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Research into the Practical and Policy Applications of Soundscape Concepts and Techniques in Urban Areas (NANR 200)

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Research into the Practical and
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Executive Summary

- 1 The aim of this review was to investigate existing research into soundscape concepts and to produce recommendations for future research into the practical identification, management and enhancement of soundscapes in urban areas.
- 2 Existing research on soundscapes was investigated using four methods:
 - i. a survey of more than 500 papers in the academic literature,
 - ii. an analysis of 27 case studies of soundscape assessment,
 - iii. an analysis of 15 case studies of soundscape design, and
 - iv. interviews with five key soundscape experts.Analysis of this data was conducted to identify significant gaps in the knowledge base and suggest a way of obtaining a practical soundscape assessment method.
- 3 Soundscapes were found to be a highly multi-disciplinary topic, with many different ideas, concepts, aims and methods evident in the literature. The definition of the term soundscape is itself not settled; for the purposes of this project, we have defined it as “the totality of all sounds within a location with an emphasis on the relationship between individual’s or society’s perception of, understanding of and interaction with the sonic environment.”
- 4 This review highlights that a range of methodological approaches have been used to establish classifications and categorisations of *sounds* and *soundscapes*. The relationship between different categories of *sounds* and their interaction needs to be considered to increase the understanding of *soundscape* assessments and to derive soundscape classifications.
- 5 The different methods and tools used to assess soundscapes, in a variety of locations, each have advantages and disadvantages; using a number of methods in one case study can help to mitigate against the disadvantages of any one method. The case studies assessed in this report demonstrate the importance of individual and demographic similarities/differences, people’s behaviour, physical aspects of the soundscape, other sensory and environmental elements, and the general location and context, in understanding and assessing soundscapes.
- 6 Soundscape assessments involving a subjective component have highlighted a number of variables that play a part in the assessment. These include the individual’s knowledge and prior experience of the soundscape, the meaning they derive from it, their attitude towards the sound source, their behaviour, their noise sensitivity, demographic and cultural dimensions, and their sense of control over the noise.
- 7 Research has shown that sometimes a soundscape is perceived as a collection of the individual sounds of which it is comprised; soundscape assessments are therefore related to the assessment of those sound types. This implies that soundscape assessment relies upon the identification of the sounds, the prominence of the sounds, and potentially the ratio of certain sound types to other sound types within the soundscape. It is also highlighted that, because the soundscape varies over time, note must be taken of the fact that any soundscape assessment relates to a singular

moment in time. Furthermore, research has shown that soundscape assessments can be dependent on an individual's memory (when using subjective assessments methods) and/or the segment of the soundscape that was recorded (when playing back recorded soundscapes in a laboratory situation).

- 8 Multi-sensory experience is also shown to be highly relevant to soundscape assessment and must therefore be acknowledged as soundscapes are not perceived in sensory isolation; in particular audio-visual interactions have been shown to have an effect on soundscape perception. Many researchers point to the importance of understanding the full environmental and social context for soundscape assessment, the relevance of comparing similar place types, and the effect of moving between one soundscape and another on an assessment.
- 9 Turning to the subject of soundscape design, it is noted that there is a dearth of case studies involving the modification and design of soundscapes, both in the UK and internationally. The rationale behind many of the case studies' focus upon or consideration of sound was the improvement of a soundscape that was negatively affected by the sound of traffic. Approaches to soundscape design varied, ranging from the use of noise control elements, such as barriers and absorbers, to the utilisation or exploitation of natural elements that already exist in the location. Some case studies introduced sounds to the soundscape, in particular water sounds, while others incorporated specific sonic art installations to alter the soundscape or detract attention from existing features of the soundscape. A number of case studies used design alterations to improve the soundscape and perception of the soundscape including altering visual aspects of the place, altering the layout of the area, pedestrianisation of the area, and providing entertainment facilities (e.g. cafes).
- 10 Case studies whereby design modifications or interventions have taken place, have had little or no formal evaluation of their success. The studies that were evaluated used a number of different methods involving both objective and subjective measures and included the experimental comparison of subjective ratings, observations of people's behaviour, recognition and awards for good designs, and level of complaints about the soundscape. This demonstrates that different evaluation tools may be necessary dependent upon the type of soundscape intervention being evaluated. Additionally, by combining methods to produce an interdisciplinary evaluation, a more accurate understanding of the success of the soundscape design is possible, hence improving future interventions.
- 11 The relationship between environment and individual is complex, with many factors, some of which cannot currently be quantified. Important factors include: prominent individual sound sources, the interaction of sources, other sensory stimuli and contextual and individual factors such as meaning, and expectation. Some of these factors can be captured by subjective rating scales for high-level concepts like 'calmness', 'vibrancy' and 'spaciousness'. Other factors, such as the semantic meaning of a soundscape are best characterised currently by qualitative descriptors. There are good prospects for developing objective acoustic metrics to evaluate some factors but in most cases this work is still at an early stage, and the methods developed so far have only been applied in specific contexts; to provide

metrics that are more broadly applicable they would need to be evaluated in a broader range of locations and conditions. The expert interviews and case studies illustrated the diversity of views across different disciplines on the most promising soundscape methods. All the interviewees agreed on the need for an interdisciplinary approach, and on the need to retain some form of subjective rating when assessing soundscapes.

- 12 Ultimately, six important gaps have been identified in the soundscape knowledge base. These are areas where more research would significantly improve understanding soundscape assessments. These gaps have been identified as:
 - i. a lack of genuinely interdisciplinary projects (characterised by a shared perspective) instead of multidisciplinary projects (where researchers work in parallel within their own disciplines). These are needed to deal with the multidimensional experience of soundscape perception.
 - ii. a lack of basic knowledge on many aspects of soundscape cognition, perception and classification.
 - iii. a need for large-scale robust field trials of soundscape assessment methods instead of the more common experiment of a new method in a single location.
 - iv. a need to develop more soundscape-specific indicators and tools that could eventually be used for soundscape design.
 - v. a need to rigorously assess deliberate soundscape interventions to understand which design aspects work and which do not.
 - vi. a lack of a close connection between soundscape research, design and planning practice.
- 13 Finally, a new research project is proposed to develop a robust field assessment method. The aim of this project is to develop a method based on existing research methods but introducing greater confidence by trialling the method across many real urban soundscapes. Options are presented for developing a purely qualitative assessment tool or one that incorporates and integrates both qualitative and quantitative ratings.
- 14 We recommend that a first step for an assessment method, which could realistically be developed in the near future, should be based on qualitative methods. A second iteration of this soundscape assessment tool could supplement the qualitative techniques with quantitative methods, first based on subjective rating scales and eventually on objective metrics which predict the subjective ratings.

