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Sound in Landscape Architecture

A Soundscape Approach to Noise

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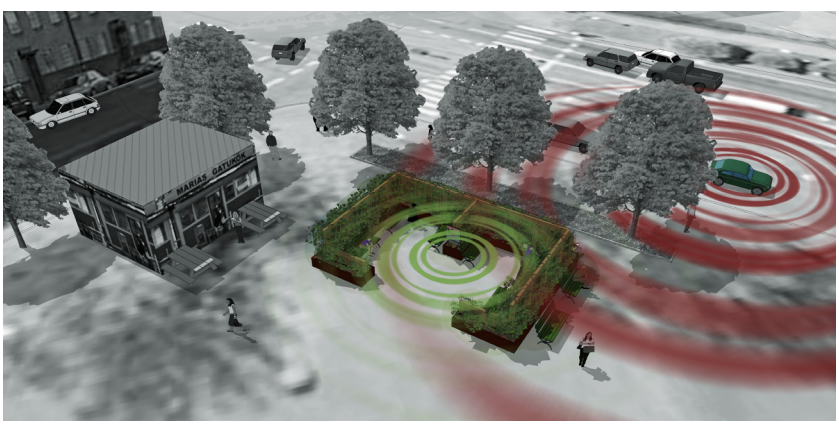

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Cover: 3D sketch depicting an urban soundscape intervention that was built and studied as part of this thesis (Paper III). The schematic colour circles represent traffic sounds (red) and forest sounds (green). The traffic sounds were screened by the arbour intervention and the forest sounds were generated by speakers to produce an additional masking effect.

(Image rendered by: Gunnar Cerwén)

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Abstract

Landscape planning and design involve decisions that have far-reaching effects, positive and negative, on the soundscape. However, landscape architecture and related disciplines have not fully recognised the possibilities of considering sound issues in design projects. This is problematic, considering that sound influences health and wellbeing and is an important factor in environmental experience.

This thesis examines how soundscape thinking can be facilitated in landscape architecture. The work is based on a mixed-method approach and it is practice-orientated in the sense that it studies how landscape architects currently work with sound and how they could work with sound in the future. The soundscape concept is used to emphasise the experiential characteristics of the sonic environment and to discuss the role of sound in landscape architecture, particularly in noise-exposed situations. Applications of soundscape design are raised in several examples, including construction of a design intervention as a reference project involving noise masking.

The understandings obtained are used to formulate a set of strategies and tools for the profession as a soundscape approach to noise, in which problems and possibilities are given consideration to ensure a varied and purposeful environment. A model based on three categories is presented to evaluate and facilitate such a comprehensive approach, where each of the three categories (localisation of functions, reduction of unwanted sounds and introduction of wanted sounds) represents a central consideration that can be taken in landscape architecture.

An extended version of the comprehensive model is also presented. It comprises a list of 23 ‘soundscape actions’, each of which represents a concrete, general strategy that can be adopted to improve soundscapes, particularly focusing on noise-exposed situations. To increase applicability, the soundscape actions were developed in collaboration with professional landscape architects, Master’s students, acousticians, artists and other experts.

The findings are discussed in relation to contemporary challenges in the profession, particularly focusing on the sustainability discourse and covering issues such as green structures, densification and the notion of ‘quiet areas’.

Keywords: soundscape design, landscape architecture, acoustic environment, noise, informational masking, urban design, quiet areas, sustainable development

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Preface

This thesis is a result of several years of exploration at the intersection between landscape architecture and sound, particularly in practice-orientated situations and through empirical studies. I have been interested in the topic ever since my time as a student in landscape architecture.

In 2009, I produced a Master's thesis investigating the relationship between speaker sounds and outdoor environments. Following that work, I have continued to explore sound in landscape architecture, gradually becoming more interested in landscape architecture as a cultural practice and how soundscape thinking can be given more focus in design solutions.

My own interest in the sound environment grew out of music and this seems to be a path I share with many researchers in soundscape. For me, it was experimental psychedelic garage rock music that would first stir a deeper interest in sound. After many years of playing and recording music, I gradually started to become more interested in related fields, such as psychoacoustics, recording techniques, atmospheres and soundscapes.

As a landscape architect, I had a brief period of professional experience, particularly working at design scale on projects such as playgrounds, parks, private gardens and art installations. In addition to landscape architecture, I also have academic training in fields that are specifically orientated towards sound, such as music theory, music psychology, sound art and film sound. My qualitative understanding of sound was the starting point and driving force for the present thesis. This perspective was applied in noise-exposed situations, an area where calculations and quantitative measures have dominated to date. In the thesis work, I attempted to combine these perspectives.

To sum up, the thesis is about two of my major interests; sound and landscape. It has been very interesting to work at the intersection between these areas and, as it happens, this work has coincided with renewed interest in sound within landscape architecture, in practice and in theory. I would like to think that this is not a temporary trend, but rather a (re)discovery of a fundamental design element within the discipline. With this thesis, I hope to contribute to future explorations in sound.

Gunnar Cerwén
Alnarp, July 24, 2017

ah this silence / sinking into the rocks / voice of cicada
Matsuo Bashō, Yama-dera 1689

Contents

List of publications

This thesis is based on the work contained in the following four research papers, which are referred to by their respective Roman numeral in the text:

I Cerwén, G., Pedersen, E. & Pálsdóttir, A-M. (2016). The role of soundscape in nature-based rehabilitation: A patient perspective. *International Journal of Environmental Research and Public Health* 13 (12), 1229.

II Cerwén, G., Wingren, C. & Qviström, M. (2017). Evaluating soundscape intentions in landscape architecture: A study of competition entries for a new cemetery in Järva, Stockholm. *Journal of Environmental Planning and Management* 60 (7), 1253-1275.

III Cerwén, G. (2016). Urban soundscapes: A quasi experiment in landscape architecture. *Landscape Research* 41 (5), 481-494.

IV Cerwén, G., Kreutzfeldt, J. & Wingren, C. (2017). Soundscape actions: A tool for noise treatment based on three workshops in landscape architecture. Revised manuscript submitted on September 4th 2017 to *Frontiers of Architectural Research*.

In the printed version of the thesis, Papers I-IV are reproduced with the permission of the publishers.

My contribution to the papers included in this thesis was as follows:

I All authors were involved in the writing process. As first and corresponding author, I had general responsibility and performed the majority of the writing for this paper. The study was based on interviews that were originally carried out for a different purpose by the third author. In Paper I, the transcript material was re-analysed with a focus on soundscape. The new analysis and research design was carried out in a joint collaboration in which all authors participated.

II All listed authors participated in discussions concerning the research design. I was responsible for the analysis and for writing the paper. Both co-authors contributed to the writing process.

III As sole author, I was responsible for all parts of this study. The research was based on a landscape design intervention, for which I had the main responsibility for development. The design of the intervention was discussed in an expert group, and the construction was carried out in collaboration with Jitka Svensson, Martin Malmquist and Anders Svensson. The research design was formulated together with Mats Lieberg. I was responsible for data collection, aided on some occasions by Sigrid Lönnerholm. In writing the paper, I received valuable comments from my two supervisors, Carola Wingren and Mattias Qviström, and from statistician Jan-Eric Englund.

IV All listed authors participated in the research design. I was responsible for analysis of the material and for writing the paper. Both co-authors contributed to the writing process. The study was based on three workshops in different contexts, all of which I was responsible for arranging. In two cases, the third author was involved as project leader.

Abbreviations and central concepts

COST	European COoperation in Science and Technology
CRESSON	Le Centre de Recherche sur l'ESpace SONore et l'environnement urbain. An influential research institute for sound and ambience research in architecture, located at the architectural school in Grenoble, France.
dBA	A-weighted decibel levels
EEA	European Environment Agency
END	Environmental Noise Directive
ENM	Environmental Noise Management
EU	European Union
HOSANNA	HOlistic and Sustainable Abatement of Noise by optimised combinations of Natural and Artificial means
ISO	International Organisation for Standardisation
NBHBP	National Board of Housing, Building and Planning [Boverket]
SPL	Sound pressure levels
UN	United Nations
WCED	World Commission on Environment and Development
WFAE	World Forum for Acoustic Ecology
WHO	World Health Organisation

Auralisation	A technique that makes it possible to simulate what a sound environment will sound like (*cf.* Vorländer, 2008). It can be compared to the corresponding term for visual representation of landscapes, visualisation.

Environmental noise directive (END)	An influential directive on noise implemented by the European Union, 2002/49/EC.
Environmental noise management (ENM)	Term used in this thesis to refer to a sound management approach in which the focus is on protection from noise and measurements of sound pressure levels. This approach, which has also been denoted defensive (Hellström, 2002; Amphoux, 1993), is the most established approach (Brown & Muhar, 2004), although the soundscape approach to noise has developed significantly in recent years (see separate heading).
Masking	The introduction of a sound (masker) to reduce the impact from another sound (target sound). There are two different kinds of masking; energetic masking, where the target sound becomes inaudible (or less loud) when the masker is introduced, and informational (or attentional) masking, where the target sound is still audible, but the masker sound shifts focus by drawing attention (Moore, 2012).
Quiet areas	The END (EU, 2002) directive on noise stipulates that member states should map and protect quiet areas. Quiet areas have different definitions and applications depending on context and member state and typically vary between 25 and 55 dBA (*cf.* EEA, 2014).
Soft fascination	A term coined and popularised by Kaplan & Kaplan (1989) (*cf.* James, 1962) as part of their attention restoration theory. It is described as an effortless state of being that can facilitate recovery from fatigue.
Sonic experience	A term used in this thesis to refer to the role sound plays in the everyday experience. The term is broad and includes, among other things, the connection between sound and behaviour and preferences for various environmental sounds.
Sonotope	Emphasises the connection between a certain type of location and the sounds it is likely to produce (Hedfors, 2003). A parallel can be drawn to the concept biotope.
Sound pressure levels (SPL)	A critical parameter in discussions on sound and particularly used in environmental noise management, where it can be calculated or measured. SPL are

	described on a logarithmic scale, decibels (dB), usually A-weighted (dBA) to account for the relative hearing sensitivity of the human ear in different frequency bands. Moreover, SPL often refer to an average (equivalent) value accumulated over a certain period of time.
Soundscape	A broad concept that can have different meanings in different contexts (Schafer, 1994 [1977]), *e.g.* to describe musical compositions, field recordings and art. In this thesis, the concept refers to the everyday experience of the sonic environment. It is defined by the International Organisation for Standardisation (ISO) as the "acoustic environment as perceived or experienced and/or understood by a person or people, in context" (ISO, 2014).
Soundscape action	A tool developed in this thesis for soundscape consideration in landscape architecture and urban design.
Soundscape approach to noise	A term used in the thesis to refer to situations where soundscape thinking is applied in noise exposed situations. The soundscape approach to noise is sometimes referred to as a comprehensive approach, or a soundscape approach, but the longer form is used in the thesis when there is a need to emphasise a noise-exposed context.
Soundscape thinking	A term used in the thesis to describe situations where the experiential possibilities in the sound environment are considered. Soundscape thinking can be used in noise exposed situations, in which case it is akin to the soundscape approach to noise.

1 Introduction

Landscape architecture is inherently related to sound. Whether the context is urban or rural, the shaping of the land has far-reaching consequences for the sonic environment. The sonic environment, in turn, influences people's experiences, health and wellbeing[1].

The relationship between sound and landscape architecture can be further illustrated through appropriation of a metaphor proposed by the Canadian composer R. Murray Schafer (1994 [1977]). Drawing on artistic work by John Cage, Schafer suggests that the everyday sonic environment can be regarded as a major continuously ongoing composition where everyone participates. All sounds – whether they are created by footsteps on a gravel path, noise from a car engine or conversations in a café – would be part of such a composition.

This metaphor is interesting, as it raises the enjoyment of everyday sound as a topic to be discussed. In some contexts, discussions on environmental sounds have been overshadowed by considerations about noise. Problems with noise, while a significant issue, have tended to dominate discussions on sound and, it could be argued, have given it a bad name.

The idea of a musical composition also implies that every environment can be treated as a concert hall. Concert halls are generally given great attention in terms of acoustic furnishings, but what about the everyday composition taking place in ordinary streets, parks and squares? The passive acoustics of such spaces are created, consciously or unconsciously, by the landscape architect. The quality of materials used and spatial solutions determine how sound is distributed in space. Shaping the land thus also involves shaping the passive acoustics or, in other words, the prerequisites for the composition.

[1] This introductory section summarises the background and starting points of the thesis. The connection between sound, humans and the built environment is further elaborated and substantiated throughout the thesis. The research situation is described in sections 1.2, 1.3 and 2.

Furthermore, because landscape architects are involved in decisions that influence where and when different outdoor activities take place, one could even go so far as to suggest that the landscape architect, in a similar manner to a composer, arranges or directs the sonic environment.

Despite the possibilities in landscape architecture to influence the sonic environment, there has been a perception that sound is mostly a concern for trained specialists like acousticians and noise control engineers to deal with. However, the past 15-20 years have seen increased awareness of the possibilities in landscape architecture to consider sound. This development is paralleled by a general interest in sound as a subject for research and design in several disciplines in a wide variety of fields. However, as will be shown in this thesis, there is still a tendency to neglect sound, or at least treat it in a simplified manner in landscape architecture. This is problematic, considering the documented effects that sound has on health and well-being.

Throughout the thesis, it is argued that sound could, and should, be better integrated into landscape architecture and related practices, but that appropriate tools, methods and strategies need to be formulated and made available. The thesis sets out to achieve this through an investigation of the relationship between soundscape thinking and landscape architecture practice.

The overall aim of the thesis was *to facilitate soundscape thinking in landscape architecture*. *Soundscape thinking* is about allowing the *experience* of sound to come forward when thinking about sound-space relationships. As such, soundscape thinking entails problems as well as possibilities.

In the thesis, soundscape thinking has been applied in noise exposed situations, as this was argued to be a good context to reach practitioners. This application of soundscape thinking is denoted *a soundscape approach to noise*[2] in the thesis. Part of the challenge lies in combining two worlds: environmental noise management on the one hand and design discourses and qualitative considerations of sound on the other.

1.1 Sound in landscape architecture

Landscape architecture is a broad concept that includes the design and planning of urban and rural areas. The scale on which the landscape architect works is equally broad. It ranges from designing the individual planting bed in the

[2] This approach has also been referred to as the *soundscape approach* (*see e.g.* De Coensel *et al.*, 2010), or a *comprehensive approach* (in the thesis). The longer form; *a soundscape approach to noise*, is used in the thesis to emphasise noise-exposed contexts, and to avoid confusion with soundscape thinking (which is not necessarily performed in noise exposed contexts).

private garden to laying out the structure of whole cities, or of roads through regions.

The first use of landscape architecture as a professional term to refer to design of outdoor environments can be traced to 1858, when Calvert Vaux and Fredrick Law Olmsted described themselves as landscape architects in their winning proposal for central park in New York (Turner, 1990). The profession itself, although not specifically referred to as landscape architecture, is much older than this, however. Geoffrey and Susan Jellicoe (1995) suggest, for instance, that the first known examples of landscape design appear in cave paintings in France and northern Spain, dating back to between 30,000 and 10,000 BC. Interestingly, it has been suggested elsewhere that these early 'landscape architects' also considered sound. For example, on performing quantitative measures in Lascaux and other caves, Waller (1993) found that the images depicting animals tended to be positioned where the acoustic qualities of the caves would resonate sound, thus making it possible for animals to "come alive".

Similarly to other aspects in landscape architecture, awareness, interpretation and application of sound-space relationships have undoubtedly varied among practitioners, and in different cultures, contexts and eras. It is beyond the scope of this thesis to investigate in detail how sound has been treated in different contexts throughout history. Suffice it to say that there are many interesting examples, ranging from the subtle sonic embellishments of garden design features like *suikinkutsu* in edo-era Japan, through to the mechanical singing birds found in oriental gardens and to the rich and clever use of water features in Renaissance Italy.

It has been argued that, particularly during the modernistic era and onwards, landscape architecture and related professions have failed to pay significant attention to sound (Pallasmaa, 2012 [1996]; Jakobsson, 2009; Hedfors, 2003; Lynch, 1976; Rasmussen, 1964 [1959]). This critique was first raised around the mid-20th century and culminated around the turn of the 21st century. The character and contexts of the publications concerned vary, but there is generally a connection to a broader and more general reaction to modernistic planning and architecture in the Western world, particularly concerning its focus on visual expression in favour of other sensory experiences. This reaction against what has also been referred to as "ocularcentrism" (Pallasmaa, 2012 [1996]) was fuelled in part by contemporary philosophical discourses on modernity and its "hegemony of vision" (*cf.* Levin, 1993). It is argued elsewhere in the thesis that there is scope for some of this critique, but it has tended to be too categorical and has failed to articulate *how* consideration for sound is lacking.

1.1.1 Contemporary challenges in landscape architecture

Contemporary landscape architecture discourses have been increasingly concerned with sustainability and resilience. Questions like efficient land use (densification), green and blue infrastructures, climate threats and the role of natural processes are becoming increasingly important. Sustainability has become established as a significant consideration within the field and there has been renewed interest in the ecological approaches and ideas of the 1960s and 1970s, such as permaculture (Mollison & Holmgren, 1978), urban metabolism (Wolman, 1965) and "design with nature" (McHarg, 1971 [1969]), as well as newer contributions like cradle-to-cradle (McDonough & Braungart, 2002) and landscape urbanism (Waldheim, 2006).

As a broad concept, sustainability includes aspects of social, economic and environmental concerns (WCED, 1987), where it could be argued that sound relates particularly to social sustainability (*cf*. Hedfors & Berg, 2003).

More than half the world's population is now living in urban environments (UN, 2014). While offering many qualities and much stimulation, the urban environment may also be perceived as demanding and stressful, due to *e.g*. attention-demanding stimuli and noise. Nature and nature-like environments have been raised as important spaces for restoration by several researchers in environmental psychology (Hartig *et al.*, 2014; Stigsdotter *et al.*, 2011; Kaplan & Kaplan, 1989; Ulrich, 1984). The sound environment has been identified as a key aspect to provide such tranquil qualities in urban areas, such as parks or pocket parks (Pheasant *et al.*, 2008; Nilsson & Berglund, 2006).

As densification proceeds and activities come closer, there is a challenge to provide calmer areas required for recuperation. Consideration of soundscapes is likely to become more important as space is used more efficiently. Acoustically soft material, for instance, as found in vegetated soil (see *e.g*. Nilsson *et al.*, 2015), can be used to reduce unwanted sounds while at the same time producing other ecosystem services. New physical structures of densified urban spaces, if planned appropriately, can be used as screens that separate city spaces acoustically (Hellström *et al.*, 2013). The increased use of water in retaining systems is also interesting from a soundscape perspective, as water features can provide sound and offer masking capabilities (Brown & Rutherford, 1994).

Technological developments also pose new challenges to soundscape thinking. The increased use of vehicles driven by electricity rather than the combustion engine can reduce the problem of noise. However, the new quiet automobiles can be dangerous if they are not noticed, a fact that has led some manufacturers to incorporate warning sounds as part of their machines. Moreover, at speeds above approximately 30 km/h for light combustion

vehicles and 70 km/h for heavy combustion vehicles, problems with noise are more likely to arise from the connection between tyres and road surface (traction noise), rather than noise related to the engine and propulsion system (Forssén *et al.*, 2015). The problem with traction noise may in turn be reduced by further development and application of quiet road surfaces and improved tyre construction.

1.2 Sonic experience

The role of sound in environmental experiences is multifaceted. The following section shows that sound is a factor to consider, not only in terms of problems with noise, but also in terms of potential.

1.2.1 The nature of sonic experience

Physically, sound is a vibration caused by an activity. The vibrations cause fluctuations in air pressure over time, resulting in sound waves that the human ear can detect (Moore, 2012). One way of interpreting this relationship is that activities speak to us through sound. Sounds are carriers of important information about the environment. Whether they are induced by nature, man or any other source, activities communicate through sound.

In comparison to human sight, which is limited to a field of vision of around 180 degrees, human hearing can perceive sounds from any direction. However, while the eyes have eyelids there is no corresponding mechanism for the ears, which are continually immersed in sound.

To locate sounds spatially, humans rely on a number of perceptual cues and mechanisms[3]. Humans have a good ability to locate sound in the horizontal plane (particularly left-right separation), but less so in the vertical plane (up-down), and poor distance judgement (Moore, 2012). Overall, the ability to locate sound is a useful factor to aid orientation in the environment (not least owing to the ability to hear sounds from any direction). For instance, Schafer (1994 [1977]) proposes the term “soundmark” to correspond with Lynch’s (1960) more visually orientated term “landmark”.

[3] There are several cues and mechanisms that humans use to locate sound sources in space. The specific mechanism varies depending on where in the spatial plane the sound is coming from (Moore, 2012). For instance, in order to distinguish between left and right, the brain makes a calculation based on the difference between the signals that reach the ear on the respective side of the head (interaural time difference and interaural level difference). On the other hand, to distinguish between up/down and front/back, the shape of the pinnae is important (causing frequency coloration that changes depending on the source’s direction).

A number of attempts have been made to explain how the sonic environment can be listened to (Truax, 2001 [1984]; Gaver, 1993; Schaeffer, 1966). A recurring distinction is between active and focused 'listening' and more passive 'hearing' that happens in the background. The attentive state, *i.e*. listening, can be focused on different aspects, for instance physical qualities inherent in the sounds or, as is most common among laypersons (Payne *et al.*, 2009), orientated towards sources. It is popularly argued that perception of sound tends to be unconscious, as in hearing, making it prone to use in subconscious "manipulation" (*cf.* Chion, 1994).

Sound has an ability to stir emotional responses, both positive and negative. The auditory system is connected with the limbic (emotional) system of the brain (Kraus & Canlon, 2012), a fact that can partly explain this. The relationship between sound and emotion is well known and exploited in several fields in society, including music, marketing and film sound.

Sound plays an important role in social communication, the most obvious example perhaps being the sound of speech. In addition to speech, however, there are several other social actions that are communicated through sound, like the sound of movement, of working or of any other everyday activity. The presence of other people can be effectively communicated through sound (Gehl, 2006), an aspect that can be considered in city planning. The sounds from a café or a market, for instance, offer potential qualities that can be located strategically for atmospheric effects (*cf.* Alexander *et al.*, 1977) or to indicate territory (*cf*. Kreutzfeldt, 2009).

