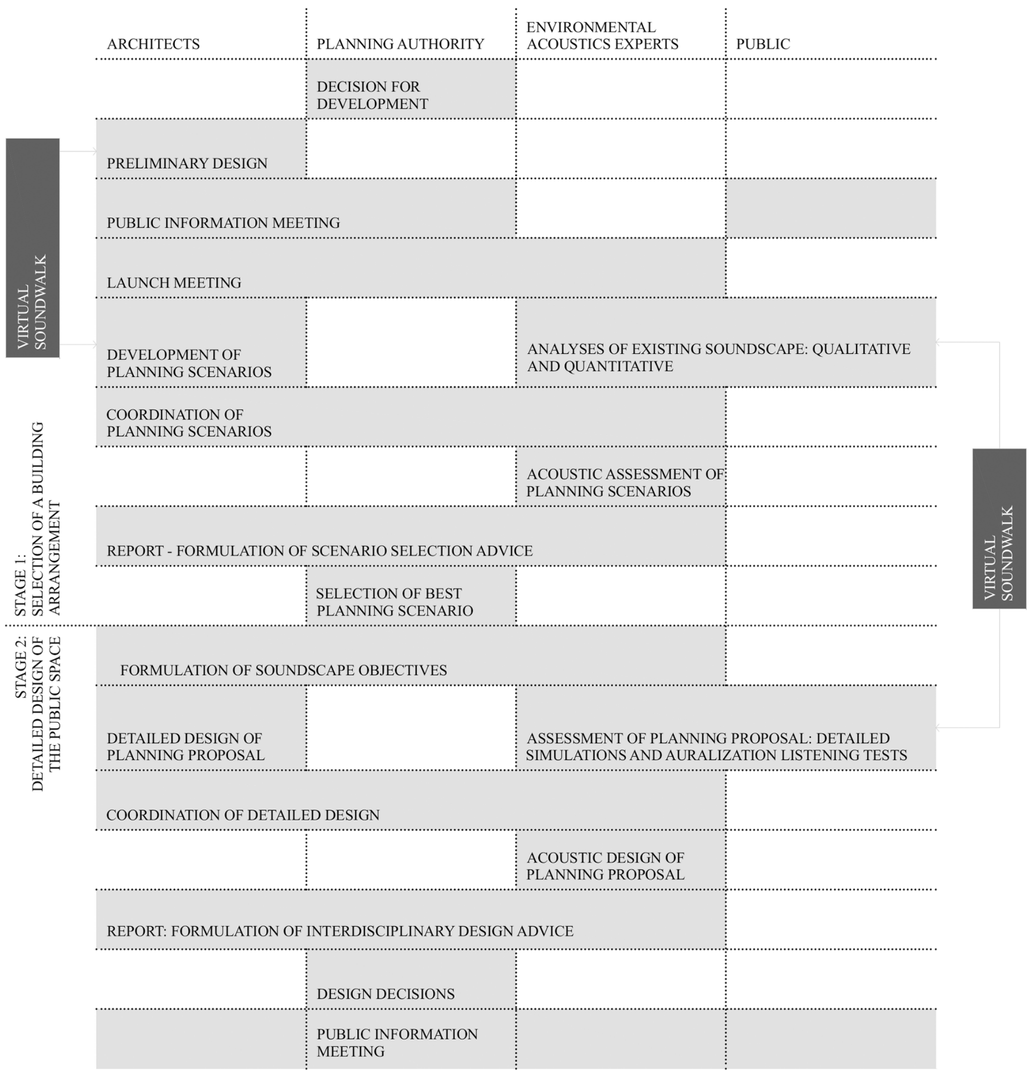
The prototype described has been tested in the assessment of existing soundscapes, but its framework can be used for designed soundscape simulations as well. The convenience and ease of use of the described interface can be used to control simulations. The only modification would be using audio tracks produced for the purpose or adjusting the level of separate sound sources during the simulation, instead of recorded existing soundscapes. Therefore, it is compatible with proposed integration models for both approaches. The potential use of the presented prototype within both integration models and both approaches by substituting or complementing the soundwalk *in situ* is shown in Figure 10.