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1 Introduction

1.1 Background to research project

- 1.1.1 The term soundscapes is often considered an adaptation of the visual term landscapes (Schafer, 1994 – originally published 1977), changing the focus from the visual to the sonic environment. Currently there is no one agreed definition of soundscapes (Genuit & Fiebig, 2006), but a working definition used for the purposes of this report is as follows: soundscapes are the totality of all sounds within a location with an emphasis on the relationship between individual's or society's perception of, understanding of and interaction with the sonic environment. This definition is based upon original soundscape definitions and landscape definitions (Defra, 2007; Schafer, 1994; Schulte-Fortkamp & Dubois, 2006; Truax, 1978). Soundscapes can be studied at the micro (individual place, e.g. urban park, street, room), meso (small area, e.g. residential area, large shopping mall) or macro level (large area, e.g. whole city).
- 1.1.2 Soundscapes are important as they may affect people's well being and quality of life (CALM, 2004; Mayor of London, 2004). They can be evaluated in positive and negative terms, yet they are still relatively poorly understood. Like individual noises, some soundscapes can be detrimental to people's physical and mental health, causing sleep disorders, stress, and reduced cognitive capabilities amongst other deleterious effects, affecting both children and adults (Department of Health, 2009; World Health Organisation, 2000). The presence of such negative soundscapes and the lack of access to positive soundscapes may prevent individual's restoration (Gidlöf-Gunnarsson & Öhrström, 2007; Payne, 2008; Soundscape Support to Health, 2008), thus adding to the social and economic costs to society (Grahm & Stigsdotter, 2003).
- 1.1.3 Soundscapes can influence individual's behaviour, as awareness of peripheral environmental cues can be limited if attention is taken up by the intensity and complexity of competing dominant stimuli information. Depending on the evaluation of the soundscape, individuals may be inclined to stay for longer or shorter periods of time in a place in addition to altering their activities and their communication with one another. For example, loud traffic sound levels reduced the awareness of unusual objects (e.g. balloons tied to lampposts, an individual wearing a party pink hat) and increased individuals' walking speeds (Korte & Grant, 1980), while high 'noise' levels can also reduce people's willingness to help others (Mathews & Canon, 1975; Moser, 1988).
- 1.1.4 This project was commissioned by the Department for Environment, Food and Rural Affairs (Defra), the Devolved Administrations of the Scottish Executive, the Welsh Assembly Government and the Department for Environment in Northern Ireland, with the objective of reviewing the present state of soundscape research and providing recommendations for the future direction of soundscape research in the United Kingdom.

1.2 Policy context

- 1.2.1 It is important to consider the current policy context relating to soundscapes, to set the scene as to how soundscapes and related issues are currently defined and managed. In addition, the political handling and regulations for soundscapes can alter the conceptualisation of sounds and how they are assessed (Bröer, 2002, 2007). This is because the language used by the public can depend upon the language used within policies; for example, the Dutch consider noise to be an environmental problem, while the Swiss consider noise in relation to living conditions (Bröer, 2007). Additionally, policy practice can also influence the level of complaints, which in turn is viewed by some as an indicator of noise annoyance (the Dutch complain more than the Swiss about aircraft noise; Bröer, 2007). There are also indirect effects involved with the evaluation of soundscapes, such as socio-economic costs as 'quieter areas' are highly valued; the impact of noise on rents in Geneva are around 0.7 to 1% per decibel (Baranzini & Ramirez, 2005). Moreover, as the social acceptance of certain sounds become known and reacted too, patterns of social behaviour change, with some behaviours being adapted and others becoming prohibited (Atkinson, 2007). Therefore, when soundscapes are to be managed and controlled in one area, but left in another, such implications should be considered.
- 1.2.2 The Environmental Noise Directive addresses issues around the assessment and management of environmental noise (European Parliament & Council, 2002). It aims to seek a common approach between European Community Member States, to "avoid, prevent or reduce, on a prioritised basis the harmful effects, including annoyance due to exposure to environmental noise" (European Parliament & Council, 2002, pp.L189/13). This included the production of noise maps of large agglomerations, through the use of noise indicators, such as L_{den} and L_{night} . In addition to communicating these noise maps to the public and creating action plans to prevent and reduce environmental noise in identified areas, a specific mention was made of "preserving environmental noise quality where it is good" (European Parliament & Council, 2002, pp.L189/13) and preserving 'quiet areas'. The development and use of 'supplementary noise indicators' was also recommended for 'special noise situations', such as, infrequent noise events and combined noise sources. The broad terminology used, provides the potential to incorporate a soundscape approach and a positive perspective to the management and preservation of good environmental noise (sound) quality.
- 1.2.3 A review of research relating to quiet areas established that no precise definition of 'quiet areas' could yet be determined as recommendations varied (Defra, 2006). Instead, procedures for identifying quiet areas were recommended for both the short and long term. A series of filters were suggested to identify quiet areas. These included quiet areas having a total combined sound level L_{day} below 55dB(A) (decibels, A-weighted) in the daytime and the size of the area needing to be a minimum of 9 hectares, with at least 4.5 hectares having a L_{day} below 55dB(A). Flexibility in the use of filters and recommended values was advisable depending on the type of land being considered (Defra, 2006). For example, more stringent protection measures may be advised for church yards and cemeteries, because one of their primary purposes is for 'quiet contemplation'

(PPG17, 2002). Policy documents also comment upon open spaces' potential to provide quiet areas (SPP11, 2007), while others are aware that activities in open spaces can even add to community noise (TAN16, 2009; PPS8, 2004). In Sweden, the importance of 'quiet sides' to residential properties ($L_{Aeq24} < 45\text{dB}$) has been acknowledged and incorporated into planning, but the inclusion of a soundscape concept is still limited within political discussions (Kihlman, 2007).