The interactive nature of sound should be emphasised, as human beings have the possibility to create sound with their own bodies, as well as through interaction with the surroundings (Thibaud, 1998). A walk on a gravel road in a park, for instance, constitutes an activity that involves a continuous contribution to the soundscape, as well as involving choices relating to how and where to move. The sound of one's own footsteps has been raised as a potential quality that can be emphasised through material choices and other aspects of landscape architecture (Cerwén, 2010a; Hedfors & Westerlund, 2004). The act of walking is interactive, and the sound reinforces and gives feedback on the walker's own movement (*cf*. Pallasmaa, 2006). Moreover, people choose to attend to certain environments, while avoiding others (based on sounds and many other aspects). In other words, perception of sound is not, as is sometimes implied in acoustic disciplines orientated towards the natural sciences, restricted to being a passive activity.

1.2.2 Environmental preference and noise

There have been a number of attempts to divide sounds into categories based on the cause (source) of sound (Aiello *et al.*, 2016; Krause, 2012; Matsinos *et al.*, 2008; Nilsson & Berglund, 2006; Schafer, 1994 [1977]). This thesis uses an established division based on three categories: natural, technological and human sounds (Nilsson & Berglund, 2006). Previous research has shown that, generally speaking, sounds from natural sources are perceived as pleasant, whereas sounds from technological sources are perceived as annoying (Axelsson *et al.*, 2010) and sounds from human beings are somewhere in between. Such categorical preferences vary depending on other factors like physical properties of sound, sound source, personal cues and context (Hong & Jeon, 2015; Ratcliffe *et al.*, 2013; Bjerke & Østdahl, 2004). Moreover, sounds are seldom found in isolation, but in combination with other sounds.

Prominent sounds in the environment can mask the presence of other sounds. For instance, some of the sounds produced by human beings are of a relatively subtle character, which means that social communication can easily be obstructed if the surrounding sound pressure levels are too high (Gehl, 2006). Similarly, other subtle sounds, like sounds from nature, can be masked by noise. This, in addition to negative health effects (Basner *et al.*, 2014), indicates a need for a reduction in sound pressure levels in areas where such issues are important.

The effect of traffic noise in masking out other sonic experiences can perhaps best be understood in the limited numbers of cities, like Venice, where automobiles are absent and the soundscape, as a result, becomes more dynamic. The following description by American landscape architect Lawrence Halprin, recounting his favourite urban experience, provides an example:

> There was no sound - no automobile exhausts, no buses. Absolute quiet in the very heart of a great city. In the distance you could hear faintly some young people singing. All of a sudden the air became dark with birds, the square filled with the beating of thousands of wings, the noise increased and increased until it was deafening, and the deserted square became absolutely filled with pigeons. The noise was incredible - even frightening. They had come to feed, and when they had finished, they left just as quickly, and the great square was empty and quiet again. (Halprin, 1973 [1963], 9)

The dynamic soundscape described by Halprin would be difficult to find in many modern cities, where traffic and other white noise sources raise the ambient noise level.

In addition to preference, noise can influence behaviour. It has been shown that willingness to help other people with small tasks can be reduced if sound pressure levels are high. In a review of such studies, Cohen and Spacapan (1984) suggest that this behaviour change may be due to several probably overlapping explanations, one of which concerns the masking effect of noise on the social situation. Other suggested explanations include induction of a negative state caused by noise, a changed focus of attention and a desire to get away from the noise as quickly as possible.

To complicate matters, however, traffic sounds can be perceived as less annoying in certain urban situations, where they may even be appreciated (Anderson *et al.*, 1983) and/or exciting (Whyte, 1980). It has been proposed that such perceptual variations can be based on how well visual and auditory cues correlate (relating to expectations on the environment). Using three different methods Anderson *et al.* (1983) showed that expectation of the sound environment had an influence on the rating of different audio-visual settings, so that *e.g.* noise from road traffic was the most enhancing sound in an urban setting. The congruence between auditory and visual stimuli was subsequently confirmed in a laboratory setting by Carles *et al.* (1999), and to some extent by Pheasant *et al.* (2010) and Viollon *et al.* (2002).

Viollon *et al.* (2002) argue that there is an additional mechanism that could potentially override audio-visual congruence. Drawing on Björk (1995), they suggest that some perceptual cues (like sounds from other humans) are more attention-demanding, and thus less prone to be dependent on congruence between different perceptual cues. There are also other related factors to take into account, such as context and subjects' expectations on the environment (Hong & Jeon, 2015; Preis *et al.*, 2015; Brambilla & Maffei, 2006). However, it should be pointed out that, in the studies cited above, the purpose (*e.g.* evaluation of tranquillity or aesthetics) and evaluation scale (*e.g.* degree of pleasantness or enhancement) varied to some degree.

Noise has several definitions. In urban planning contexts and within environmental noise management, noise has tended to be defined as unwanted sounds (typically technological sounds), measured in sound pressure levels (dBA). This would seem like a rather straightforward definition. However, as Hellström (2003) argues convincingly, perception of noise can vary, and what is noise for one person in one context may not necessarily be noise in another context, or for another person. In addition, findings from studies like that conducted by Anderson *et al.* (1983) and observations by Whyte (1980) support the importance of contextualising and problematising noise treatment. There is a need for better understanding of the perceptions of noise in planning situations.

1.3 Health effects

1.3.1 Negative health effects

Much previous research concerning the effect of sound on human beings has been concerned with understanding and mapping health effects related to noise exposure. There is now a convincing body of available research that shows correlations between noise exposure and negative health effects (Basner *et al.*, 2014; Stansfeld *et al.*, 2000; WHO, 2000).

Exposure to noise can damage the auditory system and cause hearing loss and tinnitus. Exposure to noise has also been shown to cause non-auditory negative effects on health, like sleep disturbance, annoyance, cardiovascular disease and hypertension. Furthermore, there is a connection between noise exposure and problems with mental health (Beutel *et al.*, 2016). The World Health Organisation (WHO) has estimated that the combined burden from noise pollution in the European Union amounts to somewhere between 1.0 and 1.6 million Disability Adjusted Life Years (DALYs) annually (WHO, 2011).

In addition to negative effects on health, exposure to noise reduces environmental quality (Yang & Kang, 2005) and has been shown to reduce subjects' willingness to help other people (Cohen & Spacapan, 1984).

1.3.2 Positive health effects

The negative effects on health are well documented, while it is only quite recently that research has started to investigate the potential for positive effects. This strand of research has typically looked into the possibility that sounds of nature, such as sounds from birds, vegetation or water, can reduce stress levels (for a review, see Hägerhäll *et al.*, 2017). Given the dominant focus on natural sounds, this approach is also related to research in environmental psychology that has identified links between experience of nature and recovery from stress (Stigsdotter & Grahn, 2003; Kaplan & Kaplan, 1989; Ulrich, 1984).

Growing numbers of studies have found that sounds of nature can play a part in recovery from stressful situations. In a laboratory study where subjects were exposed to a psychological stressor (Alvarsson *et al.*, 2010), it was found that a nature sound played at 50 dBA increased recovery speed in comparison with exposure to three different types of noises (varying between 40-80dBA). Similarly, Annerstedt *et al.* (2013) found that subjects recovered faster after stress when exposed to virtual reality nature with nature sounds, in comparison with virtual reality nature without nature sounds. In a study investigating the

restorative potential of different soundscapes, Medvedev *et al.* (2015) found that, in addition to recovery from stress, positive experience of sounds could also reduce arousal in subjects at rest.

In healthcare, nature-based sound therapy is a method whereby sounds from nature are played through speakers with the aim of reducing negative experiences associated with treatments in difficult situations. Nature-based sound therapy has been studied in practical situations and shows good effects in reducing pain (Diette *et al.*, 2003), as well as anxiety and stress (Saadatmand *et al.*, 2013).

To sum up, research thus far indicates that there is a relationship between exposure to nature sounds and positive health effects relating to healing processes in certain situations. However, a better understanding is needed of this relationship in terms of contextual cues, types of sounds involved, physical properties of sounds and interactions with other sensory inputs (*cf.* Hägerhäll *et al.*, 2017).

1.4 Reflection: A relevant pursuit

The above review illustrates how sound is a factor in environmental experience and has a bearing on health. It also shows that sound can have positive or negative effects in influencing environmental preference, wellbeing, environmental interaction, social communication and health. Moreover, sonic experience is complex and dependent on several different factors, including sound sources, physical properties of sound, personal cues and contextual cues.

Noise exposure from technological sources can be associated with negative health effects, as well as reduced environmental experience and infringement on social interaction. Noise reduction would thus seem like a pertinent undertaking in most cases, not least by allowing other, more subtle sounds to emerge. In some cases, however, noise can be perceived as an urban quality, underlining the importance of considering context.

In the remainder of this thesis, the sound-related outcomes described above, and particularly problems with noise, constitute a basis to formulate strategies for environmental design, where problems with noise can be addressed as part of design solutions. Ultimately, the thesis presents a set of strategies and tools by which landscape architects can consider sound in the design of outdoor environments.

2 Positioning of the thesis

The following section outlines and describes prevailing traditions pertaining to landscape architecture and sonic research. This is used as a foundation to position the thesis and to formulate the aim and methods (see section 2.4).

The description of the field starts with a practice-orientated perspective and outlines two traditions of sonic treatments in environmental design (section 2.1): *environmental noise management* and *the design tradition*.

The focus then shifts to a description and review of some of the sonically orientated research traditions for addressing sound in and around architectural disciplines (section 2.2). This review outlines four traditions; *sound studies, the soundscape movement/acoustic ecology, the soundscape approach to noise* and *sound research in architectural disciplines*. This is followed by a reflection and positioning of the thesis in relation to these traditions (section 2.2.5).

A more detailed review of previous research, particularly focusing on practice-orientated work, is provided in section 2.3.

2.1 Two sensory traditions

According to Lynch (1976), when it comes to treatment of sensory aspects in urban planning, two general approaches or traditions can be discerned. On the one hand, there is the environmental protection tradition, which for sound corresponds to *environmental noise management*. This tradition is the newer of the two, and for sound, it has been influential from around the 1970s in the Western world (Goldsmith, 2012). On the other hand, there is the *design tradition* which, according to Lynch (1976), is the older of the two and is concerned with the qualitative and experiential aspects of sensory input. The design tradition can be traced to classic architecture and landscape design.

Below, Lynch's two traditions are used as a framework to outline how sound is treated in and around landscape architecture. The environmental noise

management tradition is characterised by a quantitative approach to sound, and its practice relies on trained professionals in acoustics (Bild *et al.*, 2016a). Yet landscape architects are likely to be involved in environmental noise management to various extents, for instance in environmental impact assessments for infrastructure developments.

The design tradition is more diverse and its development stretches over a longer period. In order to outline the contemporary design tradition and illustrate how the field has developed over time, a review of seminal publications in the field between 1959 and 2012 was conducted.

2.1.1 Environmental noise management

It would be rather safe to suggest that noise, as in unwanted sound, has always existed. The first known example of noise regulation, for instance, is said to be from around 700 BC, when the province of Sybaris in Greece ordered that tinsmiths, potters and other noise-generating tradesmen were to live outside the city walls (Goldsmith, 2015).

Societies are continuously changing; old practices are abandoned, while new are developed. People change their habits and make use of new technical devices. This is also reflected in the soundscape. Much of what is considered noise today can be traced to the industrial and electrical revolutions of the past 200-300 years, particularly white noise from infrastructure. While critical voices were raised quite early against the new soundscape associated with these rapid developments, it was not until the post-war era that environmental noise policies to address the issue began to be developed in the Western world. The first legislation to specify maximum sound pressure levels for traffic was implemented in Chicago in 1957 (Goldsmith, 2012). In the 1970s, as part of the influential environmental protection movement of the time, national policies for environmental noise started to become established in the Western world. From around that time, noise also began to be considered a major problem that urban planners were obliged to deal with (Raimbault & Dubois, 2005).

Environmental noise management is today supported by well-documented research on negative health effects (Basner *et al.*, 2014) and is grounded in large international organisations such as the WHO and the European Union (EU). Noise from different sources, such as aeroplanes, trains, road traffic and industry, is regulated in public policies on national and regional level. In general, there are two stages that can be discerned in environmental noise management: a diagnostic phase and a prescriptive phase (Bild *et al.*, 2016a; Gaver, 1988). The diagnostic phase involves measurements, calculations and

mapping of noise to gain an understanding of the prevailing situation. The resulting diagnosis is then used as a starting point for the prescriptive phase, in which counteractions, such as stricter regulations, noise screening or zoning, are formulated.

In 2002, the EU implemented a new directive, commonly referred to as the Environmental Noise Directive (END), which aims to define a common approach for environmental noise management for member countries (EU, 2002). The directive has three objectives: determination of exposure through noise mapping; information to the public; and adoption of action plans. The directive is noteworthy as, in addition to focusing on noise, it also emphasises the mapping and preservation of what are referred to as "quiet areas", which has opened the way for new applications relating to soundscape thinking (Bild *et al.*, 2016a; EEA, 2014; Brown, 2010b).

Environmental noise management has been criticised as being too focused on sound pressure levels and failing to provide a nuanced understanding in which the actual experience of sound is given due recognition (Hedfors, 2003; Hellström, 2003). It has also been argued that environmental noise management focuses mostly on residential areas and how sounds are perceived from within dwellings, but fails to consider outdoor environments (Brown & Muhar, 2004).

Sound pressure levels constitute the basis in environmental noise management but, as the reviews in sections 1.2 and 1.3 illustrate, there are many other factors to consider. Lynch (1976) argues for integration of the environmental protection tradition and the design tradition. Such integration has been initiated in recent years, as exemplified in *the soundscape approach to noise* tradition (Section 2.2.3). Further development of the relationship could aid the overall perspective and lead to technical solutions that are grounded in design aesthetics.

2.1.2 Sonic treatments in the design tradition: A review of seminal publications in landscape architecture

Tracing sound in design thinking requires a nuanced understanding in which account is taken of different approaches and ways of thinking, as well as changes over time. In order to provide such an understanding, a review of seminal publications in landscape architecture and related design disciplines was carried out and the results are summarised below. The review is based on publications that are regarded as classics within Swedish landscape

architecture[4]. The review focuses on *how* sound has been treated in the different publications (rather than evaluating the extent of treatment). In addition, the review pinpoints descriptions *about* how sound is treated within the field, particularly focusing on a recurring critique of the discipline's presumed visual focus in different eras (see also section 1.1).

It should be noted that a review of this kind provides an academic perspective that is not necessarily reflected in the practice of landscape architecture and design. However, because several of the authors are involved in practice, discuss practice and/or are orientated towards practice, the review is also informative for the latter purpose.

The publications reviewed date from 1959 to 20012 and, in order to indicate any changes over time, are reviewed here in chronological order.

Incidentally, the first publication to be reviewed is not from landscape architecture, but it is included here as it has been influential in the field, not least in terms of how sound is approached. Within housing architecture, one of the first publications to raise sound in the Nordic context was "*Experiencing Architecture*" by Danish architect Steen Eiler Rasmussen (1964 [1959]). It criticises the modernistic movement through what could be described as a celebration of architectural experience. In the final chapter, entitled "Hearing architecture", Rasmussen writes convincingly about the sound of architecture, and how it is possible not only to see, but also to hear architecture:

> Can architecture be heard? Most people would probably say that as architecture does not produce sound, it cannot be heard. But neither does it radiate light and yet it can be seen. We see the light it reflects and thereby gain an impression of form and material. In the same way we hear the sounds it reflects and they, too, give us an impression of form and material. (Rasmussen, 1964 [1959], 224)

That statement, and the chapter as a whole, suggest that sound was not a normal consideration for architects at that time. While there was an existing tradition to consider sound in special contexts, like concert halls, this was not a concern in everyday architecture. Furthermore, treatment of sound in concert halls was handled by acousticians rather than architects, but Rasmussen describes how architects could also benefit from consideration of sound.

[4] The selection is based on publications regarded as classics within the field at the author's Department. The publications were selected based on course reading lists, recommendations and discussions with lecturers and researchers at the Department. They may not necessarily correspond to perceived classics in other parts in the world, and influential works may have been excluded.

Gordon Cullen's treatment on city planning, "*The Concise Townscape*" (Cullen, 1971 [1961]), is perhaps most famous for its sketches depicting the progression of vistas as they develop while moving. In the presentation of his three arguments, serial vision, relative positions and architectural fabric, Cullen uses an approach akin to phenomenology, yet focuses on vision: "We turn to the faculty of sight, for it is almost entirely through vision that the environment is apprehended." (Cullen, 1971 [1961], 8). Nevertheless, as also noted by Hedfors (2003), Cullen makes reference to other sensory impressions, including sound. However, these references tend to be used as descriptions that reinforce the visual experience, rather than being reflections in their own right. In terms of sound, Cullen mentions the contrast between noise and relative silence, as well as echoing footsteps.

In "*Cities*" from 1963, American landscape architect Lawrence Halprin (1973 [1963]) writes about some basic components of cityscapes, such as street furniture, city floors and spatiality. The approach is clearly grounded in what would now be called a phenomenological approach, and Halprin discusses, for instance, the choreography of cities and the sensory experiences in urban gardens as a contrast to the sometimes "overwhelming scale and density of urban living" (Halprin, 1973 [1963], 37). Halprin makes great use of vivid descriptions of sonic experiences, particularly in a section of the book that describes water features: "Water has sounds as well. It gurgles, it splashes. It goes plop, plop, plop. And fshzzzsh. And spaatzzz!" (Halprin, 1973 [1963], 143). In this way, Halprin connects to a long tradition of acknowledging sensory qualities in water features. While he does not go into any detail about how specific characters of sounds are to be created, his use of onomatopoetic language suggests tacitly that such decisions could be made.

In 1969, Ian McHarg published "*Design With Nature*" (McHarg, 1971 [1969]), which would become an influential source in the field, not least for the ecological movement that followed in the 1970s. The publication is well known for its use of overlay maps as a way to understand and analyse landscapes. McHarg shows, among other things, how sound pressure levels could constitute one such map layer. A development of his method of overlaying maps is potentially useful as a way for landscape architects to understand and work with experiential qualities in sound, as illustrated by the application of the method suggested by Hedfors (2003). The technique is now established in various digital platforms, such as GIS. McHarg's book would be classified as landscape planning, yet it is interesting how he, in a similar way to Halprin in "*Cities*", makes use of rich descriptions of sonic experiences in the introductory chapter, thus suggesting that his arguments are rooted in the human scale.

In 1969, when reporting on a pioneering study on sounds in urban environments (see section 2.2.4), Michael Southworth (1969) described a profession relying on "the eye alone" to design urban environments, a situation which he considered particularly problematic given the noisy technological developments of the time: "it seems that even before attempting sonic design, it will be necessary to confront the problem of existing city noise" (Southworth, 1969, 67). This statement implies that noise treatment and sound design are two separate entities for Southworth, thus supporting Lynch's (1976) previously discussed observation of two distinct traditions.

Jan Gehl's "*Life Between Buildings*", which explores social life in cities, was first published in Danish (Gehl, 1971). In a section devoted to "Seeing, hearing and talking", Gehl raises the sound environment as an important prerequisite for social communication. He proposes that it is particularly difficult to communicate verbally in environments which are exposed to background noise of around 60dBA or more, but calls for significantly lower levels, around 40-50 dBA (in subsequent publications adjusted to 45-50 dBA), if subtle sounds like footsteps, soft voices or street musicians are to be heard. Gehl goes on to raise a number of experiential benefits that come from excluding traffic in urban areas, and mentions Venice and other quiet cities/areas as examples.

Kevin Lynch is perhaps best known for his visually orientated analysis and description of mental and conceptual images in "*The Image of the City*" (Lynch, 1960). In "*Managing the Sense of a Region*" (Lynch, 1976), he incorporates a different perspective when he discusses how the "sensuous" qualities of regions can be managed, *i.e*. the phenomenological experience. The approach is grounded in a critique of planning practice, which in Lynch's view has a tendency to forget about sensuous qualities. He suggests that the reason could be that such aspects are considered "too obvious to dally over or, if not obvious, then trivial – too unpredictable and too personal to be part of any public discussion." (Lynch, 1976, 3). Lynch goes on to argue the relevance associated with consideration of the sensuous, proposes a number of norms for implementation and discusses different aspects of the planning process in relation to this.

In a broad publication on architecture and urban planning entitled "*A Pattern Language*", Alexander *et al.* (1977) present a comprehensive list of 253 "patterns" or solutions to design situations that they refer to as a new language for designers. Sound is mentioned in several of the 253 patterns, including the quality of sound in "quiet backs", and the role of sound in "entrance transitions". The atmospheric presence of sound is a recurring theme,

and one which it is proposed can be designed through consideration of concrete actions like the relative location of functions.

From 1970 onwards, William H. Whyte led a small research group that conducted a number of social observations in New York, the results of which are published in "*The Social Life of Small Urban Spaces*" (Whyte, 1980). Based on the observations, and akin to Gehl's (1971) "*Life Between Buildings*", Whyte describes a number of relationships between social behaviour and the urban fabric. In terms of sound, and in contrast to Gehl's argumentation, Whyte's report finds a positive correlation between urban noise and social quality. Whyte argues that "where there is the most noise and pollution", there is also "the most action to look at" (Whyte, 1980, 72). Another noteworthy example is Whyte's description of the rather loud waterfall in Paley Park in New York and the way this functions to mask out the noise from the surrounding city. Whyte argues that the sound of the waterfall, in addition to producing pleasant associations, offers a sense of privacy, as it is difficult to hear other people in the vicinity. A similar observation has been made in Japan, where the loud background sound in popular *pachinko* halls excludes people from holding conversations (Ogawa & Cerwén, 2016), thus producing a sense of privacy.

Written as a resource for new landscape architects, Norman Booth's "*Basic Elements of Landscape Architectural Design*" (Booth, 1983) describes some of the central components in landscape architecture in an insightful manner. In a section on water, Booth discusses the sound of water features and how changes in movement and volume can be used to control the character of the sound, thus supporting the desired "visual aspects of an outdoor space" (Booth, 1983, 256). Booth also discusses the relationship between human emotions and the character of water sounds, and mentions how the "rhythmic motions of waves against a shoreline may be quiet and peaceful, while the roar of a waterfall may be motivating" (Booth, 1983, 256). Booth also illustrates how water sounds can be used as a masking element in urban areas and raises a few examples, including the above-mentioned Paley Park in New York and Freeway Park in Seattle, Washington.