## Technical Considerations for Implementing the Virtual Soundwalk in Planning and Design Processes

As the implementation of soundscape research in planning and design involves professionals engaged in interdisciplinary collaboration on the one hand, and request for public participation on the other, the need arises to adjust the simulation layout to target users (Maffei, Masullo, Pascale, & Puyana Romero, 2016). Certainly, the final virtual soundwalk layout should be simplified for both groups in terms of the necessary audio system and interface complexity.

Realistic, three-dimensional sound cannot be achieved by using stereo/binaural systems alone. The use of microphones for ambisonics has been somewhat limited, since it requires at least four separate channels to be recorded simultaneously, which is not supported by most practical and widely used mobile recording devices, but confined to the professional domain. The technical requirements for the accurate reproduction of the recording are also complex: an ambisonics equipped room consists of a system of at least eight speakers carefully positioned in vertical and horizontal planes. Three-dimensional aural

*Figure 10. Proposal for the integration of the virtual soundwalk in the urban sound planning model by De Coensel, Bockstael, Dekoninck, Botteldooren, Schulte-Fortkamp, Kang and Nilsson (2010)*
*Source: (De Coensel, Bockstael, Dekoninck, Botteldooren, Schulte-Fortkamp, Kang and Nilsson, 2010; Oberman, 2015)*




simulations are even more complex than the reproduction of the recordings. Researchers engaged in the Sonorus project (the Initial Training Network under the FP7 People Programme, conducted in the period 2012-2016) used a complex modelling system to simulate the relationship between the moving listener and moving sound sources, for use with headphones and a virtual reality head set type of interface (Echevarria Sanchez, Van Renterghem, Sun, De Coensel, & Botteldooren, 2016). Soundwalking in a simulated environment opens up a whole new topic covering the use of a wide base of pre-recorded sounds which could be used for simulations of designed environments, also addressed by To, Chung and Shulte-Fortkamp (2017).

Recent software development in the field of audio production plug-ins makes possible the effective use of ambisonic recordings for listening with headphones and easy integration in the usual digital audio workstation systems. This, with the integration of gyroscope-equipped devices, enables the experience of realistic, accurate, three-dimensional aural information, captured by a 1st order ambisonics microphone, using only headphones. As the listener turns their head, the gyroscope sends movement information to the plug-in, which then filters the audio information to match the exact listener orientation in space. It is expected that this or a similar system will become increasingly accessible and widely used.

Another possible way of simplifying the recording and reproduction would be to use binaural recordings or simulations when appropriate to the research purpose, regardless of ambisonics, as in an online viewer made by Jiang, Maffei and Masullo (2016).

The most significant step regarding the simplification of the interface would be the development of stand-alone applications on smart devices intended for the auralisation of a virtual tour, similar to the example reported by To, Chung and Shulte-Fortkamp (2017), or perhaps even more convenient online viewers, which would integrate all the functionality of ambisonics within an internet browser. There are currently many smartphone applications on the market offering visual virtual reality experiences, using stereo playback, and virtual reality simulations are being considered as a tool in architectural and urban design (Piga & Morello, 2015), supporting this method.

## CONCLUSION

The main purpose of this chapter was to explain the advantages of the virtual soundwalk prototype for the soundscape assessment of urban open space, designed as a listening experiment conducted in an auralisation laboratory. The importance of the soundwalk concept was elaborated within the discourse of architectural theory, comparing the results of the example in Zadar with a similar study conducted *in situ* using a spatially unconnected sample of urban open spaces, and then by comparing the issues and problems presented with other known experiments based on simulated soundwalks.

Since soundscape assessments are generally intended for use in designing and planning the built environment, the standpoint of architectural theory was considered important. From the aspect of both theory and research dating from the 1950s, 1960s and 1970s, the soundwalk concept was considered vital. Authors including Rasmussen, Alexander, Southworth, Westerkamp and Augoyard have found that the diversity and congruence of audio-visual ambiences experienced by walking through urban open spaces greatly contribute to their quality.