- 1.2.4 To guide local authorities' consideration of planning proposals in relation to noise, and the protection of citizens from any of its adverse impacts, planning policies were developed throughout the four UK countries. In England, there is Planning Policy Guidance 24: Planning and Noise (PPG24, 1994); in Scotland, there is Planning Advice Note: PAN 56, Planning and Noise (PAN56, 1999); in Wales, there is Technical Advice Note 11: Noise (TAN11, 1997); in Northern Ireland, although not enacted the PPG24 (1994) is sometimes used for guidance on noise exposure. Guidelines included considering the daytime and night time sound levels in proposed areas for different types of industrial, transportation and mixed sources. The proposed sites and dwellings are then classified according to sound levels and the noise implications are considered as part of the rejection/ acceptance of the planning proposal, along with various mitigation approaches that could reduce the impact of any noise (PPG24, 1994).
- 1.2.5 A National Ambient Noise Strategy is to be developed which incorporates both environmental and neighbourhood noise (Defra, 2008a). London already has its own ambient noise strategy which has the practical aim "to minimise the adverse impacts of noise on people living in and working in, and visiting London using the best available practices and technology within a sustainable development framework" (Mayor of London, 2004, pp.8). In addition to a focus upon noise and reducing transportation noise, there is a focus upon positive sound elements and a consideration of soundscapes in particular. This has led to further work on relative tranquillity and quiet areas (Mayor of London, 2006) as well as a review of popular soundscape indicators (Arup Acoustics, 2007) and exemplar 'sound-conscious urban design' in various cities (Mayor of London, 2007).
- 1.2.6 Individual councils, such as the City of Westminster, are also in the process of producing local authority noise strategies. The draft report for the City of Westminster (2008) identifies the need to consider noise in the production of sustainable cities due to the cognitive and health effects it can have on people. The draft report also acknowledges the importance of considering positive sounds and the preservation or production of positive soundscapes rather than just the mitigation of negative soundscapes (City of Westminster, 2008). The consideration of sound (both positive and negative) in the design of the built environment and the policies being developed, alongside good communication and understanding between the local authority and residents are identified as important aspects for the local authority (City of Westminster, 2008).
- 1.2.7 To summarise, the sonic environment has been recognised as an important component of people's experience of places, impacting upon their health, general well being and quality of life. This has led to political concerns over sound levels and the need to produce noise maps and action plans to mitigate the impact on

humans (European Parliament & Council, 2002). A number of surveys have been conducted confirming people's concerns about noise (e.g. National Noise Survey, by MORI Social Research Institute, 2006; National Noise Attitude Survey, by Skinner, Ling, Grimwood & Raw, 2002) but the focus has been on noise annoyance, in particular relating to neighbours and road traffic (e.g. noise maps). To date, little work in policy has included the concept of soundscapes, considered positive evaluations of sounds, or considered how laypeople's perception and evaluation of soundscapes can be incorporated into the planning process (Adams, Cox, Moore *et al.*, 2006).

1.3 Objectives

The objectives of this project were:

- 1) To report upon current soundscape research and identify the methods and techniques used for soundscape assessment and management.
- 2) To produce recommendations as to which soundscape concepts and techniques should be the focus of future soundscape research in the UK.
- 3) To produce a research proposal which provides a robust evidence base for enabling the development of practical guidance to identify, manage and enhance soundscapes in urban areas.

2 Overview of Soundscape Research

Research into soundscapes is a very broad and multidisciplinary topic. This section briefly covers the origins of the soundscape concept and describes some of the theoretical approaches involved in its conception. A few soundscape specific models and frameworks have been developed to describe soundscapes. These are depicted here along with the variety of methodological approaches used in soundscape research and planning.

2.1 Origins of the soundscape concept

- 2.1.1 Soundscapes were investigated, and possibly first defined, in the 1970s by musical composers, in particular R. Murray Schafer and his World Soundscape Project colleagues (Schafer, 1994 – originally published in 1977). Schafer and his colleagues took a phenomenological approach to soundscapes providing detailed descriptions of present and past sounds in villages and their construed meanings (Five villages soundscapes project, cited by Schafer, 1994). An emphasis was placed on examining noise not just by its physical properties, but also by studying the social meanings attached to the sound, thus what it is communicating and the relationship between the listener (perceiver) and the (sonic) environment (Truax, 2001). Schafer's work tended to accentuate the positive aspects of rural soundscapes and highlight the negative aspects of urban soundscapes (e.g. Schafer, 1994).
- 2.1.2 Environmental sounds were also used as the basis of the composition of musical pieces, hence also describing some music as 'soundscapes' (Schafer, 1994). This alternative description of soundscapes has continued today, including research into individuals' preference of listening to their own created soundscape from their personal stereo equipment (e.g. mp3 players; Bull 2004) instead of the soundscape produced in the surrounding environment.
- 2.1.3 Environmental psychologists also started contributing to an awareness of the sonic environment within cities at the end of the 1960s (Southworth, 1969). This added an experimental approach to the study of soundscapes and their assessment, albeit one based on separating sound and visual perception in the experience of a place.
- 2.1.4 In addition to a new focus and development of research entitled 'soundscapes', its theoretical and methodological approaches were also adapted and applied to existing research on environmental sounds. For example, Schulte-Fortkamp & Dubois (2006) stated that soundscape concepts were introduced into community noise research in the mid 1990s.
- 2.1.5 Coupled with understanding the perception of sounds via the behavioural measurement techniques used by psychoacoustics (Plack, 2005) and the objective measures of acoustical properties, the different theoretical approaches have developed a range of methods for researching soundscapes.

2.2 Theoretical approaches

- 2.2.1 Research into soundscapes is carried out by a number of different disciplines, such as acoustics, psychoacoustics, psychology, sociology, architecture, geography, landscape planning, engineering, music, sonic art and anthropology, amongst others. It is also considered by the Government and the public and, as such, is often reported in the media, in particular in relation to noise. As might be expected, from the array of interested parties, soundscapes have been approached from a variety of theoretical approaches and one definition has yet to be decided upon (European Acoustics Association symposium on soundscapes, 31st January 2009; Genuit & Fiebig 2006). Each approach focuses on slightly different aspects of a soundscape definition, with different elements considered necessary to gain a thorough assessment of soundscapes alongside the best approach to be taken for their management and enhancement.
- 2.2.2 In addition to research grounded in soundscape approaches, traditional forms of research relating to noise, noise mapping, neighbourhood noise and annoyance, also provide relevant methodologies for understanding soundscapes and their evaluation. The advantage of soundscape research is that it focuses not only on the negative aspects of the sonic environment, but also the positive aspects (e.g. Adams *et al.*, 2006; Cain, Jennings, Adams *et al.*, 2008; Davies, Adams, Bruce *et al.*, 2007; Guastavino, 2006; Stockfelt, 1991), therefore it is also strongly linked with sound quality research and methodologies. Unfortunately, although many disciplines write about soundscapes and consider its importance, some have not focussed specifically on environmental sounds (Schulte-Fortkamp & Lercher, 2003).
- 2.2.3 Considering the variety of people with an interest in soundscapes, an interdisciplinary approach, as opposed to a multidisciplinary approach, is necessary (Davies *et al.*, 2007; Epstein, 2003; Kull, 2006; Schulte-Fortkamp & Dubois, 2006; Schulte-Fortkamp & Fiebig, 2006; Schulte-Fortkamp & Lercher, 2003; Zhang & Kang, 2007) to make a thorough assessment as well as appropriate plans for the management of soundscapes. Individual projects such as the Positive Soundscape Project (Davies *et al.*, 2007) are starting to address this need for interdisciplinary research.