In a 1988 publication entitled "*The Poetics of Gardens*", American architects Charles Moore, William Mitchell and William Turnbull describe and analyse historical gardens from a designer's perspective. There are several references to sound throughout the publication, and a short section entitled "Filling with sound" in the first part is also devoted to the topic. In this section, the authors acknowledge that, through garden design, sounds can be either "attenuated or intensified" (Moore *et al.*, 1988, 40), and mention biotopes for birds as an example by which to intensify. They go on to describe how

associations can vary depending on the specific sonic character of different water features, or the sound of wind in different trees.

In "*The Language of Landscape*" (Whiston Spirn, 1998), American landscape architect Anne Whiston Spirn writes about the relationship between humans and their habitat – the landscape. Spirn suggests that landscapes have a language that it is possible to read and write, the skills of which are dependent on the sensory apparatus. Spirn's descriptions of landscapes are based on a language which is rich with references to sound, and the subtle qualities that can be related to it. The following passage is from a section dedicated to the sensual and dynamic qualities of matter and illustrates how differences in sonic qualities can contribute to define a space:

> The courtyard of the hotel de Sully in Paris is a garden cloistered between the raucous Rue de Saint Antoine and the stately Place des Vosges, quiet, protected from street noise by massive stone buildings. Birds bring the space alive, chirping from within ivy on the walls, hidden but for their sudden flitting and the moving leaves. (Whiston Spirn, 1998, 97).

In another context in the same publication, Spirn (1998) describes how water sounds can be used to mask traffic noise and mentions the waterfall in Paley Park as an example. Spirn also describes a personal experience of how a speaker installation in Parc de La Vilette influenced her in such a way that the borders between music and environmental sounds became blurred.

In "*The Eyes of the Skin: Architecture and the Senses*" (Pallasmaa, 2012 [1996]), Finnish architect Juhani Pallasmaa applies a phenomenological perspective to discuss architectural experience from a multisensory perspective. He describes the contemporary practice as being visually focused and draws on various sources from the arts, philosophy and phenomenology to argue for what could be described as an aesthetics of the senses. In a section devoted to sound, entitled "Acoustic intimacy", Pallasmaa discusses the atmospheric and enveloping character of sound. The role of sound in architectural experience, he argues, constitutes an important, yet forgotten, feature, as sound has the potential to communicate directly between space and user in an interactive manner. Pallasmaa believes that "a space is understood and appreciated through its echo as much as through its visual shape", but that "the acoustic percept usually remains as an unconscious background experience." (Pallasmaa, 2012 [1996], 50). Pallasmaa goes on to formulate a short critique of the modern city and its inability to offer sonic experience: "The wide, open spaces of contemporary streets do not return sound, and in the interiors of today's buildings echoes are absorbed and censored. The

programmed recorded music of shopping malls and public spaces eliminates the possibility of grasping the acoustic volume of space. Our ears have been blinded." (Pallasmaa, 2012 [1996], 51).

Similar criticisms of the visual aesthetics have been made, in various contexts, from the turn of the millennium onwards. In a discussion on the aesthetics of atmospheres and acoustic ecology, German philosopher Gernot Böhme argues that "city planning can no longer be content with noise control and abatement, but must pay attention to the character of the acoustic atmospheres of squares, pedestrian zones, of whole cities" (Böhme, 2000, 16). Hedfors (2003) speaks of a visual (landscape architect) profession and Hellström (2003) notes that architecture is commonly regarded as being about static materials rather than "the immaterial". Degen (2008) describes how modern planning has a way of discouraging experience and sensual variation in cities, while Botteldooren *et al.* (2008) describe a field that, up to that time, had been visually focused. Furthermore, Botteldooren *et al*. (2008) argue that even though environmental noise management is regarded as a "good" approach, it has not been successful in all aspects and requires creative strategies as complements.

In parallel to the growing criticism of the visual focus in the discipline, which culminated around the turn of the century, it is possible to discern increasing interest in what has been called "the immaterial" in landscape architecture and related disciplines. At that time, architectural discourses started to pay more attention to aspects such as phenomenology (Pallasmaa, 2012 [1996]; Pallasmaa, 2009; Holl *et al.*, 2006; Seamon, 2000), atmospheres (Thibaud, 2011; Böhme, 2010; Zumthor, 2006; Böhme, 2000) and sensory impressions (Jakobsson, 2009; Degen, 2008; Barbara & Perliss, 2006; Ionides & Howell, 2005; Zardini, 2005; Malnar & Vodvarka, 2004). Research specifically dealing with sound in architectural disciplines was also conducted at that time, the development of which is reviewed elsewhere in this thesis (section 2.2.4).This development is to some extent reflected in more recent literature in landscape architecture.

Landscape urbanism can be described as a discourse or collection of ideas (Thompson, 2012), the formulation of which was initiated during the 1990s and popularised in the influential publication "*The Landscape Urbanism Reader*" (Waldheim, 2006). One of the main ideas in landscape urbanism is that cities should be considered as processes, *i.e*. landscapes, rather than as individual buildings, a view clearly related to ecological thinking. The landscape architect's working methods have been raised as another (and closely related) issue in landscape urbanism. Sound does not emerge as a significant concern in "*The Landscape Urbanism Reader*", but it is mentioned

in relation to video representations of landscapes as discussed by Christophe Girot:

> It is important to reconsider the perceptual limitations that pertain to landscape thinking in general. Why, for instance, has movement remained so marginal in our visual and sensitive assessment of urban environments? Aren't the fleeting sounds of the city just as significant as the tweet of a bird [sic] in our appreciation of a given place? (Girot, 2006, 96)

Catherine Dee's "*To Design Landscape*" (2012) is a practically orientated publication for landscape designers, including the formulation of design principles and strategies, as well as a number of illustrated sample projects. One of the design principles, denoted "Elemental register", is concerned with nature connectedness. Dee exemplifies how such connections can be enhanced by "engaging multiple senses in addition to sight" to emphasise processes in the landscape:

> For example, a plant will be chosen because its leaves amplify the sound of rain. A poplar might be selected for the way its canopy flutters in the slightest of breezes. Orchestrating stones of differing shapes to manipulate flowing water will heighten sounds and eddies. Conserving a tree that might otherwise have been removed in construction leads to the continuance of birdsong. (Dee, 2012, 57)

Furthermore, several of the example projects chosen for the publication are known for their soundscape thinking, such as "Paley Park", "A sound garden" and "Cylinder sonore". Yet, surprisingly, the soundscapes of these gardens are not discussed in the contexts where they are raised.

Reflections on the review

Having studied some of the most influential writings in landscape architecture through a sonic perspective, a few general trends can be discerned.

First, sound is rarely the primary focus in any of the publications orientated toward landscape architects. Few have dedicated more than a short section to sound. Instead, when sound is mentioned, it tends to be in *ad hoc* situations, and sometimes (particularly in the earlier publications) as part of a description of visual experience. One way of interpreting this is that it could, to some extent, be representational of the way in which the environment is perceived, where sound constitutes one aspect of several interrelated stimuli experienced simultaneously. Or, as the French composer Michel Chion describes the nature

of an everyday (multi-sensory) experience in "*Audio-Vision – Sound on Screen*":

> It is morning; I open the shutters of my bedroom window. All at once I am hit with images that stun me, a violent sensation of light on my corneas, the heat of the sun if it's a nice day out, and outdoor noises that get louder as the shutters open. All this comes upon me as a whole, not dissociated into separate elements. (Chion, 1994, 112)

A second point, which is closely related to the first, is the fact that few of the early publications elaborate in a detailed manner on how sonic qualities can be designed. While there are several examples of rich sonic descriptions throughout the period, there are few detailed explanations that investigate the relationship between concrete design actions and their potential effect on the soundscape. It seems that several of the authors are intuitively aware of such relationships, but they are not formulated until around the 1980s. This could suggest that knowledge about sound was not sufficiently developed in order to formulate design recommendations, or that it was not prioritised. Another possible explanation is that sound is part of tacit knowledge among designers and/or there are difficulties in representing soundscapes.

Third, noise is a recurring theme, predominantly raised as a problem. Descriptions of how landscape architects could consider noise in their *designs* are lacking, however. Problems with noise seem to be mostly perceived as a problem for acousticians to deal with. Some of the more recent publications raise the possibility of landscape architects working with acoustics. Masking is a recurring theme, particularly from around the 1980s, and tends to be described as a rather straightforward effect. Potential problems and limitations with masking are not raised, however.

To sum up, the review of seminal publications in the field suggests that sound started to become increasingly recognised as a significant issue during the 1970s and 1980s, but that prior to this, it was mostly present as tacit knowledge that was described *ad hoc* or as part of a "visual" experience. The review confirmed, to some extent, the previously mentioned critique of the field as being visually focused, but it also suggests that much of this critique was unnuanced. There have been several interesting examples of sound treatment in the field, yet there has been a lack of articulations of the role of sound, at least until around the turn of the 21st century. In addition, the review suggests that the connection between landscape architecture and environmental noise management could be further developed.

2.2 Sonic research traditions

Studies on sound exist in all of the three major research cultures (natural sciences, social sciences and humanities), yet the approaches and purposes differ. For instance, sound is studied in all of the following, yet significantly different, fields: psychoacoustics, acoustics, communication, music psychology, art and film sound. These are also examples of fields that were important in informing the present thesis work. In the review that follows, however, the focus is on research traditions dealing directly with the relationship between sound, humans and the built environment.

For the purposes of this thesis, a division was made into four traditions: *sound studies; the soundscape movement/acoustic ecology; the soundscape approach to noise*; and *sound research in architectural disciplines*. The review is followed by a reflection and positioning of the thesis in section 2.2.5 and a more detailed review related to this in section 2.3.

2.2.1 Sound studies

Sound studies constitutes a broad and interdisciplinary academic field, where the common denominator is the understanding of sound and sonic practices in society. Since its initial development in the late 1990s, sound studies has seen different delimitations and definitions and has also been referred to as *e.g. auditory culture* (Back & Bull, 2003) or *hearing culture* (Erlmann, 2004). Pinch and Bijsterveld (2004, 636) describe sound studies as "an emerging interdisciplinary area that studies the material production and consumption of music, sound, noise and silence and how these have changed throughout history and within different societies". Sound studies could be regarded as a subcategory of the even broader field of *sensory studies* from which it, at least partly, evolved (Pinch & Bijsterveld, 2012a).

Sound studies focuses on sound and sonic practices in society and deals with a wide variety of topics, including sound art, urban soundscapes, media, musicology, listening cultures, historical soundscapes, the history of sonic practices and politics (*cf.* Gandy & Nilsen, 2014; Sterne, 2012b; Back & Bull, 2003). Sound studies may, in this sense, be regarded as an umbrella term. The field is also concerned with the interplay between topics, as in the mutual relationship between music and soundscapes (Papenburg & Schulze, 2016). Publications in the field include "*Auditory Culture Reader*" (Back & Bull, 2003), "*The Oxford Handbook of Sound Studies*" (Pinch & Bijsterveld, 2012b),

"*The Sound Studies Reader*" (Sterne, 2012b) and "*The Acoustic City*" (Gandy & Nilsen, 2014).

Sound studies is interesting, not only through its contribution to an increased understanding of sound in society, but also through its different approach to understanding society (from a sonic perspective). In other words, sound studies is interesting from an epistemological perspective, as it can partly be understood as an 'alternative' analytical approach through which society can be understood. Jonathan Sterne, for instance, speaks about sound studies as an "interdisciplinary ferment in the human sciences that takes sound as its analytical point of departure or arrival" (Sterne, 2012a, 2). Holger Schulze (2016), similarly, argues for "sonic epistemologies" in science.

Sound studies may, in this sense, be regarded partly as an epistemological counter-reaction to previous shortcomings in understanding society from a sonic perspective in the human sciences (*cf.* Schulze, 2016; Pinch & Bijsterveld, 2012a). Sound studies may also be regarded as "an intellectual reaction to changes in culture and technology" (Sterne, 2012a, 3) or changes in the way academia thinks about, and organises, disciplines (Sterne, 2012a).

Several of the topics that are dealt with in the present thesis relate to sound studies, or are considered part of sound studies in some contexts. These topics include *urban soundscapes*, *acoustic ecology* and *soundscape design*.

2.2.2 The soundscape movement and acoustic ecology

Research on soundscape was first initiated in the late 1960s (see *e.g.* Truax, 1974; Schafer, 1970; Schafer, 1969; Southworth, 1969; Schafer, 1967). Its development is usually associated with Canadian composer Murray R. Schafer and his colleagues in the World Soundscape Project, which he led from 1969 onwards. While previous attention to the sonic environment had tended to focus on how to protect people from noise, this new branch of studies started instead to explore the potential and qualities inherent in the sonic world.

One of the original intentions behind this undertaking was in fact to address the same kind of problem as environmental noise management around the same time, but from a different angle. Instead of considering sound as something negative, the soundscape movement sought to present the sonic environment as positive, and thus also worthy of protecting from noise. It was argued that this path would stir a wider interest than environmental noise management had done by that time. Schafer writes:

> Noise pollution results when man does not listen carefully. Noises are the sounds we have learned to ignore. Noise pollution today is being resisted by

> noise abatement. This is a negative approach. We must seek a way to make environmental acoustics a positive study program. Which sounds do we want to preserve, encourage, multiply? When we know this, the boring or destructive sounds will be conspicuous enough and we will know why we must eliminate them. (Schafer, 1994 [1977], 4)

The origin of the concept 'soundscape' is somewhat unclear. The term is commonly attributed to Schafer around the time of the World Soundscape Project's initiation in 1969. However, it was also used by Southworth in connection with a contemporary project in Boston, the findings of which were published in 1969 (Southworth, 1969). Schafer has since attributed the concept to Southworth (Darò, 2013; Sterne, 2013). However, the term had been used prior to this on an occasional basis in various publications, dating back to the 1930s, according to a search in Google Ngram.

The most influential source to date when it comes to soundscape research is undoubtedly the 1977 publication by Schafer, "*The Tuning of the World*" (Schafer, 1994 [1977]). It comprises a collection and organisation of Schafer's work, covering among other things the findings from the World Soundscape Project. In "*The Tuning of the World*", Schafer proposes how the soundscape can be approached, understood and developed, and introduces a number of methods and concepts to do so. Schafer's standpoint in this undertaking can be criticised as being conservative and normative, as he is clearly favouring rural, natural and historical soundscapes over urban and modern correspondents (*cf*. Hellström, 2003).

Other influential publications related to the World Soundscape Project include the "*Handbook for Acoustic Ecology*" (Truax, 1978), which is essentially a dictionary of acoustic terms and definitions. It was edited by composer Barry Truax, who also authored "*Acoustic Communication*" (Truax, 2001 [1984]). It introduces what Truax calls "a communicational approach" to understanding the sonic environment. This approach could be regarded as an elaboration and adaption of the soundscape discipline into acoustic ecology (Hedfors, 2003). Like ecology, the communicational approach emphasises the interaction between the listener and the surrounding environment (through sound). This interactive understanding of sound also acknowledges the active part that the listener can take, for instance, in creating sound. Truax also introduces a series of distinctions and conceptualisations.

A collection of international approaches on how to study soundscape, "*Soundscape Studies and Methods*" (2002), edited by Helmi Järviluoma and Gregg Wagstaff, was published in Finland in 2002. It covers a variety of predominantly European approaches, as well as a contribution from Japan

describing some of Keiko Torigoe's work in Tokyo and the Kanda soundscape project (Torigoe, 2002). The soundscape tradition was established in Japan in the 1980s and included early applications of soundscape design (Torigoe, 2007), as well as studies on the meaning of soundscapes (as in the Kanda soundscape project) (Hiramatsu, 2006).

Soundscape is described in "*The Tuning of the World*" as a rather broad and interdisciplinary term that may be employed in different contexts, varying from musical compositions and radio programmes to the outdoor acoustic environment (Schafer, 1994 [1977]). This broad way of defining soundscape was intentional by Schafer, as he sought to stimulate the formulation of an interdisciplinary field:

> It devolves on us now to invent a subject which we might call acoustic design, an interdiscipline in which musicians, acousticians, psychologists, sociologists and others would study the world soundscape together in order to make intelligent recommendations for its improvement. (Schafer, 1994 [1977], 4)

Today, soundscape is indeed studied, not in one but in several interconnected fields of research. In 1993, an organisation to coordinate soundscape research was formed, known as the World Forum for Acoustic Ecology (WFAE). It followed in the same tradition as the World Soundscape Project, as members from the original World Soundscape Project were also involved in forming the WFAE. The latter describes itself as "an international association of affiliated organizations and individuals in Europe, North America, Japan, and Australia that share a common concern with the state of the world's soundscapes." (WFAE, 2017). Similar to the standpoints described by Schafer in "*The Tuning of the World*", WFAE takes a clear stand against noise from modern and urban developments. Starting in 2000, WFAE publishes *Soundscape: The Journal of Acoustic Ecology*.

The term soundscape is used in several other contexts besides the everyday sound environment, including sound art, field recordings and music. In such contexts, the term seems to be used particularly when there is a need to emphasise a contextual experience of sound. The different meanings of soundscape, while beneficial in some respects, can also cause confusion. For instance, there seems to be an understanding among some professionals working with environmental noise management that soundscape research is concerned predominantly with positive aspects of the sonic environment (like masking). This understanding might be related to the many parallel uses of the term soundscape (many of which are found in the arts). In the present thesis, soundscape is used to refer to the overall experience of the acoustic

environment or, as it is defined by the International Organisation for Standardisation (ISO), an "acoustic environment as perceived or experienced and/or understood by a person or people, in context" (ISO, 2014).

2.2.3 The soundscape approach to noise

For the soundscape movement, noise was a central concern already at the beginning of the 1960s. Even though it was their focus on experience of sound that received the most attention, noise was an important agenda too. For Schafer (1994 [1977]), there was a dichotomy between noise, on the one hand, and sound quality, on the other. These were considered to be opposite poles that could not be combined and were referred to as lo-fi and hi-fi soundscapes respectively. In "*The Tuning of the World*", Schafer (1994 [1977]) argues strongly against elevator music, muzak and similar strategies that try to mask noise with "more sound". Thus it is ironic that the soundscape concept is used sometimes in environmental noise management as a way to refer to masking strategies.

Somewhere around the 1990s, soundscape thinking started to become increasingly incorporated into previously established areas focusing on negative effects of noise[5] (*cf.* sections 1.3 and 2.1.1 of this thesis). While the negative effects caused by noise were relatively well-documented at this time, little research had problematised the field significantly and investigated to what extent negative effects could be compensated for by other cues. As argued by van Kamp *et al.* (2016) in a general discussion on human response to noise, the negative health effects can be related to acoustic factors, like sound pressure levels and frequency response but, can also depend on non-acoustic factors, such as contexts, expectations and attitudes. Yet, the field had been mostly focusing on the acoustic factors. Since the 1990s, there has been increasing interest in the other mechanisms behind negative health effects, including studies that further connect noise annoyance with the soundscape perspective, thus merging the fields.

These initiatives have often focused on users' experiences, in order to understand how different factors influenced the perceived quality of the sound environment, particularly in terms of possible reduction in noise disturbance. One such factor that was investigated was how the quality associated with 'positive' sounds, like water sounds, could be used to mask noise (Rådsten Ekman, 2015; Galbrun & Ali, 2013). Other central questions have included

[5] This is commonly referred to as *the soundscape approach* (*eg*. De Coensel *et al.*, 2010). In the thesis, the longer form *soundscape approach to noise* is used to emphasise the noise-exposed context and to suggest that soundscape thinking can be employed in other situations as well.

compensation strategies, like access to a *quiet façade* (de Kluizenaar *et al.*, 2011; Öhrström *et al.*, 2006), access to nature (Pheasant *et al.*, 2008; Gidlöf-Gunnarsson & Öhrström, 2007) and visual connection (Botteldooren *et al.*, 2016; Pedersen & Larsman, 2008).

The Swedish research programme 'Soundscape support to health' (Gidlöf-Gunnarsson *et al.*, 2008), which was carried out between 1999 and 2007, focused on sound environments for residential areas. Employing qualitative methods, like soundscape walks, and quantitative surveys, the programme problematised the relationship between noise annoyance and sound pressure levels by showing that the perceived quality also depended on other factors, like characteristic sound sources.

The programme introduced a methodology that would later be called "the Swedish soundscape quality protocol" (*cf.* Axelsson *et al.*, 2012; Axelsson *et al.*, 2010; Nilsson & Berglund, 2006), in which soundscapes are evaluated based on their perceived pleasantness, perceived eventfulness and characteristic sound sources (natural, technological and human sounds). Another aspect investigated was the relationship between noise annoyance and other aspects of environmental quality. It was shown, for instance, that access to nearby green areas could have an effect in reducing long-term noise annoyance, along with other positive health effects (Gidlöf-Gunnarsson & Öhrström, 2007). The programme also found that it was possible, to some extent, to compensate for noise annoyance through access to a *quiet façade* (Öhrström *et al.*, 2006), and this strategy was implemented as part of the 2002 directive (END) on noise in the European Union (EU, 2002). That directive has played a part in integration of the soundscape tradition with environmental noise management. In addition to the *quiet façade*, the notion of *quiet areas* and mapping these are important (*cf.* Bild *et al.*, 2016a; EEA, 2014; Brown, 2010b).

The relationship between soundscape thinking and noise has been further studied by the research group led by Professor Jian Kang in Sheffield (Kang, 2010; Kang, 2007; Zhang & Kang, 2007; Yang & Kang, 2005). Among other things, the group has been working with assessment of soundscape quality in urban squares and thereby increased understanding of how characteristic sound sources interact with sound pressure levels and other cues to influence perceived sound quality. Yang and Kang (2005), for instance, found that sounds that were perceived as positive could reduce annoyance "even when its sound level is rather high" (Yang & Kang, 2005, 228), and suggested that this finding supported the use of masking techniques to abate noise. Zhang and Kang (2007) subsequently proposed a limit at 65-70 dBA, and argued that, if

the sound pressure level exceeds this limit, all sounds are disturbing and masking techniques are not relevant.

As indicated in the review in section 2.1.2 masking has generally been regarded as a fruitful and rather straightforward strategy in city planning. However, besides Whyte's (1980) explorative observations in Paley Park, masking had not been studied in such contexts until rather recently. In her thesis "*Wanted Unwanted Sounds*", Maria Rådsten-Ekman (2015) investigated the potential to use water features as a way to mask noise in urban settings. Her work, which was based on three studies on users' perception, showed that there was potential for water sounds to mask noise, but that the masking doesn't necessarily improve the soundscape. It was found that water sounds with a low loudness and of fluctuating character (as in rippling and purling water) were preferred over sources with a high flow rate and akin to white noise. In other words, in addition to sound pressure levels, successful masking is dependent on other experiential characteristics of the inherent sounds as well.