Obala Petra Krešimira IV promenade in Zadar, Croatia, proved to be the right example to illustrate a gradation of diverse and congruent ambiences within one urban open space. Further, a comparison between different studies of two corresponding measurement points on this promenade in Zadar was presented: the Sea Organ at the tip of the peninsula and the point on the southeast base of the peninsula. The studies compared were conducted in 2011 and 2014. The former was conducted *in situ* and considered typologically different, indirectly connected public spaces in the historical centre of Zadar, while the latter focused on a partially virtual soundwalk of key points within an elongated urban open space - the waterfront promenade. As both studies used the same questionnaire, the comparison was based on soundscape perception values, an assessment of visual features, audio-visual congruence and average sound pressure level, bearing in mind incalculable factors relating to different circumstances influencing these locations in time. However, the differences in results may hint that the order of the reproduced ambiences does influence the assessment in a way that is beneficial to the actual diversity of positive ambiences. Similarities between the results show the described prototype's efficiency, despite the limitations of the laboratory environment.

The results of the experiment conducted confirmed that the virtual soundwalk prototype used can describe spatial relationships between factors which indicate urban open space quality, such as congruence between visual and aural experiences. Differences in assessments of the selected measurement points within the same urban open space during the 2014 study indicated the importance of analysing precise measurement points, in order to understand the influence of spatial relationships between the sound sources and visual features of an urban landscape. The results also confirmed that this prototype can elaborate an architectural concept, such as a harmonious sequence of contrasting but congruent ambiences - however elusive, which is crucial, bearing in mind its intended use in urban design tasks.

Although the mentioned comparable experiments that used simulated soundwalks were based on virtual models instead of field recordings, they share the common concept and point out issues which should be considered while designing the most efficient virtual soundwalk. A highly immersive, virtual soundwalk is possible, but is still technically demanding in terms of a realistic, three-dimensional soundscape simulation and its potential usefulness would depend primarily on the selection strategy of the evaluation positions. Given the experience the authors acquired during several listening experiments conducted between 2014 and 2017, this chapter outlined the possible benefits and key concepts of this tool, regarding its use in soundscape research and design and planning practice.

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## KEY TERMS AND DEFINITIONS

**Ambience:** A term from architectural theory. A holistically experienced space, or within this chapter, more specifically, the audio-visual experience of a place. Its scope is defined by the level of differences between it and its neighbours.

**Ambisonics:** A complete 3D-surround sound technique for sound recording and/or sound reproduction using an arbitrary loudspeaker configuration. Although in theory any audio recording in the ambisonic format can be reproduced using any number of loudspeakers, there are strong recommendations for the system setup to achieve the best possible rendering of the sound field in a wide 'sweet spot'. The system provides a realistic 3D illusion of aural space. Stereophonic speaker systems, such as stereo or surround systems, cannot produce the illusion of sound sources on a vertical axis. One technical challenge in recording and sound events in the ambisonic format is that special, multichannel ambisonic microphones must be used to record aural information in three dimensions. The accuracy of the spatial illusion generally depends on the number of separate recorded and playback channels.

**Auralisation:** A technique for sound creation and reproduction based on computer simulation. The main purpose of auralisation is the recreation of a sound field in a controlled environment (loudspeakers or headphone reproduction in laboratories) for subjective evaluation of sounds by listeners.

**Listening Experiment:** A common method in soundscape research. It is conducted in a controlled environment and includes the reproduction of sound material for the participants.

**MIDI:** A digital data transfer protocol developed in the 1980s for the synchronisation of early digital musical instruments, audio workstations, and computers. It was standardised in 1983 and is still in use.

**Public Sound Art:** Sound art temporarily or permanently exhibited in a public space.

**Sound Map:** A map showing information on the relation between geospatial data and sound-related content.

**Spatial Sequence:** The effect of different spaces/ambiences experienced in chronological order while moving from one to the next (since walking is a linear activity).

**Urban Open Space:** There is no definition of this term common to all concerned fields. However, it is widespread and its broadest meaning includes private and public city spaces that cannot be considered as interiors: squares, streets, parks, private gardens, or steps in front of buildings, among others.

**Zadar:** A city in Croatia located on the Adriatic coast. It developed from a Roman city on the peninsula that is still the hub of the city.