2.3 Models and frameworks

- 2.3.1 A number of models and frameworks incorporating elements important to the description and evaluation of soundscapes have been developed. They generally combine the variety of elements that different disciplines consider necessary. These may provide the basis for developing a soundscape research programme, to ensure all the diverse attributes are considered.
- 2.3.2 One simplified hypothetical model is by Kull (2006), based on his definition of soundscapes incorporating both natural (non-anthropogenic) and manmade (anthropogenic) sources. The non-anthropogenic sound elements include the weather, animals, natural physical/mechanical, vegetation, and the terrain. Anthropogenic sound elements include mobile sources, stationary sources,

structures/materials, noise controls, and barriers. After breaking each of the elements down into these sub components, Kull (2006) identified the different measurable parameters involved.

- 2.3.3 Another model with broadly identified components is by Job, Hatfield, Carter *et al.* (1999). They state that research into soundscapes (with an emphasis upon the contribution of all sounds, not individual sounds) should include both 'enviroscape' (other environmental attributes such as air pollution and the neighbourhood in general) and 'psychscape' elements (all socio-cultural and psychological variables such as attitude and home ownership). This has been used as the basis for describing case study sites (Botteldooren & De Coensel, 2006), so that an awareness of other influential elements in soundscape study results are acknowledged.
- 2.3.4 A model developed by Kang and colleagues (Kang, 2007; Zhang & Kang, 2007) for describing soundscapes is similar to the one above, with the addition of one more component. It covers four important facets, entitled, source, space, people, and environment, yet the definition of the facets overlap with one another. The 'source' involves the sound characteristics, both physical and the meaning attributed to the sound, thereby also incorporating socio-cultural aspects. The 'space' refers to physical elements (e.g. reverberation) that can influence the perception of the sound, but also notes other sounds in the area, contributing to the soundscape. In addition, 'environment' includes the actual architectural elements that may influence elements within the 'space' alongside metrological conditions and other sensory inputs. The 'people' facet includes individual socio-demographic aspects, expectations, and comparative soundscapes.
- 2.3.5 Schulte-Fortkamp and Fiebig (2006) generated a model for the evaluation of a soundscape from their explorative study of a street with a promenade. They identified five elements involved in the evaluation process. Firstly, there are the acoustic and psychoacoustic aspects. Secondly, the perception of these varies depending on the identification of the source as well as the individual's own disposition towards certain sounds. Thirdly, there is an 'internal negotiation process' whereby the individual's socio-cultural background interprets the perceived stimuli (e.g. consideration of context, control, and meaning). Fourthly, psychological reactions arise, which may be positive, negative, or severely negative, such as when the individual's health is affected. Finally, there is a behavioural response whereby the individual makes strategies and takes action if necessary. This process is not considered to be linear, instead all aspects are considered to occur simultaneously and influence one another (Schulte-Fortkamp & Fiebig, 2006).
- 2.3.6 Another framework generated by Cain *et al.* (2008) provided a basis for understanding soundscapes, which aided informative inputs to be contributed from an interdisciplinary team. The framework revolves around considering 'sound' as physical aspects that can be measured by psychoacoustic metrics, while the 'scape' is the relationship between various sources, that can constantly change and are perceived by an individual. The second crux is that it is an activity-centric framework, thus the soundscapes that are considered positive

depend upon the individuals activity and location, among other factors. In brief, different people (demographics), carry out different activities (e.g. shopping, eating), thus altering their listening state. Temporal elements (e.g. season, time of day) will also relate to the activity they carry out, along with the type of place they perform the activity (e.g. shopping centre, school), which will contain various aspects of the built environment (e.g. façade, planting) and other people. These aspects may also vary depending on the geographical location (which city).

- 2.3.7 To summarise, all the frameworks, break the concept of soundscape into manageable sections, identifying the aspects that each think are important in the understanding of soundscapes. The influence of the individual and also physical factors of the surrounding environment plays a part in most of the models.

2.4 Methodological approaches

- 2.4.1 A range of methodological approaches are used to study soundscapes due to the diverse nature of the disciplines involved. These have included quantitative and qualitative approaches for determining the objective and subjective measures relating to soundscapes and perceived soundscapes.
- 2.4.2 Research grounded in acoustics assumes a positivist paradigm and takes a quantitative, objective approach to soundscapes (e.g. De Coensel, De Muir, Yperman *et al.*, 2005). In general, psychoacousticians take a quantitative approach, using behavioural measurement techniques (Plack, 2005) and subjective responses to presented sounds (e.g. Ballas, 1993; Fastl, 2002). Psychologists, sociologists, and geographers use quantitative and/or qualitative methods to ascertain subjective responses (e.g. Adams & Bruce, 2008; Carles, Bernáldez & Lucio, 1992; Job, Hatfield, Hede *et al.*, 2007). Occasionally objective and subjective measures are combined, thus providing a more complete description and evaluation of soundscapes (e.g. Berglund & Nilsson, 2006; Davies *et al.*, 2007; Lavandier & Defréville, 2006; Payne, 2008; Raimbault, Lavandier & Bérengier, 2003; Semidor, 2006; Yang & Kang, 2005a).
- 2.4.3 Research has been carried out in a variety of locations, such as in laboratories, including using computer simulations, as well as studies *in situ*. Results from each type of study are likely to vary even with the presentation of the same stimuli, as different contributory factors are often considered via controlling them or using measurements. For example, perceptual variations to the response towards a sound or soundscape heard *in situ* and the same recording of the sound/soundscape presented in a laboratory are likely to occur. Those *in situ*, may become habituated towards the sound thus no longer noticing it (or conversely are unable to ignore it and are extremely annoyed by it), while in a laboratory each occurrence of the sound is more likely to be perceived (Fields, 1984) as different listening styles may be used (Tardieu, Susini, Poisson *et al.*, 2008). However, some evaluations, including the general direction of the results, made *in situ* and those made in a laboratory may be similar (Viollon & Lavandier, 2000). This suggests that general results can be produced in laboratory situations, instead of doing work *in situ*; however, more nuances and other complexities in the general results can be determined with *in situ* research.