The 'Positive soundscape' project was carried out as a collaboration between five universities in the UK during 2006-2009, and the findings were summarised in a scientific article (Davies *et al.*, 2013). The project identified three different areas to which descriptions of soundscapes could be ascribed; sound sources, sound descriptors (descriptions of physical qualities of a sound) and soundscape descriptors (descriptions concerning the combined effects of several sounds, such as hubbub). The project also identified that the overall character of soundscapes could be pinned down to two dimensions, or principal components: calmness and vibrancy (Davies *et al.*, 2013). This finding is akin to the 'Soundscape support to health' project, and its use of pleasantness and eventfulness to describe soundscapes (Axelsson *et al.*, 2012; Axelsson *et al.*, 2010; Nilsson & Berglund, 2006).

More recently, there have been increasing efforts to collaborate on soundscape research internationally, in order to reach common understandings and guidelines. Much of this work can be related to the EU COST Action collaboration 'Soundscape of European Cities and Landscapes', which involved more than 30 countries within and outside the European Union (Brown, 2012). The aim of the project, which was initiated in 2009 and ended in 2013, was "to provide the underpinning science for soundscape research and make the field go significantly beyond the current state-of-the-art" (COST, 2008, 2). A harmonisation of studies on soundscape was thus initiated in order to simplify comparisons between studies on the topic, among other things. The project also worked pragmatically with implementation of soundscape into policies and legislation. The international collaboration in the project resulted in *e.g.* the publication "*Soundscape and the Built Environment*" (Kang &

Schulte-Fortkamp, 2016), in which the project's "consensus on the current state of the art" is provided (Kang & Schulte-Fortkamp, 2016, back cover).

In parallel to the COST Action, another EU-funded project called 'HOSANNA' (HOlistic and Sustainable Abatement of Noise by optimized combinations of Natural and Artificial means) was carried out. The HOSANNA project investigated how alternative approaches, like the absorbing characteristics of vegetated soil, could be used in city planning to reduce noise. The project findings are reported in an illustrated brochure published online (HOSANNA, 2013) and in "*Environmental Methods for Transport Noise Reduction*" (Nilsson *et al.*, 2015).

The international collaboration on soundscape is also reflected in the previously mentioned ISO definition of soundscape (ISO, 2014) and the SONORUS research programme for urban sound planning. The SONORUS programme, which ran between 2012 and 2015, brought together young researchers from around the world, all of whom were working on one or more of the following six themes: planning skills, public outreach skills, prediction methods, soundscaping, noise control engineering and a holistic approach. At the end of the SONORUS programme, an illustrated booklet (Kropp *et al.*, 2016) summarising the situation in urban sound planning was published.

2.2.4 Sound research in architectural disciplines

The following section covers some of the research specifically relating to architectural disciplines. Such research has been fuelled in recent years by the establishment of sound studies, but the research tradition can be traced to the 1960s. As mentioned previously, some of the first experiments on city sound experiences were carried out in the late 1960s, by the World Soundscape Project (Truax, 1974) and by Michael Southworth (1969). Southworth's work differed from that of the World Soundscape Project because he came from a city planning background (he was a student of Kevin Lynch, who in turn was a student of Frank Lloyd Wright), rather than musicology or the arts. Southworth's (1969) work was explorative in character and investigated the role of city sounds, particularly in relation to visual cues. In the article reporting on the project, Southworth notes that the "visual experience of cities is closely related to the sounds that accompany it" (Southworth, 1969, 65). He goes on to discuss potential applications in city planning, including proposing four strategies to deal with noise: "careful location of noisy activities, new types of highway and street design, special vehicle design, and masking of existing noise by added sound" (Southworth, 1969, 67). He also discusses the relationship between architectural spaces and their acoustic characteristics.

Ten years later, in 1979, the research institute CRESSON was initiated. Situated in the architectural school in Grenoble, the institute is well known for its interdisciplinary research spanning architecture, ambiences and urban sounds. The institute brings together researchers from different disciplines, including sociology, philosophy, acoustics, architecture and music. Since most of the research at CRESSON is published in French, its accessibility to the wider research community was limited in the early years. Some of the important publications are now available in English (see *e.g.* Augoyard & Torgue, 2005). The work at CRESSON has also been summarised in English by Augoyard (1998) and Hellström (2003; 2002).

Similarly to Schafer and the World Soundscape Project, CRESSON approaches the sonic environment in a qualitative way. However, at CRESSON the relationship between sound, subject and the architectural environment is more emphasised. In one of the most influential publications from CRESSON, "*Sonic Experience – A Guide to Everyday Sounds*" (Augoyard & Torgue, 2005; Augoyard & Torgue, 1995), the conceptual tool "sonic effect" is introduced as a way of handling or describing sound-subject-space-relationships. Sonic effect consists of a list of 82 effects, which can be categorised by means of three different and overlapping levels: 1) Major/minor effects (16 major and 66 minor), 2) disciplinary context (six different contexts) and 3) type of effect (five different themes) (Hellström, 2003). Augoyard & Torgue (2005) refer to the sonic effect as "sonic grammar" and an "instrumentarium" through which the sonic environment can be understood and shaped.

Another major publication associated with the research environment in CRESSON is "*The Sonic Identity of European Cities*" (Amphoux, 1993), which has been made available in English through translations and essays by Hellström (2003; 2002). It can be described as a methodological manual, fuelled by concepts and terminology. In his work, Amphoux (1993) identifies three possible approaches to urban sound environments. These have been denoted in English by Hellström (2003; 2002) as: offensive, defensive and creative approaches. A defensive approach is more or less equal to the conventional established environmental noise management, where the focus is on negative aspects of sound. In the offensive approach, on the other hand, the focus shifts from noise to what people want to hear. The offensive approach, in other words, is about diagnosing what is good, rather than what is bad (Hellström, 2002). The creative approach focuses on how the acoustic environment can be designed or composed, and how citizens can be made aware of it.

Björn Hellström, a Swedish architect, conducted part of his thesis work based on theories developed at CRESSON. His thesis, entitled "*Noise Design*" (2003), could be described as an exploration of aesthetics in urban acoustic space. The thesis particularly explores seemingly paradoxical situations, such as situations in which noise becomes aesthetic or when unstable acoustic space is perceived as stable, *i.e*. the metabolic effect (*cf.* Amphoux, 1993). Hellström's (2003) work is based on practical and artistic examples, combined with theories and conceptual tools. This intersection between theory and practice constitutes yet another paradoxical situation, which Hellström deals with through descriptions and examples presented on a CD-ROM. Two theories are central, both developed at the CRESSON institute in Grenoble; "sonic effect" (Augoyard & Torgue, 2005; Augoyard & Torgue, 1995), and the "The sonic identity of European cities" (Hellström, 2002; Amphoux, 1993). Sonic effect, particularly the metabolic effect (in the 2005 translation by Andrea McCartney and David Paquette, this effect is denoted "metamorphosis"), is central throughout the thesis.

In more recent works from CRESSON, the focus has been less on sound as an "isolated" perception and more on sound as part of a "holistic" sensory fabric, as in the study of urban ambience (Chelkoff & Paris, 2016; Thibaud, 2011). 'The Ambience Network' – founded by CRESSON researcher Jean-Paul Thibaud and based in France – concerns the relationship between atmosphere and architecture where all senses (including sound) are considered. Similarly, the 'Sensory Cities Network' is another international platform for cross-disciplinary dialogue.

There is also an ambition within CRESSON to develop tools that are more readily accessible to architects and urban planners; one such tool developed for sound is called Esquis'sons! (Marchal *et al.*, 2016; Rémy & Chelkoff, 2016). Some of the work previously performed at CRESSON, while essential to provide a thorough comprehension of sound, may seem too difficult to implement for practitioners with no previous knowledge in the subject (*cf*. Hällgren, 2012b). The Esquis'sons! tool, on the other hand, is developed to allow the architect to sketch in real time and experience how different solutions influence the sonic environment. Related tools for *auralisation* (*cf*. visualisation) are being developed elsewhere (Kropp *et al.*, 2016; Pelzer *et al.*, 2014; Hällgren, 2012a; Lundén *et al.*, 2010).

In parallel with the research conducted at CRESSON and with the findings from the World Soundscape Project popularised with the publication of "*The Tuning of the World*" in 1977, application of soundscape thinking in architectural disciplines was initiated.

One of the first attempts to incorporate soundscape thinking as developed in the World Soundscape Project was by American landscape architect Kerry J. Dawson in 1988. In an article entitled 'Flight, fancy and the garden's song', Dawson (1988) uses some of the nomenclature developed in the World Soundscape Project to discuss the sonic character of natural biotopes as a quality that can be considered in design of gardens. He describes his work as being part of "a current shift in design away from an aesthetic based solely on visual attributes, and toward qualities which offer variety in sensual experience" (Dawson, 1988, 170).

In 1993, Keiko Torigoe designed a soniferous garden in Japan, based on the concept of soundscape (Hiramatsu, 2006), for a memorial house for Rentaroh Taki, a famous Japanese composer active around the turn of the 20th century. The design was based on various considerations, including design for natural biotopes and sounds of human activities (visitors to the site). In a description of the design project, Torigoe (2007) proposes an expanded framework for design based on four aspects: sounds of sound-producing devices and instruments, sounds of human activities, sounds of nature and sounds in memory/imagination.

The thesis "*Site Soundscapes: Landscape Architecture in the Light of Sound*" by Per Hedfors (2003) describes another early attempt at applying sonic thinking in landscape architecture. The thesis aimed to supply a field, described as visually orientated, with techniques and methods through which the potential in planning and designing for sound could be accommodated and practically implemented. The approach was broad and qualitative; part of the research methodology included "skilled listeners", such as musicians, to evaluate the sonic environment in relation to two landscape settings (one urban and one rural) (*cf.* Hedfors & Berg, 2003). This resulted in an increased understanding of how sounds can be discussed in landscape architecture, and a model to aid such discussions was proposed (model of prominence). The thesis also introduces a number of terms and concepts applicable to landscape architecture practice, including *sonotope* and *auditory refuge*, and describes a prototype for a CD-ROM-based tool aimed at aiding discussions on sound for landscape architects. Some of the nomenclature originally developed in the thesis has been further developed as an application available in iOS, the soundscape characterisation tool (SCT) (*cf.* Cerwén *et al.*, 2016; Berglund *et al.*, 2013; Hedfors & Howell, 2011).

A more recent contribution to the field of landscape architecture came with the 2017 publication "*Sound and Scent in the Garden*" (Ruggles, 2017). It is a broad collection of papers originally presented at a symposium in Dumbarton Oaks in 2014. The publication, which is historically orientated, covers a broad

range of geographical, cultural and chronological contexts relating to landscape architecture. It illustrates how sound has been used as a design element in various contexts throughout history.

In "*Spaces Speak, Are You Listening*?", digital acoustician Bary Blesser and independent scholar Linda Ruth-Salter (2007) explore (passive) acoustic qualities in architectural spaces through a broad and interdisciplinary approach. In a similar manner as Rasmussen in "*Experiencing Architecture*" (1964 [1959]) and Pallasma in "*The Eyes of the Skin*" (2012 [1996]), Blesser and Ruth-Salter (2007) point out the experiential potential inherent in passive acoustics of everyday architecture, but in a more thorough way. Through historical examples and the introduction of concepts such as "aural architecture", "acoustic arena", and "acoustic horizon", Blesser and Ruth-Salter (2007) increase understanding of the role and experience potential inherent in architecture's acoustics.

The Auditory Architecture Research Unit at Berlin University of the Arts has developed a new and embodied approach for the study of auditory activities in environments. The research, which is based on a case study on a square in Berlin, has resulted in strategies and practices for implementation in design of architecture, based on a phenomenological approach to sound as an "aural surrounding world". The case study and the group's approaches are described in the publication "*Klangumwelt Ernst-Reuter-Platz: A project of the Auditory Architecture Research Unit*" (Arteaga *et al.*, 2017).

Urban researcher and sound artist Jordan Lacey (2016; 2014) has combined affect theory with his own artistic practice to formulate a tool for urban soundscape design denoted as "sonic rupture". Even though Lacey's work is based in artistic practice, the strategies seem to be applicable in other contexts, including landscape architecture.

2.2.5 Reflection on sonic research traditions

In the above review, four sonic research traditions were outlined and described: *sound studies; the soundscape movement/acoustic ecology; the soundscape approach to noise*; and *sound research in architectural disciplines*. While divided into four areas for the purposes of this thesis, these fields are closely related and often overlapping.

Notes on interconnections between sonic research traditions

The soundscape movement was the earliest of the initiatives, and ultimately led to the formation of a field denoted acoustic ecology. Acoustic ecology is prescriptive, as it favours natural and traditional soundscapes over modern and

urban soundscapes. While this stance is supported by research on negative effects on noise and preference studies on sound (see sections 1.2 and 1.3), it fails to account for many of the qualities found in urban environments, such as the excitement and eventfulness of a market.

The qualities of urban life, including social and cultural phenomena, are better accounted for in sound studies, which could be described as a broader and less prescriptive discipline than acoustic ecology. Sound studies is sometimes considered an umbrella term, in which case it is inclusive of the other fields.

The qualities of urban life are also accounted for in the tradition denoted sound research in architectural disciplines, which is based on a deep understanding of sound-space relationships. However, it seems that much of the work carried out in that tradition has been too complex to be of direct interest for the average practitioner, although it constitutes an important resource to inform the other fields.

Acoustic ecology shares its aversion to noise with environmental noise management (see section 2.1.1). It is surprising that it would take until the 1990s before these areas started to merge in what is denoted here the soundscape approach to noise. Combining the qualitative thinking in acoustic ecology with the quantitative thinking in environmental noise management opens the way for optimal treatment of noise. The soundscape approach to noise could be described as problem-driven in its focus on noise, yet this focus does not exclude qualitative considerations of sound. On the contrary, qualitative considerations constitute an important part (as in masking strategies).

Positioning of the research areas in the thesis

All four research areas outlined were important in informing the thesis. A problem-driven approach was considered a fruitful starting point to facilitate soundscape thinking in practice. Problems with noise seem to make it possible to introduce pragmatic applications of soundscape design in well-established channels, as noise is already acknowledged as an important consideration in society and in landscape architecture[6]. By choosing to work in noise-exposed

[6]Noise issues constitute an important factor for various stakeholders in society, not least in relation to health problems. Such a focus therefore ensures relevance on a societal basis. In the thesis, it was also a factor when study objects were chosen and finances secured. Noise is likely to become increasingly important to consider as densification in urban environments proceeds. With densification, the need for contrasting and restorative environments on limited space could be expected to increase, a development which would call for increased knowledge in soundscapes to deal with noise.

situations, it was argued that it would seem particularly relevant for practitioners to consider sound.

However, it has previously been suggested that a problem-driven approach, as found in environmental noise management, is not enough to stir the imagination among designers (Brown, 2010b; Schafer, 1994 [1977]). The soundscape approach to noise adds a qualitative perspective which seems useful in this respect. The combination of the problem-driven approach with qualitative considerations is not only more likely to stimulate interest, but could also be considered a more optimal tool for working with noise, as it is more comprehensive. Furthermore, if noise-exposed situations are approached qualitatively and with a focus on design, they could be used as platforms to potentially motivate further interest in soundscape and act as a bridge to connect acousticians and architects.

All four studies in the thesis (Papers I-IV) focus on areas exposed to traffic noise. In this respect, the general approach could be described as problem-driven. Yet, all studies were designed to focus on the experience of sound, and the noise-exposed contexts of the studies did not exclude a deeper consideration of sound-space relationships (as found in sound research in architectural discipline).

To conclude, all four traditions outlined in the review above were important in the thesis. The soundscape approach to noise was the most influential, but the work was also informed by the other traditions, particularly sound research in architectural disciplines.

2.3 Practice-orientated research pertaining to soundscape thinking and design

Much of the early academic work pertaining to soundscape in planning and design disciplines was concerned with raising awareness and formulating theories and concepts for understanding sound and sonic experience, but the past few years have seen an increased ambition to implement the soundscape discourse in practice. This development has been fuelled in particular by the *soundscape approach to noise* tradition described above.

This thesis aimed to contribute to this development through an approach based in landscape architectural practice (for aim and methods, see section 2.4). For this reason, the following section presents a more detailed review of previous practice-orientated research, based on a distinction between three areas: the soundscape design process, support tools and evaluation of design projects.

2.3.1 The soundscape design process

Research on the soundscape design process can either be descriptive, as in sharing experiences from projects that have been carried out, or prescriptive, as in proposing strategies for soundscape design, or combinations of the two.

The Brown and Muhar (2004) "approach to the acoustic design of outdoor space" (*cf.* Brown, 2012; Brown, 2010a; Brown, 2004) introduces a work process by which the outdoor acoustic environment can be designed from a sound quality perspective. The proposed work process is based on the formulation of acoustic objectives, which can then be fulfilled by following a number of steps that centre around identification of wanted and unwanted sounds and their enhancement and reduction, respectively.

In another approach to soundscape design, Zhang and Kang (2007) propose that considerations of sound can be divided into two general areas: sonic activities and spatial aspects. Zhang and Kang also propose a decibel limit of 65-70 dBA, above which it is not appropriate to introduce new sounds to an environment. If this level is exceeded, they argue, no sound should be added unless a reduction is achieved beforehand. Based on this distinction and other considerations, they propose a chart to illustrate a potential design process (Zhang & Kang, 2007, 78). The chart is interesting, but it is surprising that it only proposes a reduction of sound if the sound pressure level reaches 65-70 dBA (and not below this level).

Adams *et al.* (2009) introduced a process map to illustrate how soundscape expertise could be incorporated in different phases of established urban planning processes in UK. In addition to sketching out the potential roles of various stakeholders, the map includes proposed activities such as sound walks and soundscape simulations for different phases. The map has since been incorporated into a soundscape design strategy proposed by De Coensel *et al.* (2010).

As part of a case study on an urban redevelopment project, De Coensel *et al.* (2010) describe the methodology used to transform a former urban industrial site into dwellings and a park. Their approach, which emphasises the importance of early-stage consideration for soundscape, is based on two general steps. The first step constitutes positioning of building blocks in such a way that sound pressure levels are optimised at facades and in the park. In the second step, different sonic environments are created based on the varying use of spaces and their existing sounds. The authors argue that "This will imply creating different acoustic environments for different zones, from lively to quiet, from natural to more urban" (De Coensel *et al.*, 2010, 4).

Jennings and Cain (2013) formulated a framework based on three steps to aid improvement of soundscapes. The steps are: 1) Describe soundscape

elements; 2) identify factors that could influence the soundscape; and 3) link potential design interventions to perception effects. In the final step of the framework, the Kano model is borrowed from product development to evaluate soundscapes based on three factors: basics, performance and excitement.

It has been argued that soundscape design is not easily transcribed into general guidelines, approaches or methodologies (Asdrubali *et al.*, 2014), but that soundscape design requires a participatory process. Participatory processes to soundscape design that include sound walks and discussions on sonic experience have also been suggested by Siebein (2010) and described and applied in practice by Tixier (2002), Adams *et al.* (2006), Schulte-Fortkamp (2010), Asdrubali *et al.* (2014) and Claus (2015).

The viewpoint described by Asdrubali *et al.* (2014) in the context of soundscape design has also been raised in discussions on design processes in other contexts. The idea that design processes can be described in a prescriptive or rational manner has been the subject of some debate. For instance, Cross (2001) argues that for architecture, rational models might be problematic if they describe a process that is more akin to a scientific activity than a design, and calls for design research based in practice.

In the present thesis, the intention was not to describe a process for soundscape design, but rather to understand practice and formulate support tools that could aid soundscape thinking. This was done through evaluations and discussions on design projects (Papers I-IV) and development of tools to support design processes (Papers II and IV).

2.3.2 Support tools

Today, growing numbers of support tools are being developed within academia, some of which can be useful for architectural disciplines. For the purposes of providing an overview, these are divided below into three types of tools.

Conceptualisations of soundscapes

A number of attempts have been made to conceptualise soundscapes in models and diagrams, to increase understanding of the role of soundscapes in environmental experience. Such conceptual tools are typically used to illustrate some of the factors that influence assessment of soundscapes, such as sound source type, physical properties of sound, spatial composition of sounds, contextual cues and personality cues.

One such model has been specifically developed in the context of landscape architecture, *i.e*. the model of prominence (Hedfors, 2003, 36). It is based on a distinction between the amount of prominent sounds and the amount of background sounds in a given environment. Through an intersection between these two dimensions, the model of prominence defines four types of soundscape characteristics: mild, powerful, clear and crowded.

Based on a listening experiment involving one hundred listeners, Axelsson *et al*. (2010) found that the dimensions "pleasantness" and "eventfulness" could explain 50% and 18%, respectively, of the variation. A principal component model was constructed based on the intersection between these two dimensions, leading to four (additional) types of soundscape characteristics: monotonous, exciting, calm and chaotic (Axelsson *et al.*, 2010, 2844).

An illustrative framework to describe soundscape perception has been proposed by Cain *et al*. (2008). The framework makes a distinction between aspects that are easily measurable, like loudness (sound), and aspects that are more dynamic and complex (scape). The framework stands out as it takes account of spatial aspects like direction, proximity and foreground/background in an illustration.

A system to describe soundscape evaluation in urban open spaces has been proposed by Zhang & Kang (2007, 76). The system is based on the following factors identified as influencing soundscape evaluation: source, space, people and environment.

A comprehensive taxonomy to describe the acoustic environment is proposed by Brown *et al*. (2011, 390). The taxonomy illustrates the relationship between environments, expected sound source types and examples of generated sounds.

Another comprehensive conceptual model introduced by Herranz-Pascual *et al*. (2010, 6) centres on the interaction between person, activity and place in the environmental experience and proposes several factors that influence this interaction.

Tools to identify potential changes in soundscapes

In the above review of soundscape design processes, an approach proposed by Brown and Muhar (2004) was described. In addition to suggesting a process for acoustic design of outdoor space, their approach could also be considered a tool for broadly identifying potential design options to improve soundscapes. For instance, the approach is based on identification of wanted and unwanted sounds, and possibilities to control wanted and unwanted sounds are discussed briefly. However, few concrete examples are mentioned.

The findings from the HOSANNA project resulted in an illustrated brochure entitled "*Novel Solutions for Quieter and Greener Cities*" (HOSANNA, 2013). The brochure is interesting from an architectural point of view, as it contains descriptions of a number of sustainable, yet unconventional, approaches to noise treatments, many of which are related to everyday solutions and decisions in landscape architecture and city planning.

The findings from the HOSANNA project were later adjusted and formulated as a toolbox within the context of a collaboration project between four major cities in Sweden, called 'City sounds'. Development of the toolbox was coordinated by Björn Hellström and it is based on illustrative icons, each of which symbolises an approach to reduce noise impact, such as "low wall with vegetation". The icons are sorted in a way that is intended to reflect an existing professional division, as it is argued that this is the best way to allow collaborations over disciplines (NBHBP, 2016). Divisions are thus made between the categories: building types; building solutions; screens; ground surface; and traffic and sound quality, with buildings and screens containing the majority of the icons. The tool has been published, in Swedish, in various contexts (Hellström, 2016; NBHBP, 2016; City Sounds, 2013).

Based on his own artistic practice, urban researcher and sound artist Jordan Lacey (2016; 2014) has introduced a tool for urban soundscape design. The tool, called 'Sonic rupture', centres around five general approaches to designing soundscapes: addition, subtraction, disclosure, passion and transformation.

Techniques for representation of soundscapes

There are different techniques and approaches for representation of soundscapes. Visualisation of soundscapes in qualitative maps is illustrated by Vogiatzis & Remy (2014) and Aiello *et al.* (2016). Hedfors and colleagues highlight the importance of language, including appropriate terminology, in order to discuss soundscape issues (Hedfors & Howell, 2011; Hedfors, 2003; Hedfors & Berg, 2003). That work has resulted in an application which can be used to inspire conversations about sound through eight different dimensions, one of which is onomatopoeics (Berglund *et al.*, 2013; Hedfors & Howell, 2011). Hedfors compares his approach to wine tasting discussions, only for soundscapes. There are also tools that can simulate soundscapes through auralisation (Vorländer, 2008). This technique has been extended to allow sketching with sound in 3-dimensional environments like Rhinoceros 3D and Grasshopper (Marchal *et al.*, 2016; Rémy & Chelkoff, 2016).

The above review of support tools illustrates that there are a number of instruments available for urban design. However, there is scope for further development and refinement. In a COST meeting discussing challenges in soundscape research (Kang, 2010), one of the outcomes was that existing tools need further development and that new tools for use by urban planners in different contexts and stages of the process are needed. The present thesis presents two tools (see Papers II and IV), both of which could be positioned as *tools to identify potential changes in soundscapes*. Both tools stand out from previous contributions as they have been developed in relation to landscape architectural practice. One of the tools, a conceptual model for comprehensive design, was introduced to evaluate entries submitted to a design competition (Paper II). The other tool, the soundscape action (Paper IV), was developed together with practising landscape architects, Master's students, artists, acousticians and other professionals. The collaboration with practice was considered to be an asset, as it was argued that this would mirror a designer's way of thinking to increase validity (*cf.* Cross, 2001).

2.3.3 Evaluation of designed projects

Evaluation and assessment of soundscape is now an established field (see sections 1.2 and 2.4.3). Much of the work conducted in this field has been dealing with assessment of urban experiences, but relatively few have been connected to design. There have been only a handful of projects to date in which design projects are evaluated. These projects have typically involved speaker sounds as part of the research methodology, thus bordering on art to various extents.

In one such project, entitled 'The interior sound design of high-speed trains', Billström and Atienza (2012) tested different additions of speaker-generated sounds as a means "to create a comfortable and appealing environment" in high speed trains. The sound installations were developed using a simulation of the in-train environment which made site-specific experimentation possible. Using a listening test for evaluations, the authors found that, while there were differences in results between the different approaches applied, there was clear potential to use speaker sound if carefully designed. Billström and Atienza (2012, 8) concluded that "added sounds can improve/enhance environments previously experienced as noisy and uncomfortable".

In a case study of an urban square in Stockholm, Hellström *et al.* (2014) explored methods and strategies to abate noise using a qualitative approach. A sound art installation called 'Sonic space' was installed at three places in the

square. The installation consisted of a collage of sounds, including the sound of wind in trees, birds at a distance, ocean sounds and sounds from barbecue coal. The installation was designed so as to blend in with the pre-existing soundscape in the square, yet at the same time mask noise through informational masking (Moore, 2012). The psychoacoustic evaluation indicated that there could be potential for adding sound as a way to abate noise, but that methodological issues made it difficult to assess an installation that was, in fact, intended to be experienced as a background element.

Another project incorporating speaker sounds, called 'Musikiosk', was carried out in a pocket park in Montreal during two months in 2015 (Bild *et al.*, 2016b; Steele *et al.*, 2016). In that project, visitors were given the possibility to play their own music through a set of public speakers, thus appropriating the space acoustically. Using a mixed-method approach, it was found that Musikiosk offered a welcome addition to the park that had a positive influence on the social dynamics (Bild *et al.*, 2016b), and enhanced visitors' mood (Steele *et al.*, 2016).

In addition to the projects mentioned here, which have been described and/or assessed through research, there have also been a number of projects (with and without speakers) that have not been followed up in this way. Examples of such projects are given by Payne *et al.* (2009), Kang *et al.* (2016), Cerwén (2010a; 2010b) and Axelsson (2010), and include 'The sea organ' in Zadar, Croatia; the combined noise screen and water feature called 'The cutting edge sculpture' along Sheaf Square in Sheffield, UK; the motorway organ 'Harmonic bridge' in Massachusetts, US.; 'Le cylindre sonore' in Parc de la Villette, Paris, and a 'Sound garden' in Seattle, USA.

As the above review indicates, only a limited number of projects have been evaluated in terms of their soundscape design thus far. This is noteworthy, as such example projects could be important in building arguments for integration of soundscape thinking in practice. Moreover, design reflections from such evaluations could be important in creating a knowledge base for future initiatives. The present thesis contributes an evaluation of a design intervention in an urban square (Paper III), as a quasi-experiment in landscape architecture.

2.4 Aim and Methods

2.4.1 Aim of the thesis

The overarching aim of the thesis was *to facilitate soundscape thinking in landscape architecture.*

Landscape architecture is a multidisciplinary field, hovering in the borderland between natural sciences, social sciences, art and humanities (Thompson, 2017). In the profession and in academia, landscape architecture draws on methodologies found in a wide variety of fields. The present thesis follows in this tradition and draws on methodological approaches from environmental psychology and design studies.

Furthermore, the thesis work is characterised by a combination of quantitative and qualitative methods. The intention with such a mixed-method approach (Bryman, 2012) is to increase validity through triangulation of results. The mixed-method approach is also considered beneficial as it provides the opportunity to understand general trends while at the same time permitting nuanced and richer understandings of the research material.

The thesis is practice-orientated. It sets out to understand how landscape architects work with sound today in order to understand how they could work with sound in the future. Soundscape thinking is used to emphasise the overall experience of sound, where problems and possibilities are accounted for. Soundscape thinking is also used as a means by which to discuss and understand the role of sound in planning and design situations.

The thesis consists of four studies (Papers I-IV), each of which was individually designed based on a specific aim and context. The studies are all part of the general aim of the thesis, but they also differ in that they are based on different empirical material, focus on different areas and apply different methodologies.

2.4.2 Specific aims of Papers I-IV

This section introduces each of the four studies briefly, focusing on their specific aims. For an extended summary of the studies, including their respective methodological approaches and findings, see section 3.

- Paper I examined the role of soundscape in nature-based rehabilitation through a study of interviews conducted with 59 caretakers in a rehabilitation garden in Sweden. The aim was to examine the role that

soundscapes can play in nature-based rehabilitation for patients suffering from stress-related mental disorders, and to identify essential aspects to consider in future design of restorative spaces for mental recovery.

- Paper II centred on a design competition for a new cemetery outside Stockholm; 109 competition entries were studied in the paper. The aim was to increase understanding of how soundscapes are addressed in the landscape architecture profession, and to develop a model for use in evaluation of soundscape intentions in landscape planning and design situations.

- Paper III describes a design intervention built in an urban square. The aim was to increase understanding of how the urban soundscape can be altered through the design and construction of outdoor space.

- Paper IV was based on three soundscape design workshops in landscape architecture conducted on different occasions. The aim of the paper was to collect and describe experiences from these workshops, and analyse and structure the workshop proposals in a way that made the outcomes accessible to practitioners. Paper IV introduces a tool denoted ‘soundscape actions’.

2.4.3 Two focus areas

The thesis work was divided in two general methodological areas or approaches; understanding sonic experience and understanding design practice. Studies on sonic experience could be positioned within environmental psychology, whereas studies on design practice could be described as design studies. From a design perspective, the two areas are closely related, as an understanding of sonic experience is a prerequisite to designing soundscapes. Furthermore, sonic experience can be used as a method to evaluate design (*cf.* Paper III). Both areas were used in different phases of the thesis work, and were considered to be of equal importance in achieving the thesis aim of facilitating soundscape thinking in the discipline.

In the following, the two research areas are discussed in relation to Papers I-IV.

Understanding sonic experience

Sonic experience is a broad term used here to describe the phenomenological influence that everyday sounds have on human beings. Sonic experience can be about preferences for various sounds in the environment, or the relationship between sound and human behaviour. It can also be about disturbance of sound[7].

Assessment of sonic experience can be used to inform and/or evaluate design projects. In this thesis work, both Paper I and Paper III incorporated a methodological approach that focused on sonic experience.

On a general level, the study of human preference is difficult, as it entails the translation of something as intangible and ephemeral as an experience into words, explanations and concepts. This is a challenge for all preference studies. However, in relation to studies on the visual, the vocabulary to describe sonic events seems to be less well developed. Although inspiration can be found in other fields, like music or cinema (Hedfors & Howell, 2011), communication difficulties have been raised as an obstacle to understanding and clearly articulating the role of sound (Raimbault & Dubois, 2005; Hedfors, 2003). In a parallel way to images for visual representations, field recordings have been suggested as a potential complement to other forms of sonic representations (Prior, 2017).

Another challenge associated with studies on sonic preference is that human beings tend to listen to everyday sounds in an unconscious manner. This presents a potentially problematic situation, particularly when working with self-reporting (as in Papers I and III). Once participants agree to answer questions about their perception, they start to listen in a different way than they normally would (*cf.* Schaeffer, 1966). This is an issue that should be given more attention in the field, although it has already been identified as a challenge (Rådsten Ekman, 2015; Hellström *et al.*, 2014; Cerwén, 2009). One way to approach it is to work with additional methods, such as evaluation of behaviour and movement patterns (Aletta *et al.*, 2016b; Bild *et al.*, 2016b; Lavia *et al.*, 2016). It would be fruitful to conduct more studies that triangulate self-reporting with other methods, as this could be used to evaluate the credibility of self-reporting in various contexts.

Sonic experience has mostly been studied in terms of preference for various sounds in the environment, as in the study of acoustic comfort (Yang & Kang, 2005), soundscape quality (Nilsson & Berglund, 2006) or pleasantness

[7] Noise disturbance constitutes an important part of sonic experience, yet health effects related to *long-term* exposure to noise are not covered in the concept or in this thesis. The significance of such studies should nevertheless be acknowledged here.

(Viollon *et al.*, 2002; Carles *et al.*, 1999) or as part of visual aesthetics (Anderson *et al.*, 1983). Studies on behaviour are fewer, but have been increasing rapidly in recent years (Aletta *et al.*, 2016b; Bild *et al.*, 2016b; Lavia *et al.*, 2016; Cohen & Spacapan, 1984).

For the purposes of assessing soundscapes in the present thesis, the Swedish soundscape quality protocol (*cf.* Axelsson *et al.*, 2012; Axelsson *et al.*, 2010; Nilsson & Berglund, 2006) was used as a general starting point to formulate research approaches. However, the specific approaches varied depending on context. In Papers I and III, the evaluation was carried out *in situ*. Studies *in situ* can be problematic, as there are confounding factors to consider. Yet such factors can also be beneficial, as contextual information can be important in understanding how soundscapes interact with other cues in the environment. In this thesis, studies *in situ* are thus considered equally important and complementary to studies in controlled laboratory environments.

In Papers I and III, interviews constituted an important part of the research to understand preferences in soundscapes. In Paper I, the interviewees were not asked specifically for sound, yet mentioned it spontaneously. In Paper III, interviewees were aware of the purpose of the study and, once they had participated, talked about the study in a reflective manner. In both cases, the interviewees were not experts in sound, and it was clear that several descriptions were rather shallow (even though there were many rich examples too). Moreover, a few interviewees struggled with their descriptions of sonic experiences, which was a limiting factor in some cases.

The outcomes of the interviews were considered to be valuable in the contexts in which they were studied, yet it was also clear that interviews with laypersons had limitations. When the intention is to gain a deeper understanding of the sound environment, it is probably more fruitful to involve ‘skilled listeners’ such as musicians and acousticians, as part of the methodology (*cf.* Hedfors, 2003). Professionals with experiences from working with sound are more likely to be able to reflect and discuss sonic issues on a deeper level.

It should be mentioned here that, from a designer’s perspective, assessment of soundscape is a limited method, in the sense that it generally requires projects to be built or simulated. Design proposals cannot be easily assessed in this manner (yet), but require simulations based on auralisation techniques.

Understanding design practice

The other focus area, design practice, was directed towards landscape architecture as a cultural and professional practice. Here, the focus was to understand how landscape architects work/do not work with sound and how they could work. In other words, the study of design practice attempted to understand how contemporary practice works (as in Paper II and to some extent Paper I), but also to come up with fruitful strategies and approaches for future work (Papers III and IV). Both perspectives were considered to be essential for achieving the thesis aim of facilitating soundscape thinking in the field.

Design practice was studied in a number of different contexts, including design workshops, design projects and an architectural competition. The methodological approaches varied depending on context, but much of the work related to design evaluation, *i.e*. the application of a set of "measurable criteria or standards [to generate] new knowledge about a situation or phenomenon" (Deming & Swaffield, 2011, 180). In addition to the studies presented in Papers I-IV, the review of seminal publications in section 2.1.2 was used to form an understanding of design practice.

In the studies pertaining to design practice, the research design entailed organisation of workshops (Paper II) and a design intervention (Paper III). This required additional efforts, but resulted in valuable insights. The approach in Paper III proved to be a useful way to study soundscape design, as the actual construction could be evaluated *in situ*. The construction of a design intervention in a public square also stimulated interest, from the media and the general public. In this sense, the intervention not only functioned as a scientific quasi-experiment, but also as a kind of forum through which the contemporary soundscape could be discussed, thus bordering on an artistic statement. The intervention also stimulated increased awareness and heightened listening, as the following quote from one respondent illustrates: "It is even more disturbing now than usual, as [the] questions make you focus on all the negative. Ugh". There is also a relationship here to the sound walk and other listening exercises (*cf*. Schafer, 1992).

In Papers II and IV, the research did not follow an established methodology and it was unclear from the onset exactly how the method could best be designed. A suitable research design required an initial understanding of the material. This approach could be described as explorative and was partly a result of methodological insufficiencies within the field. Papers II and IV make a methodological contribution that can be used as a starting point in future work.

3 Summary of Papers I-IV

This section provides an overview and summary of Papers I-IV. The summary includes background, aim, method, results, discussion and outcomes for each of the four papers. The papers are available in full as appendices in the printed version of the thesis and online as indicated in the list of publications.

3.1 Paper I: The role of soundscape in nature-based rehabilitation: A patient perspective

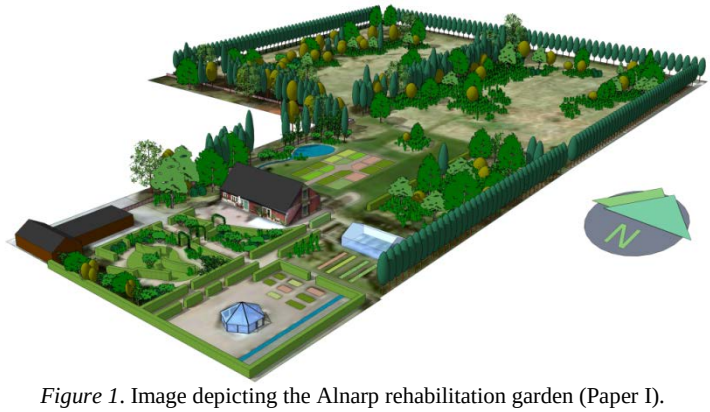

Figure 1. Image depicting the Alnarp rehabilitation garden (Paper I).

3.1.1 Background and aim

Paper I investigated the role of soundscape in a nature-based rehabilitation (NBR) garden in Alnarp, Sweden (*Figure 1*). The study was based on transcribed interviews with 59 patients suffering from mental fatigue, who had participated in a 12-week long rehabilitation programme in the garden. The

interviews were conducted over a five-year period (2007-2012) by the third author, Anna María Pálsdóttir, with the original intention of investigating the general role of nature in nature-based rehabilitation (*cf.* Pálsdóttir *et al.*, 2014). Sound was thus not an aspect that had been specifically addressed in the interviews, but had materialised as an important aspect in the analysis.

3.1.2 Methods

In Paper I, the transcribed interviews were re-analysed, this time with the focus on soundscapes. Relevant sections in the material were identified through the use of keyword searches, in which 27 of the 59 patients were found to have mentioned sound. All authors analysed the resulting material individually, using interpretative phenomenological analysis (IPA) (Smith & Osborn, 2003). All mentions of sounds were categorised as one of three sonic themes: natural, technological or human-induced sounds (Axelsson *et al.*, 2010; Nilsson & Berglund, 2006). Following individual analysis, the authors discussed and agreed on general findings.

3.1.3 Results

The findings indicated that sound could play a significant role in patients' recovery processes. Sounds perceived as pleasing could aid the process, whereas sounds perceived as intrusive could hinder it. For patients who suffered from an increased susceptibility to sound, spending time in the garden seemed to be able to mitigate recovery.

Natural sounds were generally perceived as positive and were referred to as being part of an ideal and, somewhat paradoxically, "quiet" environment. Furthermore, descriptions of nature sounds seemed to include references to other (simultaneous) sensory inputs in a manner that was reminiscent of the notion of "soft fascination" proposed by Kaplan & Kaplan (1989), and prone to evoke memories.

Technological sounds were consistently referred to as problematic, but the level of disturbance was set in relation to other environments to which the patients were accustomed. Noise from a nearby motorway made some patients move to areas in the garden that were less exposed to the noise.

Human-induced sounds were the most complex of the sonic themes and the perception varied depending on social context and loudness. For instance, the soft, gentle voice of a therapist could be referred to as a supporting feature, while sounds from loud and/or unwanted participants were problematic. The

sound of gravel could be taken as a warning signal to inform patients about other participants approaching.

The findings suggested that the interconnectedness between sound and other sensory inputs could be of value for the recovery process and possibly an important aspect to induce soft fascination. For instance, sonic feedback from the patients' own movement in the garden, particularly the sound of a wooden deck, was mentioned as soothing.

3.1.4 Discussion and outcomes

Paper I presents a discussion on the role of sound in nature-based rehabilitation and in relation to this, investigates potential design considerations. It proposes that, in order to optimise nature-based rehabilitation, the design of future gardens should include consideration, not only for reduction of noise, but also for measures to enhance appreciated sounds. This could be described as a comprehensive approach (*cf.* section 4.5). Furthermore, a varied soundscape is proposed in Paper I as a means through which each patient would have the possibility to seek out their favourite environment, based on aspects such as personal preference, mood and phase of treatment.

Natural sounds emerged as the sonic theme that was most supportive of rehabilitation, and the discussion included a review of relevant literature through which supporting biotopes could be created. This covered, for instance, sounds from vegetation, water and birds.

Paper I proposes that sound requires further attention in nature-based rehabilitation. In addition to understanding sound (in isolation), it would seem to be important to study the interaction between sonic themes, as well as the relationship between sound and other senses, as the significance of such interactions were indicated in the study. Finally, Paper I proposes that sound could be a useful means to inform general theories dealing with nature-based rehabilitation.

3.2 Paper II: Evaluating soundscape intentions in landscape architecture: A study of competition entries for a new cemetery in Järva, Stockholm

Figure 2. Aerial photo of the Järva cemetery competition site (Paper II). Photo: Lennart Johansson.

3.2.1 Background and aim

Paper II aimed to increase understanding of how soundscapes are addressed in landscape architectural practice. The study concerned a major architectural competition for a new cemetery in Järva, Stockholm. The competition area (*Figure 2*) was problematic in terms of noise, making it particularly interesting from a soundscape perspective. A total of 109 competition entries were analysed, using a model developed in Paper II. In addition to increasing understanding of landscape architecture practice, the paper also aimed to evaluate the model.

3.2.2 Methods

A model for evaluation was introduced based on three main categories: I) Localisation of functions, II) reduction of unwanted sounds and III)

introduction of wanted sounds (see also section 4.5). Each of the 109 competition entries was evaluated based on how it addressed these three categories. This approach made it possible to evaluate the rather large number of competition entries quantitatively, while at the same time allowing for a more nuanced understanding through cross-category comparison. In addition to the quantitative evaluation of the competition entries, one of the competition entries that covered all three categories was described in more detail.

3.2.3 Results

The results showed that, given the problematic situation with noise at the competition site, sound was given relatively little attention in the competition entries. One-quarter of the competition entries did not address sound at all. When sound was considered, this was generally done in a simplified manner that typically involved noise screens (category II). It was relatively unusual for competition entries to consider more than one of the three categories and only five proposals considered all three categories (*Figure 3*). This can be related to the fact that categories I and III were found to be underrepresented in the study.

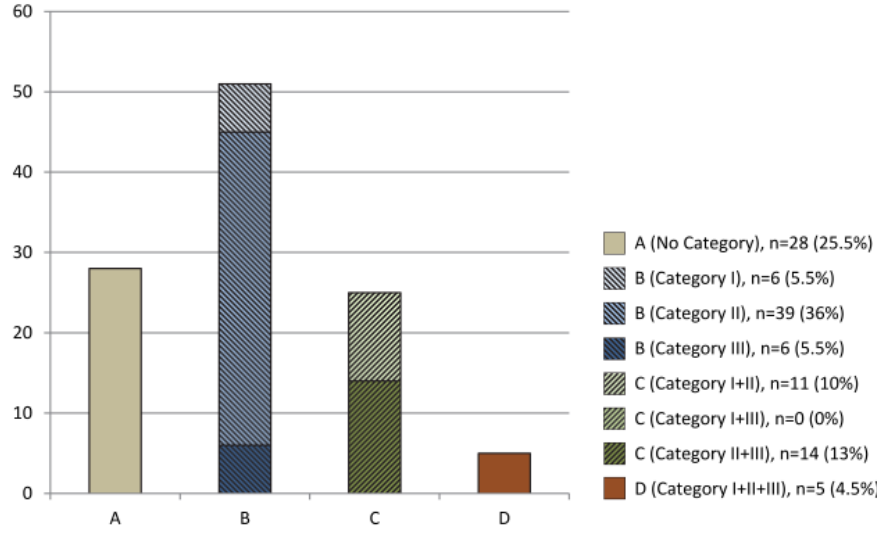

Figure 3. Overview of how the three categories (I: localisation of functions, II: reduction of unwanted sounds, III: introduction of wanted sounds) were combined in the 109 competition entries studied in Paper II. Entries in Group A addressed zero categories, entries in Group B addressed one category, entries in Group C addressed two categories and entries in Group D addressed all three categories. The diagram also indicates the combinations of categories addressed.