- 2.4.4 Computer simulations of soundscapes are based upon previous knowledge of sound pressure levels and people's reactions. They are used, in particular, with noise mapping and also modelling annoyance to soundscapes (Botteldooren, Verkeyn & Lercher, 2003; De Coensel, Botteldooren & Muer, 2003; Defra, 2008b; Rendell, 1997). It has been suggested that, to counteract the focus on noise, favourite sounds could also be mapped to provide a better overall image of the soundscape in an area (Brown, 2007). Others, however, consider it inappropriate to map soundscapes, as they constantly change as people engage with the environment (Rodway, 1994). The former viewpoint assumes that a typical sonic environment is accessible and identifiable, whilst the latter viewpoint does not acknowledge the occurrence of a typical sonic environment or similarities that can arise with perceived soundscapes. Whether soundscapes may be mapped in any manner relies on a consensus about what could, and should be mapped. It is possible that some variation/formation of soundscape mapping may aid the understanding of and practical application of soundscape assessments and management.
- 2.4.5 Research in laboratories is carried out by two different methods, either with or without a consideration of how the environmental sounds may be perceived and evaluated in real life situations. Sometimes experiments are designed to exclude all other factors to try and ascertain direct relationships between acoustic variables, perception and evaluation (Berglund, Hassmén & Preis, 2002; Kuwano, Namba & Kato, 2008; Menzel, Faccinelli & Fastl, 2008). Other times, and more appropriately for soundscape research (but not necessarily for the development of measures), the laboratory is transformed to provide some form of ecological validity (i.e. to reflect real life) by providing contextual visual cues (Guastavino, Katz, Polack *et al.*, 2005; Viollon, Lavandier & Drake, 2002). Unfortunately, experiments are often designed with little consideration for their ecological validity, with participants responding to questions with no contextual setting or stated scenarios to set the 'scene' (excluding, Alvarez, Angelakis & Rindel, 2006; and Öhrström, Gidlöf-Gunnarsson & Ögren, 2007).
- 2.4.6 Research carried out *in situ* enables an understanding of the perception and assessment of the soundscape by people who are often living and experiencing the soundscape on a regular basis. The advantage of *in situ* research is the context, meanings and all sensorial experiences are included in the results, but unfortunately, the contribution each provides is unknown. This makes outcomes harder to explain and ascertain which aspects are influential factors, thus making it hard to detect what could improve the soundscape through better design and management. However, this complexity highlights the relationship between a number of issues, thus giving an insight into how manipulating one aspect, such as soundscapes, may have knock on effects in other areas. It has been shown that negative sensory stimulators are brought about because of positive stimulators, thus the co-production of positive and negative experiences would need to be recognised and addressed (Adams, Moore, Cox *et al.*, 2007).
- 2.4.7 Research has been carried out in both urban and rural environments. In urban environments, soundscape research has often focussed on road and air traffic, as

for many it can be a prominent source; it is often considered as annoying and can produce deleterious cognitive and health effects (e.g. Clark, Stansfeld, Berglund *et al.*, 2006; Staples, Cornelius & Gibbs, 1999). Residential areas are generally discussed in terms of noise annoyance (e.g. Finegold, 2004; Job, 1988; Klæboe, Engelién & Steinnes, 2004; Klæboe, Kolbenstvedt, Fyhri *et al.*, 2005) while public spaces including urban parks and squares are often discussed in both positive and negative terms (Berglund & Nilsson, 2006; Raimbault *et al.*, 2003; Payne 2008; Yang & Kang, 2005b).

- 2.4.8 There has also been some emphasis on 'quiet areas' in line with policy terminology (Defra, 2006; European Parliament & Council, 2002; Mayor of London, 2004). Such research has been located in urban environments (e.g. Memoli, Licitra, Cerchiai *et al.*, 2008) and in rural environments (e.g. De Coensel & Botteldooren, 2006). It has been suggested that the term 'quiet areas', which has yet to be clearly defined, and the related aspect 'tranquillity' should be redefined as 'areas of high acoustic quality' (Brown, 2006). The latter definition acknowledges that it is not just quiet areas that are necessarily appreciated and 'quiet areas' may not be found in some urban cities, unless they are considered as 'relatively quiet', compared to the surrounding areas. Using terminology, such as a 'quiet area' may reduce decisions to be determined by measured sound levels only (Brown, 2006).
- 2.4.9 It has been suggested that the preferred use of quantitative evaluations and indicators by policy makers over detailed in-depth qualitative studies may owe to considerations of financial costs and time, and may explain the current focus on sound defined as a noise pollutant (Adams *et al.*, 2006). Research is called for that identifies how the two approaches, quantitative and qualitative, and the types of knowledge produced by each, can be effectively used side by side and integrated effectively into policy and practice (Adams *et al.*, 2006; Fiebig & Genuit, 2008).

3 Soundscape Perception

To be able to understand how soundscapes are evaluated, first an understanding of how soundscapes are perceived is necessary. This is to establish associations between soundscape evaluations and the individual components that are actually perceived. The physical aspect of human perception is first described, followed by the different types of listening that may be used by individuals, thereby influencing their perception of the soundscape. The importance of different sensory aspects of the environment is discussed before describing the different methods used to identify perceived soundscapes.