One of the competition entries that considered all three categories (entry no. 9, ‘Alice’) was examined more closely and is described in Paper II, as it was considered a good, illustrative example of how the three categories could be combined and how sonic issues could be dealt with.

3.2.4 Discussion and outcomes

Some general trends found in the competition are raised and discussed in Paper II:

- *Extensive use of buzz phrases:* It was common among competition entries to refer to their proposed cemeteries in terms of being “quiet” and “tranquil” places. However, these visions were seldom followed up in terms of adequate soundscape actions.
- *A defensive approach:* The main focus among the competition entries that mentioned sound was on abating noise (69%), and not on incorporating positive aspects of sound.
- *A tendency to rely on positive sounds:* In an opposite tendency to the defensive approach, it was found that some proposals (6.5%) only focused on positive aspects of sound, while disregarding possibilities to reduce noise levels. This tendency, which was also found in the jury’s brief, was considered a misinterpretation of soundscape thinking.
- *Discrepancies in communication of soundscape considerations:* Soundscape was rarely a prioritised aspect in the competition entries submitted. Even in cases where efforts seemed to have been made to improve the soundscape, this was not clearly communicated. These discrepancies could be explained, for instance, by the visually orientated tools and the potential gains in avoiding mentioning the problematic soundscape.

Based on Paper II, there seems to be a need to increase priority and/or knowledge about soundscape in landscape architectural practice in Sweden. The soundscape approach could be a way to reach architects and planners, for whom the science of acoustics has failed to raise interest. However, as Paper II show, there is a risk of the soundscape approach being misused to avoid addressing problems with noise. As a way to counteract this, it is suggested that the model developed in Paper II could be used to ensure a comprehensive (soundscape) approach to noise.

3.3 Paper III: Urban soundscapes: A quasi-experiment in landscape architecture

Figure 4. Image depicting the arbour that was the focus of the quasi-experiment in Paper III.

3.3.1 Background and aim

Paper III aimed to increase understanding of how the urban soundscape can be considered and altered in design of outdoor space. The work centres around an intervention – a small arbour that was built in a noise-exposed location in an urban square in Malmö (*Figure 4*). The arbour walls were constructed from noise screens that were covered with ivy. The arbour also contained a speaker system.

The intervention was a result of a practice-based partnership project that involved representatives from the park and road administration at the municipality of Malmö and the acoustic consultant firm Ramböll. The design intervention was discussed within an expert group consisting of landscape architects, an acoustician, a traffic planner and a sociologist. Three consultants were then appointed, together with another department at the municipality to do the detailing and build the structure.

3.3.2 Methods

The project was designed as a quasi-experiment that centred around the arbour. The arbour was evaluated through a mixed-method approach that included measurements of sound pressure levels, observations and self-reports from (in total) 205 visitors.

Visitors who agreed to participate in the study filled in a questionnaire, first outside, and then inside, the arbour. Furthermore, the participants were divided into two groups. The first group was not exposed to any extra sounds from the speakers, while the second group was exposed to forest sounds (played back inside the arbour). The responses to the questionnaire were analysed using ordinal logistic regression. Nine of the participants also took part in semi-structured interviews.

3.3.3 Results

The statistical analysis revealed that the arbour improved the soundscape. This effect was further enhanced for the second group of participants (who were exposed to forest sounds inside the arbour). The difference between the two participant groups confirmed the importance of qualitative considerations in design of soundscapes, and showed that an increase in sound pressure level can, in fact, improve soundscape assessment, at least up to around 58 dBA.

In addition to the quantitative part of the study, qualitative material such as interviews, observations and participants' comments contributed an additional understanding of how the arbour was experienced. In this part of the study, variation in the city soundscape was identified as an important aspect to consider in soundscape design, together with expectations on the sound environment.

The qualitative material also increased understanding of how masking strategies can be implemented successfully. In addition to sound pressure levels and other physical characteristics of the sound sources, the relative direction between masker and target sound was identified as an important factor for consideration.

It was also found that the use of speaker sounds could be perceived as irritating in some cases, but also as an exciting feature that could be related to the notion of soft fascination (Kaplan & Kaplan, 1989). A number of general improvements for the arbour were identified and described as the intervention was evaluated.

3.3.4 Discussion and outcomes

Paper III increases understanding of how design of soundscapes can be approached in landscape architectural practice. On a larger scale, variation in a city's soundscape was found to offer the possibility for inhabitants to choose soundscape, based on cues such as preference and mood. As a contrast to a bustling city, the need for contrasting tranquil space was identified. The concept investigated in Paper III, with the relatively small arbour, could be further investigated in the future, especially in relation to densification of cities.

Expectation is another aspect raised in Paper III. Expectation has been noted previously as a factor to consider in soundscape assessment (Brambilla & Maffei, 2006). For instance, in urban environments sounds from traffic are more likely to be accepted, or even appreciated (Anderson *et al.*, 1983; Whyte, 1980). This is also confirmed in Paper III, where it is shown that the bustle of the city could be regarded as a quality.

Finally, Paper III shows that the use of a comprehensive approach, in which masking strategies are combined with noise abatement, is fruitful when discussing soundscape applications. The use of masking strategies was found to be effective at the given sound pressure level, *i.e.* 58 dBA. This supports a claim made previously by Zhang and Kang (2007) that it is beneficial to work with masking strategies up to 65-70 dBA, but that if sound levels exceed this threshold, all sounds are disturbing.

3.4 Paper IV: Soundscape actions: A tool for noise treatment based on three workshops in landscape architecture

3.4.1 Background and aim

Paper IV is based on three workshops in landscape architecture that incorporated soundscape as a way to address noise. The purpose was to describe experiences from the workshops and structure the outcomes in a way that would make them accessible to practitioners.

The workshops were conducted in different contexts and with different combinations of participants. The first workshop was conducted in 2012 as part of a partnership project (a continuation of the project described in Paper III). This workshop involved landscape architects, acousticians and artists (see *Figure 5*). The second workshop was carried out in 2015 as part of a practice-orientated research project at the woodland cemetery in Stockholm. This

workshop involved landscape architects, researchers in soundscape, acousticians and experts in cemetery environments. The final workshop, held in 2016, was part of a Master's course in landscape architecture and all participants were landscape architecture students.

Figure 5. One of the workshop groups in action developing ideas for soundscape improvement (Paper IV).

3.4.2 Methods

The workshops were studied through an approach that made use of the model introduced in Paper II. All proposals made by the workshop participants were summarised in short keyword phrases that described the most essential aspects of each proposal. All keyword summaries were then given one of three positions in the model and were sorted so that similar proposals were clustered together (see *Figure 6*). Once the clusters had been outlined, they were described and each one was denoted a 'soundscape action'.

3.4.3 Results

The analysis resulted in identification of 22 soundscape actions. The following summary of the soundscape actions is structured based on the three categories in the model that were used to identify them.

Soundscape actions related to the model's first category were: Compensation/variation, avoid unwanted sound, embrace unwanted sound.

Soundscape actions related to the model's second category were: Vegetation for noise reduction, high noise screens, low noise screens, buildings as screens, change topography, reduce source activity, abolish certain functions, maintenance, absorbing qualities of materials.

Soundscape actions related to the model's third category were: Auditory masking, visual masking, materiality (water), materiality (vegetation), materiality (walking), atmospheric design (loud-speaker based), sound sculpture and urban furniture, biotope design, attract activities, resonance and reflections.

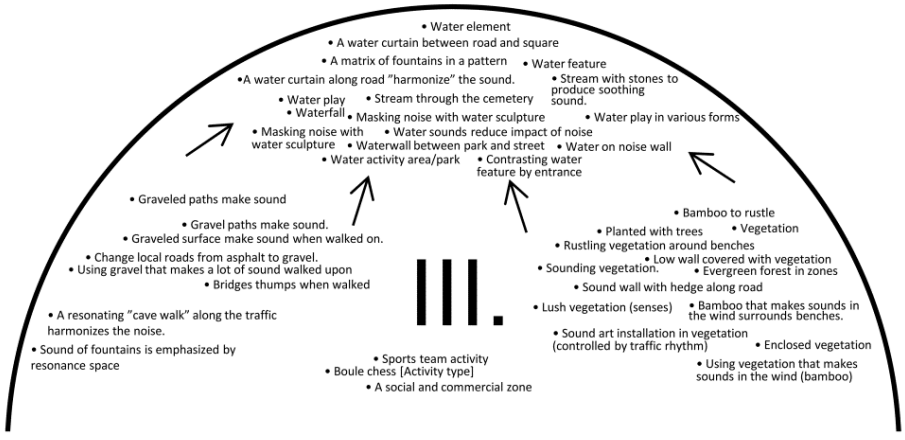

Figure 6. Illustration of how clusters were formed to become 'soundscape actions' in Paper IV.

3.4.4 Discussion and outcomes

The work in Paper IV resulted in 22 soundscape actions, each of which represents a concrete way in which soundscape thinking can be used to address noise issues. An additional action, 'Embrace wanted sounds', was identified in the discussion. This is included in the extended summary given in section 4.6, making a total of 23 soundscape actions to date.

The methodology was grounded in landscape architectural practice, as it was based on three workshops that included landscape architects, as well as other professionals. The proposals varied to some extent depending on the workshop context in which they were presented. This variation was considered an asset and potential explanations are discussed in Paper IV in terms of differences between the workshops.

The discussion covers practical applications, including the need for further research in which the soundscape action is tested and evaluated in relation to other available tools and situations. Such research could also look into the structure of the tool, which could gain from being presented on a digital platform that allows multiple tags.

4 Discussion of results

This section summarises and discusses the results obtained in Papers I-IV in relation to previous research and future work. The text is structured around a number of themes identified in the thesis work process, which are used here to collate results from the individual studies and to drive the discussion.

The first set of themes focuses on present practice and discusses how landscape architects work with sound. Using this understanding as a foundation, the discussion gradually moves on to deal with the topic of how and why practice could improve its thinking on soundscape issues. This involves discussions on strategies, tools and sonic experience.

4.1 Understanding soundscape thinking in landscape architecture practice

Making general statements about how sound is treated in landscape architecture practice is difficult. There are probably as many different ways to understand and work with soundscape as there are landscape architects. Nevertheless, some tendencies were identified in the thesis work. Some of these tendencies seemingly contradict each other, indicating the existence of overlapping understandings.

4.1.1 Increased interest in sound in landscape architecture: Influence from the soundscape approach

There are good, interesting examples of the treatment of sound in contemporary landscape architecture. Such examples are presented in this thesis, *e.g.* in Paper II, where a design proposal called ‘Alice’ is identified and described. In Paper I, the rehabilitation garden studied had been designed with consideration for sensory experience of nature, including sound (although there

were problems with noise at the site). The review of seminal publications, similarly, revealed a growing number of actual projects around the world in which consideration of sound has played a significant role (although fewer of these have actually been assessed and studied in an academic context). In addition, the review of seminal publications indicated that there has been increasing awareness about sound in the field in recent years.

This increased awareness about sound in contemporary landscape architecture can partly be explained by the development of the soundscape approach. The soundscape approach, in which the experience of sound (rather than noise) is given a greater focus, seems to have helped increase interest in sound among landscape architects. This was also one of the original intentions with the soundscape approach, *i.e*. to raise the imagination in a way that environmental noise management did not (Brown, 2010b; Schafer, 1994 [1977]). Soundscape thinking can, in this sense, open the way for landscape architects to work with sound in new approaches.

This development is interesting, but it can potentially also be problematic as there seems to be an understanding within practice that working with soundscapes can be straightforward. Paley Park[8], for instance, even though it has not been studied extensively, is commonly referred to in landscape architecture publications as a successful example of how masking can be incorporated in landscape design and how even a loud environment can be made soothing by adding water sounds (see review in section 2.1.2). However, as indicated in this thesis and other studies (Cerwén *et al.*, 2016; Rådsten Ekman, 2015; Brown & Rutherford, 1994), masking is not a straightforward task, but depends on several different factors for successful implementation, such as type of masking, type of environment, figure/ground relationships, directions of sound sources, sound pressure levels and sonic characteristics.

There is also a risk, as shown in Paper II, of soundscape thinking being used as a motive to disregard problems with noise. It is thus possible that soundscape thinking, even if intended to improve the sound environment, may in fact have the opposite effect if not implemented carefully. For instance, masking should not be regarded as a simple *ad hoc* solution to allow exploitation in noisy areas.

[8]Paley Park is a pocket park in midtown Manhattan, opened in 1967 and designed by Zion Breen Richardson Associates. It is known among other things for its waterfall, the sound of which produces a masking effect in relation to the surrounding city (Whyte, 1980).

4.1.2 A hegemony of vision in landscape architecture? A nuanced critique and a reliance on environmental noise management

As discussed previously in this thesis, landscape architecture and related disciplines have been criticised for being ocularcentric in their approaches (Pallasmaa, 2012 [1996]; Jakobsson, 2009; Hedfors, 2003; Lynch, 1976; Rasmussen, 1964 [1959]). This criticism is directed particularly at the modernistic tradition and its presumed failure to address sound and other senses in a satisfactory manner. This thesis shows that, although there has been an increased interest in sonic thinking in the field, some of this criticism is still justified. This is evident from the review of seminal publications (see section 2.1.2) and the studies of contemporary practice, particularly Paper II. However, while much of the earlier critique was categorical and failed to articulate more specifically the ways in which consideration for sound was/is lacking, this thesis contributes a nuanced understanding in this respect.

In the study of the architectural competition in Paper II, it was shown that one-quarter of competition entries did not address sound at all. This was noteworthy considering that there were severe problems with noise at the competition site. This was taken to indicate that, in these cases, sound was either not recognised as a high priority and/or that there was a reliance on acousticians to deal with the noise in later phases. The remaining three-quarters of entries addressed the problematic sound environment in their proposals. The most typical way to do this was to propose screening (59%). It is argued in Paper II that there was an overreliance on screening as a general and only solution to abate noise. On the other hand, it was shown that relatively few of the competition entries (20%) referred to localisation of functions as a way to deal with noise. This was considered a remarkably low proportion given the variation in sound pressure levels at the competition site, as well as the early stage of the design process.

It was beyond the scope of Paper II to investigate in full the reasons for these choices related to localisation of functions, but sound is clearly an overlooked consideration. A related aspect was also identified in Paper I, where the south-eastern parts of a rehabilitation garden were exposed to noise coming from an adjacent motorway. Localisation of functions seems to be a particularly overlooked aspect of soundscape design that should be raised in practice. The comprehensive model proposed in Paper II could be a means to do this (see section 4.5).

On a general level, Paper II indicates that there is scope to further integrate knowledge on sound and acoustics within the discipline. There is a tendency to either ignore problems with noise, or to depend on schematic solutions and environmental noise management to deal with them.

Reliance on environmental noise management is not surprising considering the fact that it is an established field occupied by specialists trained in acoustics. Yet, whether acousticians are involved or not, landscape architects take decisions every day that have an effect on the sonic environment. In this respect, a basic understanding of acoustics seems valuable for the profession. An increased understanding of acoustics would offer possibilities to design with sound as part of visual aesthetics, as shown in Papers II-IV (*cf.* Hellström, 2016; Nilsson *et al.*, 2015; HOSANNA, 2013; Åkerlöf *et al.*, 1998).

If the acoustic perspective is considered too late, it may have negative effects on the design process (Coelho, 2016). This is illustrated in Paper II by the fact that, after the competition, the winning proposal had to be moved to areas further from road infrastructure in order to ensure a purposeful sound environment. Training in acoustics would ensure that landscape architects could better communicate with acousticians and know when to involve them.

An important aspect in this context could be to examine how sound pressure levels relate to environmental experience, as this could be an additional way to link the disciplines. This thesis presents some investigations into such links, *e.g.* it is shown in Paper III that masking strategies can be effective at least to 58 dBA. In a study reported elsewhere (Cerwén *et al.*, 2016), the limit was extended to 64 dBA, coming close to Zhang and Kang's (2007) proposal of 65-70 dBA as an upper limit to work with masking strategies. However, as discussed in Paper II, and also reported elsewhere (Cerwén *et al.*, 2016), tranquil qualities could be difficult to achieve at this level (*cf.* Pheasant *et al.*, 2008; Nilsson & Berglund, 2006). It seems feasible to assume, therefore, that different types of sound pressure levels can be associated with different environmental qualities or affordances (*cf.* Thibaud, 1998; Gibson, 1986). It could be fruitful in future work to develop a chart where connections like those described here are summarised.

4.1.3 Shallow strategies: a call for a soundscape approach to noise

It seems that, even when sound is addressed within the field, there is scope to improve the way in which the topic is approached. For instance, when sound is mentioned, the mention tends to be limited to a short section in a publication or a conceptual idea in a design proposal. Mentions of sound typically refer either to the potential of sound or noise abatement. There are fewer examples of combinations of these perspectives and approaches.

In the evaluation in Paper II, three basic categories were used as criteria. It was found that combinations of these categories were unusual. Instead, there was a strong tendency for competition entries to use only one of the categories

(the most typical example being reduction of unwanted sounds, as in the use of noise screens). This use of conceptual, limited or shallow approaches to abate noise is also evident in the review of seminal publications.

It appears that soundscape thinking, where multiple aspects of the sound environment are considered, is not yet integrated in practice. One reason for this could be the limited number of previous applications and examples. Most previous examples have tended to focus on noise reduction and, in some cases, masking strategies. In this thesis, both strategies were combined in Paper III, where a design intervention was built in an urban square. The assessment of the intervention confirmed that the combination of strategies, as in *a soundscape approach to noise*, was the most fruitful approach to enhance the sonic environment. The project described in Paper III could therefore be used as an example to stimulate interest further. In Paper II, a similar approach was identified and referred to as a comprehensive strategy, when discussing the proposal called 'Alice'. Another example of a comprehensive strategy previously mentioned in the thesis can be found in Sheaf square[9] in Sheffield, UK. However, this site has not yet been assessed in research.

Landscape architects have several aspects besides sound that need to be considered. This requires tools to aid consideration for sound in a comprehensive manner. The comprehensive approach formed a starting point in the development of such tools in Papers II and IV, as described and discussed in sections 4.5 and 4.6.

4.2 Soundscape thinking in landscape architecture : A relevant pursuit

This section discusses the relevance of soundscape thinking in landscape architecture. More specifically, it discusses the contributions made in this thesis to understanding the role of sound in environmental experience, in particular in two studies based on a methodological approach that investigated the role of sound in environmental experience (Papers I[10] and III). Furthermore, using experiences drawn from all studies (Papers I-IV), it goes on

[9]The "cutting edge sculpture" on Sheaf square in Sheffield is designed to work as a noise screen, but it is also a water installation. In this way, noise from the road is reduced and masked simultaneously. The sculpture was designed by Si Applied and Keiko Mukaide.

[10] Paper I was based on interviews with patients suffering from stress-related mental disorders and undergoing treatment in a nature-based rehabilitation garden. It was assumed that the findings from this applied therapy situation can be useful to form an understanding of recuperation in other situations as well.

to discuss connections between sound and landscape architecture that were identified on a general level.

4.2.1 Sonic experience

Sound influences health, wellbeing and everyday experience (Meng & Kang, 2016; Preis *et al.*, 2015; Basner *et al.*, 2014). A review of the research situation (see sections 1.2 and 1.3) revealed *e.g.* recent findings indicating a connection between exposure to nature sounds and positive health effects (Annerstedt *et al.*, 2013; Alvarsson *et al.*, 2010). This connection was confirmed in Paper I, where experience of natural sounds seemed to be able to help patients recuperate from mental illness through inducement of "soft fascination" (Kaplan & Kaplan, 1989). Paper I also proposes that the interaction between various sensory inputs could be important in inducing soft fascination. The potential relationship between soft fascination and sound is also considered in Paper III, where the discovery of hidden speakers raised interest, particularly among children who visited the intervention. Fascination is one of four elements in attention restoration theory (Kaplan, 1995), the other three being extent, being away and compatibility.

The negative effects pertaining to noise exposure are well-established in research (Basner *et al.*, 2014). Papers I and III confirmed that technological sounds are generally perceived as problematic. In Paper I, technological sounds were exclusively perceived as negative and it was found that exposure could hinder the rehabilitation process. The disturbance was found to be relative to patients' previous exposure.

In Paper III, a design intervention reduced noise from an adjacent street and this was found to have a general positive effect on the soundscape. However, in the same study it was found that noise could have positive effects in enhancing urban qualities. This confirms previous observations by Whyte (1980) and findings by Anderson (1983).

The role of sound in social interaction and behaviour is discussed in Paper I. In that study, sounds from walking paths had a general positive effect, both to give feedback on the subject's own movement and as a warning signal of other potentially unwanted people approaching. It was also found that the attitudes to sounds from other humans varied depending on loudness, social context and phase of treatment.

To conclude, this thesis work confirms previous findings on the influence of sound and contributes a nuanced understanding regarding some of the relationships between sounds, humans and environments. The role of sound in environmental experience, together with the confirmed potential to influence

the sound environment in landscape architecture, as illustrated in Paper III and elaborated upon in Paper IV, motivates further investigations and implementations in the field.

4.2.2 Sound and landscape architecture on a general level: Activities, materiality and spatiality

This section draws on experiences from Papers I-IV to discuss connections between sound and landscape architecture on a general level. In the papers, three aspects seemed to recur: activities, materiality and spatiality. In what follows, each of the three aspects is used as a vehicle to discuss the relationship between sound, sonic experience and landscape architecture.

Activities

Discussions on activities in this thesis follow a distinction proposed in the Swedish soundscape protocol, where sounds are divided, based on source type, into natural, technological and human-induced sounds (Axelsson *et al.*, 2010; Nilsson & Berglund, 2006). Essentially, the thesis work confirms previous findings pertaining to assessment of these categories, as described in section 4.2.1. It seems that a general strategy for landscape architecture could be to stimulate natural sounds, while finding ways to abate technological sounds. Much of the thesis work was concerned with identifying and discussing concrete actions to achieve this (particularly Paper IV). Human sounds were considered too, but were found to be more complicated to deal with in design situations because: a) perceptions of these sounds are more varied, as indicated in Paper I, and b) localisation of people is more difficult to control in a design situation (but could be tied to certain characteristic locations, such as playgrounds, cafés and markets).

It should be noted that the three sound source categories discussed here are broad and each category covers a wide variety of sources. Moreover, in real-life situations, various combinations of sources are likely to occur. The compatibility between different kinds of activities is dealt with to some extent in the thesis, most typically in situations where masking strategies are discussed, as in Paper III where forest sounds were used to shift the focus from a road[11]. In that particular case, it seemed that the proximity to the respective sound source types could play a role in how they were assessed together. Environmental sounds are in this sense related to gestalt psychology and the

[11]In Paper III, forest sounds were transmitted by speakers to produce an effect of informational masking (Moore, 2012).

notion of figure and ground, as discussed by Hedfors (2003), Truax (2001 [1984]) and Schafer (1994 [1977]).

Such relationships seem to be important to consider when seeking to understand masking strategies. For instance, masking could be problematic if the masker and the target sounds are equally prominent, as this could cause ambiguity. It seems that both visual and auditive cues could be important to determine figure and ground. For instance, attention can be attracted by characteristics of sound, as in a fluctuating water feature (*cf*. Rådsten Ekman, 2015). It has also been shown that visual information can be used to modulate connections in the auditory system in order to change the perception of sounds (Hunter *et al.*, 2010). Visual cues could thus be used to make a water feature seem more prominent, including from a sonic perspective. It seems reasonable to assume that other sensory inputs could have similar effects.

Materiality

Materiality can be linked to a broad number of sensory and phenomenological experiences, including vision and tactility. In terms of hearing, it seems possible to discern three different ways in which sound relates to materials: actively, interactively or passively. This division is based on the way in which sound is affected, or activated, by a material. Each material can be activated in more than one way; the distinction is thus not a means by which to classify materials *per se*, but should rather be considered as a way to understand the inherent possibilities in materials and the way they can be used.

Materials are acoustically active when they produce a sound, as in water features, speakers or rustling vegetation. In active production of sound, the main intention is not to involve visitors in the production of sound. Rather, the materials produce sound independently.

The interactive acoustic characteristic of materials, on the other hand, requires some sort of involvement from visitors to be activated. Examples of acoustically interactive materials are gravel in paths (requires walking) or interactive sound art installations that are triggered by the visitor. Other examples of materials that can inspire interactivity are water mirrors or autumn leaves lying on the ground. The role of acoustically interactive materials is illustrated in Paper I, which found that the interaction with nature in a rehabilitation garden could be improved by the use of walking materials which produce sound when walked upon.

Passive characteristics refer to the passive acoustic qualities of a material and the way a material responds when sounds are projected onto it (as in reflection, absorption and/or transmission). The passive qualities of materials can be important in abating noise, as in the use of absorbing vegetated soil in

strategic positions (HOSANNA, 2013). Furthermore, different materials are known to produce different 'colourations' to the sound that is reflected from them, as experienced, for instance, in the warm atmospheric timbre of a log cabin.

The sonic qualities of architectural spaces are dependent on material and spatial qualities (Blesser & Salter, 2007; Pallasmaa, 2006; Zumthor, 2006; Rasmussen, 1964 [1959]). In addition to sound, atmospheric qualities in architectural spaces involve a number of other cues, including light and the arrangement of objects within a space (Böhme, 2000). The relationship between sound and architecture led the Swiss architect Peter Zumthor (2006) to compare interior spaces to large instruments.

The tripartite way of considering materials, described above in terms of acoustically active, interactive and passive qualities, relates to the distinction made by Hedfors (2003) between landscape as a generator (*cf*. active material) and landscape as a resonator (*cf*. passive material), but applies this distinction to materiality and adds an additional interactive dimension.

Spatiality

Spatiality, like materiality, is a central concept in architectural disciplines. Spatiality is used here to collect some of the findings in the thesis and position these in relation to landscape architecture.

In architectural contexts, spatiality is perhaps most commonly associated with physical delimitation of space, as experienced visually. Blesser and Salter (2007) have shown that it is fruitful to consider space from a sonic perspective. To facilitate discussions on sonic space, Blesser & Salter introduced concepts such as *acoustic arena*[12] and *acoustic horizon*[13] .

The relationship between visual and auditory space seems to be of interest for consideration in design situations. For instance, it is possible to seclude a space visually, yet allow contact sonically. It seems relevant to have terms to describe such connections. For vision, *sight line* is an established term in architectural disciplines used to describe a visual connection to objects of interest. An auditory counterpart seems relevant and a corresponding term for such purposes in architectural disciplines could be *sound line*[14]. The tension

[12]The area in which a sonic event (target sound) can be heard.

[13]Delineates the maximum audible distance to a sonic event.

[14]*Sound line* is introduced here with the intention that it may be used within landscape architecture and related disciplines. It can be used to emphasise a sonic connection to objects of interest in the surrounding environment (as in hearing a waterfall on a distance). Visual connection is not necessary to establish a sound line. The term *auditory channel* (Blesser & Salter, 2007) is related but emphasises the listener and the social dimension more.

between sound and vision is dealt with in Paper IV, where the notion of 'visual masking' is discussed as a potential strategy to reduce impacts from noise.

Sounds are located in space in relation to each other and in relation to an imagined listener. This thesis illustrates how such relationships are relevant to consider in landscape architecture through a strategy denoted 'localisation of functions' (Papers II and IV). A recurring consideration is the relative location of unwanted sound sources (noise) and listening position. Localisation of unwanted sounds is discussed in Papers I, II and IV, with the dominant strategy being to ensure distance to the unwanted sound. In addition to distance, a related strategy is to use positions shielded by noise through topography. In Paper III, the relative directions of sound sources are discussed, as this was identified as a potentially important aspect to consider when working with masking strategies.

Shaping the landscape and physical space also means shaping the prerequisites for sonic space. Buildings, topography and vegetation constitute some examples. When it comes to noise treatment, screens have hitherto been an important tool to control sonic space from unwanted sound. The use of screens is discussed in Papers II-IV in terms of how they could be incorporated in design solutions. In Paper III, noise screens were used to shape a small room, which was then covered with ivy to produce a sense of an arbour. This is one example of how consideration of sonic space can be integrated with the visual shaping of landscapes.

4.3 Representation of soundscapes

As found in this thesis, representations of soundscapes in landscape architecture projects can be divided broadly into visual, textual and auditory representations (*cf.* section 2.3.2).

Visual representations of soundscape proved to be uncommon in the areas of practice studied in the thesis. When visual representations were used to depict sound, their use was mostly restricted to mapping of noise. Based on the way landscape architects tend to work, *i.e.* through visual representations, this is noteworthy. As illustrated in workshops with students reported by Fowler (2013) and in other contexts (Aiello *et al.*, 2016; Vogiatzis & Remy, 2014), there is clearly potential to evolve the use of visual soundscape representations. Such tools would be compatible with established (visual) forums to communicate landscape architecture, such as magazines, posters and books. This would be a major benefit, as landscape architects are already accustomed to communicating with visual information.

Most of the references to sonic experiences encountered during the studies were conceived of in text. As expected, the character of the descriptions covered a wide range, from the rich and almost poetic language used in the literature by *e.g.* Spirn (1998), Halprin (1973 [1963]) and McHarg (1971 [1969]) to the rather limited descriptions based on conceptual words like 'quiet' and 'tranquil' found in several competition entries in Paper II.

A discrepancy in the communication of soundscapes was found in Paper II, as the 'quiet' and 'tranquil' environments often lacked corresponding actions in the design proposals. This reveals the limitations inherent in textual representations and an arbitrary attitude to sound. A similar tendency to describe sonic experiences, but not connect them with design actions, was found in the review of the literature and in Paper I.

Auralisation of soundscapes, as in the simulation of sound environments in virtual (auditory) reality, is not considered in Papers I-IV. This is related to the fact that auralisation was not possible in most cases, due to restrictions in the contexts studied. For instance, the competition in Paper II was restricted to presentation on A1/A3 sheets, which is a common and established format in landscape architecture contexts. This restriction is considered a finding in its own right, as the established tools used in various contexts (*i.e.* visual in this case) are likely to influence the resulting designs.

Drawing on Latour's (1999) notion of "circulating reference", Olwig (2004) argues that the tools used in approaching "the real" (as in a scientific study or in a landscape architecture project) influence the understanding of that situation. Maps, perspectives and drawings are examples of representations that are established as common tools in landscape architecture. Following Olwig's (2004) argumentation, and considering that tools in landscape architecture are predominantly visual, it follows that visual aspects might be given more focus in the design process than would be the case if the designer were working *in situ* or with the aid of *auralisation*.

The notion of "circulating reference" could be extended to include contexts where landscape architecture projects are discussed and evaluated, such as conferences, posters, blogs, books, journals and competitions. Similarly to the design situation, these are environments where predominantly visual representations are used. In some of these contexts, it is possible to complement sonic information digitally, as in online internet pages with sound examples, embedded video or sound recordings.

In the not-so-distant future, it should also be possible to access auralisation techniques as established working tools in the profession. Already today, examples of programmes that can be used in real-time sketching exist (Marchal

et al., 2016; Pelzer *et al.*, 2014). Further development and establishment of auralisation in practice would be a great benefit, as it would potentially be possible to try different solutions and experience how these influence the soundscape. This would provide great possibilities for landscape architects to consider sound in earlier stages of the process. Furthermore, establishment of auralisation would increase understanding among landscape architects about the role soundscapes play in experience of landscapes.

Field recording is a related, but more accessible technique that can be used to capture existing sound environments. Field recordings can be used as a means to complement other forms of landscape representations and/or to understand atmospheric nuances (Prior, 2017). This is useful in teaching situations (Fowler, 2013). Field recordings can be used to discuss relationships between landscape architecture and sound through comparison of different scenarios, or to provide examples of projects and solutions (Cerwén, 2010b).

Textual references, as discussed in section 4.3, are an established way to describe sound in landscape architecture practice. However, there seem to be some discrepancies between textual references and actual design. In a previous interview study conducted in France, it was found that urban planners were "lacking a vocabulary for describing their expectations or even to take stock of urban situations with regard to sound" (Raimbault & Dubois, 2005, 344). Part of the problem was attributed to "a lack of consensual descriptions". More recent progress in the soundscape field has included a definition of soundscape (ISO, 2014) and development of tools for discussing and representing sound (Berglund *et al.*, 2013; Hedfors & Howell, 2011). This development could perhaps also be fuelled by a related discourse as found in human geography, where it is referred to as non-representational (Thrift, 2007) or more-than-representational theory (Lorimer, 2005). Inspiration from these related fields could be used to improve representations of sound in landscape architecture.

4.4 Variation as an ideal soundscape

Much of the work pertaining to sound environments in the 20th century tended to be normative in taking a clear stance against urban noise. This is the case in acoustic ecology and in environmental noise management (*cf.* section 2.2.5). Given the negative health effects and other problems associated with noise exposure from modern infrastructure and machines, this is an understandable position. However, such a normative standpoint fails to take account of the qualities inherent in lively urban areas, where sounds that are arbitrarily labelled as noise can play an important part in an active and stimulating experience (Whyte, 1980). In Paper III this connection is confirmed, as it was

found that visitors were willing both to accept and appreciate a certain amount of urban noise.

However, it is also suggested in Paper III that stimulating experiences should be counteracted with contrasting and relative quiet environments, as this is another important quality. Similar findings are reported in Paper I, where it was found that different needs and preferences among participants could be accounted for by considering a variation in the soundscape. In a sense, a varied soundscape could therefore be regarded as democratic, as it increases the possibilities to choose. The notion of variation is also discussed in Papers II and IV.

It has previously been suggested that city planning should consider the possibility to ensure variation in sound environments, particularly emphasising access to tranquil qualities. Southworth (1969, 67) mentions the possibility to create "sound- and climate-controlled public oases in the center of the city". Hedfors (2003, 60), similarly, describes an *auditory refuge* "as a place which offers another acoustic environment than that of the surroundings". Hedfors goes on to discuss distribution of refuges in spatial planning and suggests that visitor access within 300 m (as in existing recommendations for green area distribution) could be a relevant starting point for auditory refuges. Hällgren (2012b) applies a phenomenological perspective when suggesting a connection between variation and qualitative everyday experience, thus bringing variation to a more detailed scale. More recently, Lacey (2016, 1) calls for what could be described as an *offensive* strategy in suggesting "establishment of networks of sonic ruptures throughout urban centres, to diversify sonic environments and expand the possibility for creative encounter".

Even though the approaches are different, variation is clearly a recurring theme in research on soundscape. Backed by previous research, and supported by findings in the present thesis, it seems feasible to recommend soundscape variation as a strategy to consider as a complement to other aspects in city planning. It would need to be coordinated somehow with other aspects, like visual cues to ensure purposeful environments.

An important aspect seems to be to identify different kinds of possible soundscape characteristics. Research thus far has shown that, on a general level, soundscapes experienced as positive seem to be either tranquil (calm/relaxing) or exciting (exciting/vibrant/dynamic) (Davies *et al.*, 2013; Axelsson *et al.*, 2010; Kang, 2007). The distinction between tranquil and exciting qualities in the soundscape was also a recurring theme in the thesis work and thus seems like a fruitful starting point to consider variation. Exciting qualities are acknowledged to be important, but the focus in the following is on the tranquil dimension, as this seems to be the most pertinent quality to uphold.

The EU (2002) directive on noise (END) is interesting in this context, as it stipulates that member states should map and protect *quiet areas*. It seems that this approach could be fruitful to ensure variation in soundscapes, particularly in urban areas. The END has already led to a number of initiatives, such as 'tranquillity trails' in the UK, mapping of quiet areas in Oslo and 'The Guide to Silence' in Stockholm. However, the END is rather vague in its formulation, which has led to a number of different definitions, methods and applications in member states (EEA, 2014).

It follows from the concept of *quiet areas* that sound pressure levels are important to understand and implement such areas. However, definitions depend on context (urban/rural) and member state and typically vary between 25 and 55 dBA (*cf.* EEA, 2014). For rural areas, the demands are generally higher than for urban areas, where a certain amount of noise is expected (and more easily accepted). In an extensive study of suburban green areas and city parks, Nilsson and Berglund (2006) found that good soundscape quality can only be assured at daytime sound pressure levels below 50dBA. However, they also found that good soundscape quality in such contexts is not merely about sound pressure level. It is also stated in the END (EU, 2002) that *quiet areas* is not a question of absolute silence, but rather the (relative) absence of noise. Absence of noise is beneficial, not only because noise can be disturbing in itself, but also because it makes way for other more subtle sounds, like sounds of nature, to emerge.

An important factor in the future would be to better understand 'quiet areas' in different contexts. For instance, it is possible that quietness in a pocket park is different from quietness in an urban park. Whyte (1980) argues that one of the benefits of Paley Park is the social seclusion generated by its rather powerful waterfall (in addition to masking traffic sounds, the waterfall masks the sounds of other people). This is related to the notion of social quietness (Pálsdóttir *et al.*, 2014), which is discussed in Paper I as an important quality to recover from stress. In some cases, such as in proximity to health centres, areas with a higher sound pressure level (for instance created by a fountain) could be beneficial, as they could offer seclusion from other people. According to Gehl (2006), communication difficulties start to occur at around 60 dBA and this could be a useful starting point in investigating such effects. However, there could be a fine balance here, as Zhang and Kang (2007) report that if the sound pressure level rises above 65-70 dBA, masking sound itself starts to become annoying.

In terms of spatial planning of quiet areas, it seems feasible, as Hedfors (2003) discusses, to coordinate planning of soundscape variation with planning of

green structure. Parks and other recreational areas are particularly sensitive to noise disturbance, and relative quietness constitutes an important quality to ensure tranquillity (Pheasant *et al.*, 2008). In Sweden, the national board for housing, building and planning recommends that dwellings have access to green areas within 300 m and mentions relative silence in green areas as an important consideration (NBHBP, 2007).

Moreover, it seems that active enforcement of quiet areas in practice could be further elaborated in design solutions. Paper IV collates design strategies that could be used for this purpose and the design intervention that was built and studied in Paper III could be a valuable reference object when developing quiet areas in urban situations, particularly in pocket parks and smaller areas.

In design situations, it could also be beneficial to consider variation from a phenomenological perspective. For instance, in the Japanese garden Murin-an, variation in the soundscape is used to counterpoint the visitor's entrance. On the outer side of the garden, there is a loud water feature. Upon entering the garden the visitor passes through an opening in a wall. The sound of the water is screened out by the wall, thus acting to make the experience of entering the garden seem relatively quiet and tranquil. This effect corresponds to what Augoyard & Torgue (2005) call the sonic effect "cut-out".

4.5 Facilitating soundscape thinking: A soundscape approach to noise

A starting point in the thesis work was that the most fruitful approach to working with the sound environment would be to consider it from several different perspectives. This was confirmed by the work described in Paper III, which found that, in a noise-exposed context, the combination of noise reduction and added sounds through speakers was more efficient than noise reduction alone. This was called *a soundscape approach to noise* in the thesis.

There are different ways to describe or define such a comprehensive approach. In the thesis, two different frameworks are used. In what follows, each of these is described and then the two are related in a discussion.

4.5.1 Defensive, offensive and creative strategies

The first framework, used in Papers I and III, was originally proposed by Pascal Amphoux (1993) and its three strategies are denoted by Hellström (2003; 2002) as *defensive*, *offensive* and *creative*. Each of these strategies represents a general attitude to the sound environment.

The *defensive* attitude is the most well-established, corresponding to environmental noise management and reduction of noise. The *offensive* attitude is more concerned with what people want to hear and places more focus on how wanted sounds can be stimulated. The *creative* strategy, which potentially overlaps the other two, includes creative art and design interventions, as well as increasing awareness of sound among citizens.

4.5.2 Introducing a model for comprehensive action: Localisation, reduction and introduction

In Paper II, a new, more specific framework was introduced for the purpose of evaluating a design competition. Amphoux's (1993) division could not be used in this context, particularly as the notion of a 'creative' strategy proved difficult to assess for a large number of competition entries. Thus, a new framework was introduced in the form of a model based on other research (Brown & Muhar, 2004; Hedfors, 2003; Southworth, 1969). Similarly to Amphoux's (1993) approach, this model is based on three strategies or categories; I) *Localisation of functions*, II) *reduction of unwanted sounds* and III) *Introduction of wanted sounds* (see *Figure 7*).

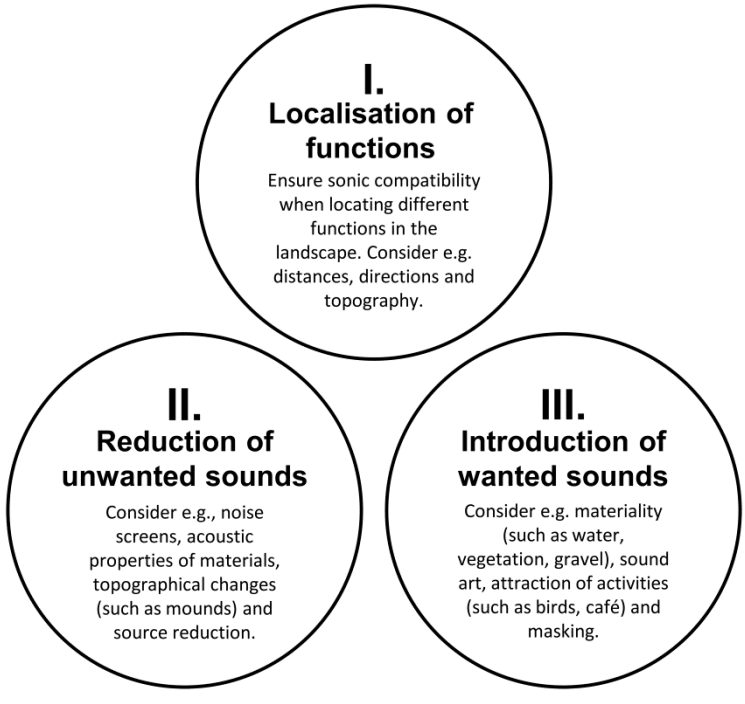

Figure 7. The approach referred to here as a model for comprehensive action, which was used to evaluate competition proposals in Paper II.

Localisation of functions is the category that is most concerned with strategic decisions and overall planning. It deals with how different functions are located in space (and time), and focuses on compatibility between new and existing functions. This typically entails considering the influence of unwanted sound sources, and how noise can be avoided by ensuring distance and/or identifying areas that are shielded by *e.g*. topography and buildings. However, it can also be about identifying existing qualities, like a river, to localise functions. The other two categories concern decisions that are taken when the locations have been fixed and are more related to design decisions. *Reduction of unwanted sounds* is concerned with how interventions in the landscape can be used to reduce noise in a given area. Examples include screens, topographical changes or application of acoustically appropriate materials. *Introduction of wanted sounds* is about introducing or finding ways to stimulate sounds that are considered wanted. Examples include water features, sound art, gravel paths and strategies to attract singing birds.

4.5.3 Comparing two frameworks

The two frameworks described above are related: Not only do they share a tripartite structure, but there is also some overlap within the structures. Amphoux's (1993) notion of a *defensive* strategy, for instance, is akin to *reduction of unwanted sounds*, even if the abstraction levels are different. Similarly, the notion of an *offensive* strategy is akin to *introduction of wanted sounds*. In other words, both frameworks acknowledge problems and possibilities as central factors. This is supported in previous discussions on soundscape design (Brown & Muhar, 2004; Schafer, 1994 [1977]; Southworth, 1969).

The main contribution in the model for comprehensive action introduced in Paper II is the category *Localisation of functions*. This category overlaps the other two and was introduced as it seemed to represent a basic, yet overlooked, consideration for practitioners. The findings in Papers I and II confirm that this is a pertinent consideration that needs further attention.

Both approaches described – that of Amphoux (1993) and the new model in Paper II – could be used to encourage comprehensive thinking on sound in landscape architecture. Amphoux's division is more general and abstract, while the model for comprehensive action introduced in Paper II is more pragmatic and action-orientated. In other words, they have different applications. It is argued in Paper II that the model for comprehensive action could be used "both for understanding and for evaluating approaches to soundscaping in landscape design" (p. 19). The model is also used in Paper IV as a means to analyse and

structure design proposals emanating from three workshops where an extended tool denoted ‘soundscape action’ was formulated (see section 4.6).