3.1 Perceiving sounds

- 3.1.1 Soundscapes are perceived physically by individuals as a collection of pressure variations that are felt within the ear. Physical properties of the pressure wave (intensity, frequency, and so on) are coded into electrical pulses by the cochlea. The series of electrical pulses are then interpreted within the brain via a series of complex procedures. In brief, the information is parsed into a number of auditory streams, most likely based upon the sound's physical properties, e.g. one high and one low frequency stream (simultaneous integration) but can also be, or in addition, due to grouping properties in terms of their time frame (sequential integration) (Bregman, 1990). One of these streams is then attended too and others ignored, although the formation of the streams can also be influenced by the individual's attentional set (what they are motivated to focus upon, Moore, 2003). In the latter case, a schematic based organisation of the auditory information occurs (one based on expectation, prior knowledge and experience; Bregman, 1990) and can be used in the interpretation of the collection of environmental sounds (Ballas & Howard, 1987).
- 3.1.2 The focus upon particular streams therefore do not just depend upon the acoustical properties, but can also be based upon the individual's knowledge, familiarity, memory, context, expectation and associated meanings of the sound (Ballas & Howard, 1987; Bregman, 1990; Moore, 2003; Repp & Knoblich, 2007). The auditory stream that is given attention is termed the figure, while the remaining streams are the background, although as stated, these can alter as attentional sets change (Valkenburg & Kubovy, 2004). This is similar to the concepts used in visual perception whereby attentional sets will vary and can be influenced by individual's cognitive set and behaviour (Gibson 1979; Leff, Gordon & Ferguson, 1974)
- 3.1.3 Individuals within a place can therefore perceive different soundscapes. In turn, this will influence the individual's assessment of the soundscape as they attend to its different aspects. Caution should be taken not to use the phrase soundscape perception when referring to soundscape assessments [although affect (emotions) may also help direct perception, Zajonc, 1980].
- 3.1.4 A variety of perceptual and cognitive items generated by different researchers were collated to assess people's identification of 41 everyday sounds (Ballas,

1993). They related to the acoustic properties of the sounds (clarity, loudness, timbre), psychological aspects (familiarity, schematic representation of the sound), and identification aspects (need to envision the sound, and ability to describe the sounds easily, context independence). From the results, the produced clusters of sounds reflected event types, while the factors explaining 84% of the variance, related to the sounds identifiability, timbre and affect, and homogeneity. This highlights the array of aspects (physical, cognitive and affective) that are involved in perception and the reporting of perceived stimuli.

3.1.5 The perception of singular sounds, such as one car, differs to the combination of a number of sounds, such as numerous cars, as the acoustic properties are altered and the perceptual processing of the stimuli varies (Haverkamp, 2007). This in turn affects the assessment of the sound, for example, the preference for the sound of traffic rather than individual car sounds, or higher levels of annoyance when hearing road *and* railway traffic, rather than just railway traffic (Öhrström *et al.*, 2007). These differences will be enhanced when different types of sounds are perceived together rather than individually. Therefore, it is important to make distinctions between research carried out on singular sounds within an environment and multiple sounds (soundscapes). Currently, more research is necessary on the interaction of environmental sounds (Finegold, 2004) and no definitive model incorporating such complexities exists (Schulte-Fortkamp & Lercher, 2003).

3.1.6 Understanding how soundscapes are perceived is also important for laboratory soundscape research. Using binaural dummy heads (an artificial human head with a microphone in each ear and various equalisers to mimic human hearing) in the collection of soundscape recordings ensures a realistic representation of acoustic properties and how they are received by humans is captured and can be replayed to individuals as if they were *in situ* (Genuit, 2003). The design of laboratory conditions need to have ecological validity in the presentation of the sounds (and other stimuli), to be able to transfer results to the real world. This involves incorporating visual and contextual information/stimuli, and possibly recreating settings within laboratories, such as a person's home (Öhrström *et al.*, 2007). If headphones are not used, the positioning and number of loudspeakers used is important in the playback of the acoustic stimuli (Guastavino & Katz, 2004; Guastavino *et al.*, 2005). Testing ecological validity also requires participants to rate their perception of the soundscape as realistic. Therefore, appropriate terms need to be developed to test the ecological validity, including spatial audio quality of the presented soundscape stimuli (Berg, 2006; Rumsey, 2002).

3.2 Types of listening

3.2.1 Truax (2001) identified three types of listening patterns; listening in search, listening in readiness and background listening. He described 'listening in search' as a form of analytical listening, where the individual is focussed upon hearing sounds relating to their activity. 'Listening in readiness' is the intermediate listening state, where the individual is listening to certain aspects of the soundscape but is also alert for other sounds that provide the individual with

important information. 'Background listening' is described as distracted listening, as the individual is focussing upon something else that does not necessarily need acoustic cues, such as reading a book, thus they are 'tuning out' the sound. Cain *et al.* (2008) included these listening styles, identified by Truax to their activity-centric framework, linking listening styles to various activities.

- 3.2.2 Gaver (1993) introduced two types of listening, musical listening and everyday listening. Musical listening is when the individual focuses upon the physical attributes of the sound such as its sound level, timbre and its masking effects. These are the types of attributes that traditional psychoacoustics measure. In contrast, everyday listening is when the individual gathers information about the environment as a whole, alongside the physical acoustic attributes, and interprets the information about sources and events within the current context. The latter is a more gestalt listening experience. This ecological approach to auditory source perception has been used by a number of researchers (e.g. Guastavino, 2006; Andringa & van Grootel, 2007) and corresponds to studies as to how laypeople describe their experience of the sonic environment (see section 4).
- 3.2.3 Raimbault and colleagues (Raimbault, 2006; Raimbault, Bérengier & Dubois, 2001) identified two distinct auditory strategies in a study of laypeople's assessments of urban soundscapes, via attributes presented as semantic scales and explanations of their responses. These were holistic hearing and descriptive listening. Holistic hearing relates to when the individual processes the soundscape as a whole, focussing upon their own subjectivity in relation to their current activity. Descriptive listening, in contrast, focuses upon the meaning of the sound as an object in the world. Differences in listening styles tended to relate to the location of the individual and the location's soundscape (e.g. boulevard or market square), the individual's reason for being there (e.g. resident or visitor) as well as some gender differences (Raimbault, 2006).
- 3.2.4 Stockfelt (1994) introduced the notion of 'dishearkening' to refer to the processing of disregarding aspects of the sonic environment. It is an active process, as the individual constantly alters which aspects of the soundscape are ignored over others.

3.3 Multisensory interaction

- 3.3.1 Sounds/soundscapes are not perceived in isolation, but with other sensory information. Indeed, individual sounds themselves are not normally perceived separately but in conjunction with numerous other sounds that create the soundscape. Other sounds and other senses are important in how sounds/soundscapes are evaluated, and may also influence which sounds are perceived, if other sensory aspects direct the attentional set of the individual (Posner, Nisser & Klein, 1976). Further work on interacting sounds is necessary (Finegold, 2004) as well as the interaction between the different senses.
- 3.3.2 Visual elements, in particular, generally play a large role in people's perception of an environment and can alter sound perception to a greater extent than acoustic elements alter visual perception (Posner *et al.*, 1976). For example, sound

localisation is effected by visual cues more so than visual localisation is by sound cues (Bregman, 1990), with the latter being only a weak effect (Warren, McCarthy & Welch, 1983). However, if visual information is inadequate, then other sensory elements such as sound play a larger role in perception (Posner *et al.*, 1976). In addition, incongruencies between information provided by different sensory modalities also influences perception; for example, if a moving object is only heard in one ear, but not the other, then visual movement is not perceived (Bregman, 1990).

- 3.3.3 Perceptual differences in the evaluation of soundscapes can also be altered by the type of information that is presented with the stimuli, e.g. visual or verbal (Abe, Ozawa, Suzuki *et al.*, 2006). Additionally, depending on how sounds are perceived (in isolation or in conjunction with visual stimuli) the evaluation of the soundscape can vary (Carles *et al.*, 1992; Viollon *et al.*, 2002). It has been suggested that for people, such as commuters, moving through a series of environments, the visual dominates the assessment of the environment, compared to auditory elements, although this fluctuates depending on the actual presented cues (Gifford & Ng, 1982). The congruency between the perceived sensory information can also affect how both the soundscape, landscape and overall environment is evaluated (Carles, López Barrio & de Lucio, 1999).
- 3.3.4 The perception and evaluation of the acoustic environment is not just altered by the visual senses, but by other senses too. The perception of multisensory information (e.g. sound, vision, tactile, proprioceptive) may occur at a peripheral and central cognitive level (Lugo, Doti, Whittich *et al.*, 2008), thus the reported perception and evaluation of one sensory stimulus may be influenced by the other sensory stimuli that are occurring at the same time. Air pollution has similar relationships with annoyance as noise (Klæboe & Amundsen, 2007) and sensed vibrations can also influence sound evaluations (Genuit, 2006). Therefore, the combined effect of multiple stressors is important to consider, rather than just each in isolation (Evans, Allen, Taffala *et al.*, 1996).
- 3.3.5 This brief introduction of how sounds are perceived, alongside intersensory interactions (when one sensory modality influences another, Warren *et al.*, 1983) and the resultant perception of an environment, identifies the complexities involved when considering perceived soundscapes and their evaluation. Further understanding of the interaction between the different senses can also provide opportunities for design work. The manipulation of certain aspects within an environment to trick an individual's perception of the various elements (similar to visual illusions) could create interesting features within a place, providing different affective experiences.

3.4 Identifying perceived soundscapes

- 3.4.1 Perceived soundscapes need to be identified to understand people's assessments of the soundscape. People identify everyday sounds by using a number of acoustic, perceptual, and cognitive factors (Ballas, 1993). Acoustical properties and ecological frequency (how often they occur) accounted for 75% of the

variance in time it takes to identify the sound, while causal uncertainty and sound typicality also contributed to the identification rates (Ballas, 1993).

- 3.4.2 A number of different methods have been used to assess people's perceived soundscapes, including both quantitative and qualitative measures. The different identification methods allow different types of evaluations of the soundscapes to be addressed. It is therefore important to know what type of assessment is of interest (whether concerned about individual sounds or soundscapes), as this will determine the questions used to identify perceived sounds/soundscapes.
- 3.4.3 Qualitative measures have included open ended questions and soundwalks where participants have been asked to identify sounds heard *in situ* (Guyot, Nathanail, Montignies *et al.*, 2005; Irvine, Devine-Wright, Payne *et al.*, 2009; Schulte-Fortkamp, Volz & Jakob, 2008; Yang & Kang, 2005b), alongside information on how the surroundings have impacted on the perceived soundscapes (Adams, in press). Other qualitative methods have involved requesting verbal descriptions of what is heard during the presentation of stimuli (McGregor, Leplâtre, Crerar *et al.*, 2006) or asking individuals to recall what they hear in familiar places (Guastavino, 2006).
- 3.4.4 Quantitative measures of perceived soundscapes have included closed ended questions, whereby a list of sounds or sound types and various response scales have been presented to participants *in situ* or in laboratories. These have ranged from the use of 26 different sound sources (7 natural, 6 human and 13 technological; Nilsson & Berglund, 2006), three different sound types (natural, human and technological; Nilsson, 2007) or seven different sound types for urban parks (natural, happy people, sad/angry people, object sounds due to people in the park, sounds from the surrounding buildings, individual vehicles, background traffic; Payne, 2008). Scales presented to individuals to identify how often they'd heard the sound source or sound type have also varied, including 'never, occasionally, often' (Nilsson & Berglund, 2006), 'not heard, heard a little, heard moderately, heard a lot, completely dominating' (Nilsson, 2007), and '0 - 100% of the time' combined with the perceived sound level (7 point semantic scale, from quiet to loud; Payne, 2008). The identification of the predominance of sounds and sound types identifies the relationship between the various sound types, thus giving a clearer description of a soundscape, than just the presence or absence of a sound.
- 3.4.5 Regardless of the type of methodology used in identifying perceived sounds/soundscapes, the *actual* perceived sounds are rarely known. Some discrepancies may arise in individuals' recall of sounds, due to a lack of awareness, reliance on memory and the interference of expectation with recall. However, it is very difficult to ascertain the exact sounds perceived without the use of physiological and cognitive imaging equipment in laboratories, thus a reliance on participants' descriptions is often necessary. Sounds that people describe hearing are most likely to be the ones that they base their affective responses on, thus validating the methodologies to some extent.

4 Describing Soundscapes

To be able to assess, manage, and design soundscapes it is necessary to understand how soundscapes are described. This section reviews the language people use to refer to sounds and soundscapes. It also reviews the variety of objective measures used to characterise the soundscape by physical terms.