4.6 Soundscape actions

A soundscape action could be described as an action that can be performed by landscape architects and urban designers for the purpose of improving soundscapes in outdoor environments, particularly in and around areas exposed to noise. Altogether, 23 soundscape actions are described below (*Figure 8*) and together can be regarded as a design tool. The soundscape actions can be used as a dictionary to inspire ideas and/or as a way of structuring knowledge on the current state-of-the-art.

Below, each soundscape action is summarised[15]. For this purpose, the 23 soundscape actions are structured around three main categories; *Localisation of functions*, *Reduction of unwanted sounds* and *Introduction of wanted sounds*.[16] This is then followed by a discussion on the development of the soundscape action, how it can be applied and its relationship with other tools.

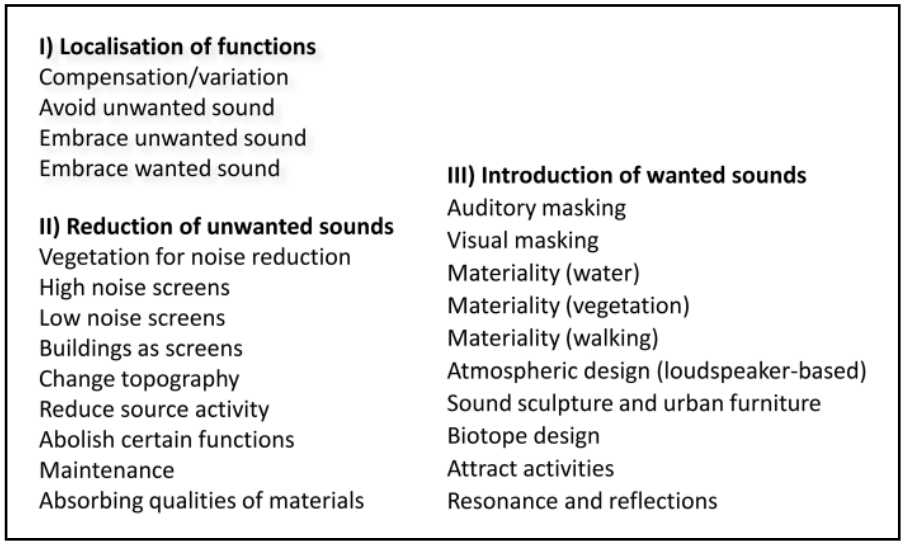

Figure 8. Overview of the 23 soundscape actions identified in this thesis

[15]A more detailed description of each soundscape action (including ideas generated in three workshops in landscape architecture) can be found in Paper IV.

[16]This division is derived from the comprehensive action model introduced in Paper II (see *Figure 7*), which was also used when the soundscape actions were developed in Paper IV.

I) Localisation of functions

Compensation/variation

Strategic use of contrasting soundscapes can be employed as a way to enhance their respective differences as qualities, such as making a tranquil area seem relatively quiet in relation to a busy street. Variation is generally discussed in terms of enforcing tranquil qualities, as in quiet areas (EU, 2002), quiet façade (de Kluizenaar *et al.*, 2011), auditory refuges (Hedfors, 2003) and tranquil space (Pheasant *et al.*, 2008). However, little has been done in terms of investigating the potential for working the other way around (*cf.* Whyte, 1980).

Avoid unwanted sounds

This involves strategic localisation of sensitive functions in positions sheltered from noise. Sheltered positions can be secured if there is sufficient distance to the noise source or by making use of the 'sound shadow' from existing structures like buildings and/or topography. Noise has been shown to have negative effects on health (Basner *et al.*, 2014), communication (Gehl, 2006), sleep (WHO, 2009), acoustic comfort (Yang & Kang, 2005) and willingness to help other people (Cohen & Spacapan, 1984). Furthermore, absence of noise correlates with tranquillity (Pheasant *et al.*, 2008), an important quality in parks, pocket parks and housing areas.

Embrace unwanted sounds

To embrace unwanted sounds is to acknowledge (existing) noise as an urban quality that may be suitable for certain functions, like markets. It has been observed that an active soundscape can have positive effects in enhancing urban situations and offering social seclusion (Whyte, 1980). Sounds that are arbitrarily described as noise may therefore in some cases be perceived as part of an urban quality (*cf.* Paper III and Hellström, 2003). Yet, as discussed in Paper III, it is also important to ensure that some areas are tranquil (*cf.* Compensation/variation).

Embrace wanted sounds

To embrace wanted sounds is to identify qualities that already exist in the soundscape so that they can be used as a prerequisite to locate new functions. For instance, a new café could be located near an existing fountain to make use of the water sound as an atmospheric quality (*cf.* Alexander *et al.*, 1977).

II) Reduction of unwanted sounds

Vegetation for noise reduction

This concerns the role vegetation can play in some contexts to reduce noise. The measurable effect of vegetation in reducing noise has been debated (Van Renterghem *et al.*, 2015), yet if the layer is thick and dense, the effect can be substantial. The ground effect related to the soil substrate should be raised in this context (HOSANNA, 2013), as well as visual screening (*cf.* visual masking) and the sound of rustling leaves (*cf.* auditory masking and materiality (vegetation)).

High noise screens

High noise screens are approximately 1.8 m and above. These screens should be located as close to the source (or listener) as possible for optimal effect (Forssén *et al.*, 2015). The effect depends on a number of factors, where height is the main determinant (HOSANNA, 2013). In addition to conventional usage, high noise screens can be used in a creative manner, as part of urban design solutions incorporating features like seating (Fusaro *et al.*, 2017), water and/or vegetation (*cf.* Paper III and Hellström *et al.*, 2013).

Low noise screens

A low noise screen compensates for its lower height (up to around 1 m) by increased proximity to the noise it is screening. The effect can be substantial in some cases (Defrance *et al.*, 2015), but there are practical issues like maintenance and traffic safety to consider. Like high screens, low screens can be combined with creative solutions that incorporate water and vegetation to form part of an urban design solution.

Buildings as screens

Strategically located buildings can be used as less obvious, yet effective, noise screens, also in combination with conventional screens. Besides the height of the buildings, the shape, location and materials applied in the building are important (Hellström *et al.*, 2013). If the buildings are intended for housing, care needs to be taken to avoid sleep disturbance (FHWA, 1976). Noise exposure on one side of the building can be compensated for to some extent by a quiet façade where bedrooms can be located (de Kluizenaar *et al.*, 2011).

Change topography

The shaping of the landscape topography can be used to form hills, berms or strategically shielded valleys. Earth berms along major infrastructure constitute a well-known application (MTH, 1997). The detailing of berms in terms of shape and use of vegetation material can have a substantial effect on performance (HOSANNA, 2013).

Reduce source activity

The reduction of source activity constitutes a broad number of measures that are aimed to influence the way an activity is carried out, so that noise is reduced. In this thesis work, this action was mostly concerned with reduction of traffic speed. Two different approaches were discernible; enforcement of rules (*e.g*. speed limits) and design solutions that affect certain behaviours (*e.g*. reduced lane size and shared space solutions). In the latter approach, a parallel can be drawn to the notion of environmental affordances (Gibson, 1986), a term which has also been applied to sound environments (Thibaud, 1998).

Abolish certain functions

Abolition or complete transformation of functions that produce unwanted sounds, like the transformation of a car road to a walking path, can be considered. Such a development would seem likely in relation to densification and sustainable development. If traffic roads are transformed into green paths, this action would be related to *biotope design* and *absorbing qualities of materials*.

Maintenance

Everyday maintenance of outdoor space can have negative influences on the soundscape, particularly through use of machines with combustion engines. Maintenance can be considered by landscape architects in maintenance plans, but also in design solutions (Cerwén, 2017). For instance, a meadow is less likely to result in noisy maintenance activities than a mown lawn. Maintenance may contribute qualities in the soundscape, as when hand-driven tools are used or when animals are involved.

Absorbing qualities of materials

The absorbing qualities of certain materials can be used, particularly in conjunction with unwanted source activities like roads, to reduce the impact

from the sound (*cf.* Forssén *et al.*, 2015). An interesting and useful example is vegetated soil, but there are also other strategies under development in collaboration with acousticians (HOSANNA, 2013).

III) Introduction of wanted sounds

Auditory masking

Auditory masking is a phenomenon that occurs when a sound (masker sound) influences the perception of another sound (target sound), so that the focus shifts from the target to the masker sound. There are two general types of auditory masking; energetic and informational (Moore, 2012). In energetic masking, the target sound is rendered inaudible (or less loud). In informational masking, both sounds are audible but the focus shifts towards the masker sound (*cf.* visual masking). Masking is a complex phenomenon that depends on several cues for successful implementation, including physical characteristics of sound sources and their relative location in space (*cf.* Paper III). Zhang and Kang (2007) suggest that it is not fruitful to use this strategy if the sound pressure level exceeds 65-70 dBA. If the intention is to achieve tranquil qualities, significantly lower levels than this seem preferable in most cases (Pheasant *et al.*, 2008; Nilsson & Berglund, 2006). A possible exception is when tranquillity is associated with social seclusion, in which case it may be desirable to have higher sound pressure levels[17] in order to obstruct communication (Whyte, 1980).

Visual masking

The general idea in visual masking is that, by hiding the visibility of an unwanted sound source, the focus can be shifted away from the noise, thus reducing the negative impact. A typical application of visual masking is using vegetation to hide a road, with the vegetation having multiple other effects as well (*cf.* vegetation for noise reduction and materiality (vegetation)). The appropriate application of visual masking has been debated and the usefulness seems to be dependent on the situation. Botteldooren *et al.* (2016) suggest that visual masking is a fruitful strategy as long as the noise is not too obvious, whereas with obvious noise the illusion is more difficult to achieve.

[17] According to Gehl (2006), communication with other people starts to become difficult at around 60 dBA.

Materiality (water)

Water is a classical component in landscape design that can be used for multi-sensory effects. There are multiple possibilities to control the sound of water, for instance in terms of location, timbre, strength and rhythm (Nikolajew, 2003; Halprin, 1973 [1963]). This could be one of the reasons why the sound of water is commonly used as part of masking strategies (*cf.* auditory masking and Rådsten Ekman, 2015; Galbrun & Ali, 2013; Brown & Rutherford, 1994).

Materiality (vegetation)

The sound of vegetation is perhaps most typically associated with leaves that rustle in the wind; this particular effect can be enhanced through strategic choice of species like poplar, bamboo and winter beech (Yang *et al.*, 2016; DeGroot, 2015). In Paper I, it is suggested that windy positions could be chosen strategically to enhance the effect of rustling leaves (*e.g.* open fields, mounds and wind tunnels). An additional benefit of vegetation in such locations could be to reduce unwanted impacts of wind. Vegetation can be associated with other sounds than rustling leaves, *e.g.* the sound of rain can be enhanced by certain species such as bamboo, lotus and plantain (Yang *et al.*, 2016).

Materiality (walking)

Walking constitutes an interaction with the landscape that can be enhanced through sonic feedback. This effect is discussed in Paper I, with gravel and (in particular) wood being examples of materials that could give positive feedback. Findings by Aletta *et al.* (2016a) confirm the impact of walking sounds on soundscape quality, yet more research is needed to assess different kinds of materials. Interestingly, it has been shown that soundscapes can influence walking pace (Maculewicz *et al.*, 2016).

Atmospheric design (loudspeaker-based)

Speakers are increasingly being used for various purposes in urban situations. Sounds emitted through speakers can be used to design atmospheric qualities in the environment. These atmospheric installations are not necessarily audible, but aim to improve the architectonic qualities, particularly focusing on the atmosphere. Two previous studies (Hellström *et al.*, 2014; Billström & Atienza, 2012) that assess users' perceptions of such installations conclude that there is potential to explore this approach further. There are also reports from

designers and artists sharing their experiences (Lacey, 2016; Dyrssen *et al.*, 2014; Hellström *et al.*, 2011; Licitra *et al.*, 2010).

Sound sculpture and urban furniture

Sound sculptures are installations that include sound as an important and obvious part of an embellishment. The sound may be introduced through speakers, or by other means. Sound sculptures can be merged with urban furniture to include visitors as part of an interactive experience, or function as a passive, yet clearly noticeable, embellishment. Musikiosk, an installation built in a pocket park in Montreal and later evaluated in research, has been found to enhance mood in visitors (Steele *et al.*, 2016) and to have a positive effect on social dynamics (Bild *et al.*, 2016b). In Paper III, it was shown that a speaker installation could be used to detract focus from noise.

Biotope design

Through consideration of biotopes, birds and other animals that contribute sonic experiences can be attracted (Dawson, 1988). Hedfors (2003) introduced the term "sonotope", which could be applied to emphasise the sonic character of biotopes. Songbirds are generally attracted by basic habitat features, such as access to water, food and sheltering vegetation (Forman, 2014; DeGraaf, 2002). Vegetation and water can attract birds, and produce sound in other ways (*cf.* materiality (vegetation and water)). To attract birds, vegetation should ideally be dense, varied and in several layers. It could also be beneficial to have older (and dead) vegetation, as there is a correlation between forest stand maturity and bird species diversity (Gil-tena *et al.*, 2009). Sounds of nature are generally perceived of as positive (Axelsson *et al.*, 2010) and bird song diversity has been shown to enhance appreciation of urban landscapes further (Hedblom *et al.*, 2014).

Attract activities

Some areas intended for specific human activities, like cafés or playgrounds, can generate a certain kind of soundscape. These soundscapes can offer qualitative experiences even for people who are not actively involved, but in the vicinity (*cf.* Embrace wanted sounds and Alexander *et al.*, 1977).

Resonance and reflections

The acoustic qualities of materials and spaces can be used to enhance certain wanted sounds through reflections and/or resonance effects. Such effects can be used to emphasise qualities in the soundscape, such as water features, meeting places and walking paths. The reflections may also constitute an experience in their own right, as in a way to interact with the landscape (Pallasmaa, 2012 [1996]; Blesser & Salter, 2007; Rasmussen, 1964 [1959]).

4.6.1 Soundscape actions: Future developments and positioning

The soundscape action model developed in Paper IV is a response to the need for knowledge specifically tailored for landscape architects. In order to develop and structure such knowledge, it was concluded that the most fruitful way would be to work close with practice. Three workshops in landscape architecture were arranged to accommodate this. The outcomes from the workshops were analysed to identify recurring ideas and approaches. This was considered as a good way to identify pertinent areas and ensure validity for practitioners. A set of 22 areas was identified and denoted 'soundscape actions'. These were then used as a framework to discuss the current state-of-the-art in research. As noted in Paper IV, an additional soundscape action, 'Embrace wanted sounds', was added in the above description, amounting to a total of 23 actions.

In Paper IV, it is suggested that there are other possible ways in which the soundscape actions could be sorted. For instance, it could be useful to distinguish between major actions (like auditory masking, visual masking and avoid unwanted sounds) and minor actions (like walking material, low noise screens and attract activities). Future work should investigate the possibility to develop an interactive version of the soundscape actions with overlapping tags or filters to allow multiple options for sorting the actions. This could aid identification of pertinent actions for designers. Such a digital platform would also allow changes and updates as the field develops[18].

The soundscape action model is one of a growing number of tools for architectural practices available today (see review in section 2.3.2). Soundscape actions represent an approach that is based in landscape architecture practice and focuses on improvement potential in the soundscape. There is a relationship to the "sonic effect" (Augoyard & Torgue, 2005; Augoyard & Torgue, 1995), which is a powerful tool offering a deep and

[18] A digital platform for similar purposes has previously been developed by the thesis author (Cerwén, 2010b). This platform could potentially be extended in future work to include 'soundscape actions'.

comprehensive understanding of the sonic environment. The total of 82 sonic effects cover a wide variety of aspects of the everyday experience of sound. The focus of the sonic effect approach on sonic experience differs from that of the soundscape action, which instead focuses on potential ways to change a sound environment. The soundscape action is thought to be a more straightforward approach to facilitate soundscape thinking for practitioners on a general level.

Among previous tools, soundscape actions relate particularly to the toolbox for acoustic design described by Hellström (Hellström, 2016; NBHBP, 2016; City Sounds, 2013) and Lacey's (2016; 2014) model for sonic rupture. The latter, which was developed in artistic practice, is based on abstractions that seem to be applicable on a general level, also for designers and architects. The toolbox for acoustic design (City Sounds, 2013) places rather more focus on building architecture and structures, while the soundscape action takes better account of issues more typical for landscape architects, including system thinking, activities and spatial localisation.

In future work, practitioners should be further involved to discuss soundscape tools in terms of applicability in different contexts. Such studies could be used to develop and position the concept of soundscape action further. A possible combination or collection of different tools could be investigated.

5 Concluding remarks and future prospects

The thesis was practice-orientated in its aim to facilitate soundscape thinking in landscape architecture. It contributes knowledge and examples of how it is possible to work with sound in landscape architecture, particularly focusing on areas exposed to noise. The thesis also increases understanding of how practising landscape architects actually work with sound and introduces strategies and tools by which such considerations can be further enhanced.

The thesis illustrates that the potential to work with sound in landscape architecture is yet to be fully recognised. The study of contemporary practice reveals a rather shallow focus on sound and a reliance on environmental noise management to deal with noise-exposed situations. Increased collaboration between these professions would seem to be a good way forward. A prerequisite would be to identify bridges between quantitative sound pressure levels and qualitative design considerations (the thesis provides several examples). There is also a need to raise examples and formulate knowledge directed at landscape architecture. The thesis illustrates how landscape architecture could approach problems with noise, *e.g*. through incorporation of basic acoustic knowledge in design solutions and through masking strategies.

The thesis emphasises a comprehensive approach where problems and possibilities in the soundscape are accounted for – also referred to as *a soundscape approach to noise*. This is summarised in a tool based on three different categories; localisation of functions, reduction of unwanted sounds and introduction of wanted sounds. Each of these three categories represents a general approach by which it is possible to achieve soundscape improvement, and each of these three major aspects should be given consideration.

An extended version of the comprehensive tool is also introduced. This tool, based on the same three basic categories, is denoted ‘soundscape action’ and includes a list of 23 concrete actions that could be taken to improve

soundscapes in noise-exposed situations. The soundscape actions were formulated in a series of workshops that involved practising landscape architects, artists, students, acousticians and other professionals. This increases the relevance of the tool for landscape architects, as well as stimulating collaboration between disciplines. In future work, the soundscape action should be evaluated together with practitioners and possibly reformulated or optimised for various contexts. In particular, it would be interesting to formulate a set of actions that are not necessarily related to noise, but focus on the role of sound as part of a phenomenological and interactive experience.

An important aspect of landscape architecture is how landscapes are represented. This was not the major focus in the thesis, yet the development of representations was identified as a strategy for further implementation of soundscape thinking in the field. Technological developments have indeed already created possibilities to represent sound in landscape projects in various ways, for instance through auralisation techniques. Future work should investigate possibilities for connecting auralisation techniques with the soundscape action, to produce a platform for soundscape action sketching. Another, possibly related, way to further develop the soundscape action approach developed in the thesis would be to present the soundscape actions interactively and online by use of overlapping tags to sort the outcomes in a flexible and user-friendly manner.

In terms of appreciation of soundscapes, it was found that variation and relationship between different kinds of soundscapes constitute a central aspect that should be given further consideration in future work. The notion of ‘quiet areas’ has attracted greater attention within the EU since the implementation of the Environmental Noise Directive in 2002. As a concept, ‘quiet areas’ seems to be a good way to enforce variation in soundscapes, particularly in urban situations, where mapping and enforcement of quiet areas could be coordinated with green plans.

The pronounced focus on sound in the thesis should not be considered as a suggested paradigm, but rather as a means by which to inform landscape architecture in general. While the thesis focuses on sound as an isolated sensory input, the connection to the other senses is raised as significant. In particular, a potential connection between sensory connectedness and health benefits through the notion of ‘soft fascination’ was identified. This connection should be studied in future work. For instance, it would be interesting to compare natural and urban experiences in terms of sensory connectedness. A health-promoting tradition called forest bathing (*shinrin-yoku*) in Japan could be interesting in this context, particularly in relation to dense cities such as Tokyo.

Contemporary landscape architecture is facing new challenges related to increasing demands for sustainable development. Densification of cities can have positive effects in stimulating urban life and activities. However, densification could also be problematic if the higher density of activities causes overstimulating environments. In particular, it seems reasonable to assume that the need for contrasting and tranquil areas will increase as a result of densification, making it pertinent to consider the soundscape in terms of effective and strategic land use, as in localisation of functions.

This thesis illustrates some of the ways in which sustainable development can have positive effects on the sound environment. For instance, the use of vegetation (soil) in strategic locations can reduce the impact from unwanted sounds. New kinds of urban furniture, as exemplified in the thesis, can be designed in a way that is also beneficial acoustically. The increased use of vegetation in cities can be a means to introduce and enhance wanted sounds to promote health and environmental experience. Landscape architecture is a profession of the times, and one in which the importance of green, blue and environmentally friendly solutions can be accommodated. Soundscape thinking adds an additional perspective to take account for.

Other related changes in society, such as increased use of electric cars and bicycles, might well alter the prerequisites for dealing with soundscapes in landscape architecture in the future. If traffic noise is reduced, this would surely change the character of cities, for better or in some cases perhaps for worse.

The intention with the present thesis was not to introduce a static set of understandings for sonic considerations in cities, but rather to stimulate soundscape thinking in the field. It was decided that the best situation to position this undertaking would be to address an issue that is already considered relevant – noise. Hopefully, the thesis work will stimulate soundscape thinking, not only about noise, but also beyond.

In the beginning of this thesis, an interesting metaphor originally proposed by the Canadian composer Murray Schafer, in which the sound environment is likened to a continuously ongoing musical orchestra, was paraphrased. Similarly to an orchestra, the soundscape has the potential to be subtle or intense.

These qualities cannot co-exist, but the variation or tension between these states is often what constitutes the essence of an experience.

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Looking back on these last few years of working with this thesis, I have mixed emotions. On the one hand, it is satisfactory to finish a great undertaking. On the other hand, there are many things I will miss, such as the freedom associated with writing and the possibility to combine travel and work. Most of all, however, I will miss the people involved in the project. I would like to take the opportunity here to thank some of the many people who were involved in, or associated with, the project.

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This thesis is about sound in landscape architecture. The soundscape concept is used to emphasise the experience of sound and discuss design applications, particularly in noise-exposed situations. A set of strategies and tools for the profession is introduced as *a soundscape approach to noise,* where problems and possibilities are accounted for. This approach is exemplified in a reference project that was built and evaluated as part of the thesis.

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