4.1 Terminologies for describing sounds and soundscapes

- 4.1.1 There is little agreement on the terminologies used for describing sounds and soundscapes by different disciplines and professions (McGregor *et al.*, 2006) as well as between professionals (practitioners and academics) and laypeople (Dubois, 2000; Dubois & Guastavino, 2006; Lemaitre, Houix, Misdariis *et al.*, 2008; Rimbault & Dubois, 2005). The language used is important to consider, when deciding upon the method to measure and assess the soundscape (Dubois, 2003; Guastavino, 2006; Payne, Devine-Wright & Irvine, 2007). Presenting descriptions of soundscapes to be identified and/or assessed may direct participants to respond in a certain way, which does not necessarily relate to how they would normally conceptualise and consider the soundscape. Understanding laypeople's description of sounds and soundscapes is also important when mediating between different groups of laypeople and trying to educate them about the science of soundscapes (e.g. Sonic Postcards, 2009; The Sound Around You Project, Mydlarz, Drumm & Cox, 2008) and inform them about noise (European Parliament and Council, 2002).
- 4.1.2 Acoustic engineers describe sounds using the physical properties that they consist of, in particular their dynamics such as sound level, alongside the use of spectral aspects and architectural acoustics (McGregor *et al.*, 2006). It has also been recommended that descriptions should include the "rate and pattern of the sound occurrence; sound sequences and passages of time such as acoustic actions of starting and stopping, adding and subtracting, and expanding and contracting" alongside other physical and environmental conditions (Zhang & Kang, 2007, pp.77).
- 4.1.3 In contrast, laypeople frequently describe sounds by the source that makes the sound (Dubois, 2000; Guyot *et al.*, 2005; Lemaitre *et al.*, 2008; McGregor *et al.*, 2006; Payne *et al.*, 2007). This suggests sounds are not conceptualised as abstract acoustical effects, without any meaning or context, instead the effect of the object producing the sound on the individual is often included in descriptions (Dubois, 2000; Guastavino, 2006). Thus, laypeople also use the mode of the sound's production and affective terms, as well as referencing some acoustical properties, such as loudness (Dubois, 2000; Guastavino, 2006; McGregor *et al.*, 2006; Payne *et al.*, 2007).
- 4.1.4 In general, there is little consistency in the descriptive terms used to depict sounds and soundscapes by laypeople, compared to a more consistent terminology for visual stimuli, such as its colour (Guastavino, 2006; Davies, Adams, Bruce *et al.*, 2009). There are also differences in the language used

depending on the type of description given, such as if it relates to source events (sound sources) or to background noise (collection of sounds sources) (Guastavino *et al.*, 2005). Analysis of sound walk interviews showed that built environment professionals (architects, acoustic consultants, property developers) and laypeople described the sonic environment through sound sources, sound descriptors (onomatopoeias and production of sound) and soundscape descriptors, with fewer terms used for describing the overall soundscape (Davies *et al.*, 2009). Moreover, analysis of semi-structured interviews identified that people familiar with urban soundscapes generally describe sound sources, and occasionally background noises, in terms of the effect the sound has on the perceiver, such as affect ('subject centred' descriptions; Guastavino *et al.*, 2005). Background noises are mostly described though by their acoustic parameters, such as their frequency, temporal structure and level ('object centred' descriptions), but with no reference to individual sources and the whole soundscape is conceived of as one 'source' (Guastavino *et al.*, 2005).

- 4.1.5 To start with, soundscape concepts were defined in terms used and recognised by musicians. A brief summary of terms identified by Schafer and acoustic ecology colleagues (Schafer, 1994, pg 271-275) are presented.

Keynote	The sound that is continuously heard or frequently heard, thus it provides the background to the perception of all other sounds, although it may not be consciously perceived. It is also termed Background sounds. An example is the sound of the sea for a maritime community.
Sound signals	Sounds which are designed to attract attention, thus contrasting with keynotes. They are also termed Foreground sounds, in relation to a foreground-background distinction that is made in visual perception. An example is a church bell in a village.
Soundmark	A sound that is of importance to the community and/or has unique qualities. It is adapted from the word landmark.
Lo-fi	Low fidelity is an "unfavourable signal to noise ratio" (pp.272). The soundscape consists of numerous signals that compete to be heard, masking each other.
High-fi	High fidelity is a "favourable signal to noise ratio" (pp.272). Sounds can be clearly distinguished as there is little masking.

- 4.1.6 This terminology has been used to describe case studies in research (e.g. Hedfors & Berg, 2003; Memoli, Bloomfield & Dixon, 2008; Porteous & Mastin 1985; Southworth, 1969; Yang & Kang, 2005b; Yu, Kang & Harrison, 2007) and to emphasise the need to move beyond assessing sounds in terms of noise, while still allowing for a classification of sounds (Adams *et al.*, 2006). However ecological psychology and the discussion of sound perception (see section 3.1), suggests distinctions between keynote sounds (foreground) and sound signals

(background) may vary with the individual perceiver. It would vary depending on their attentional and cognitive set, which may be directed by factors such as their knowledge and how they intend to/are interacting with the environment (Gibson 1979; Leff *et al.*, 1974). It is therefore important that researchers clearly state if their description of the soundscape is about the actual physical characteristics that exist, that may or may not be perceived, or if they are describing elements of the soundscape that individuals have reported perceiving.

- 4.1.7 In addition to the specific terminologies used to describe soundscape aspects, the models described earlier (section 2.3) also identify elements that should be considered in the description of soundscapes (e.g. Kull, 2006; Zhang & Kang, 2007).

4.2 Characterising soundscapes by objective measures

Physical measures of the soundscape, as well as being described as an assessment of the sonic environment, could also be called the 'sound character' (Letowski, 1989, cited by Rumsey, 2002), as they are value free measures, which are generally regarded as objective.

4.2.1 L_{Aeq}

L_{Aeq} is the A-weighted equivalent continuous sound pressure level and is used very widely to provide a single-figure level of a sound or soundscape where the level varies with time. (A weighting is usually applied because it is a standardised way of adjusting the measured sound level to match perceived loudness at different frequencies.) Many soundscape studies have used L_{Aeq} to provide a description of the sonic environment (e.g. Berglund & Nilsson, 2006; Brambilla & Maffei, 2006). This is particular common practice within research based around annoyance and environmental quality in general (e.g. Lam, Ng, Hui *et al.*, 2005) and is used to provide noise maps of all major cities due to policy directives (Defra 2008b; European Parliament and Council 2002).

In soundscape research, many have commented upon, or shown experimentally, that the use of L_{Aeq} alone is not sufficient for an assessment of the soundscape, either objectively or for explaining subjective assessments (e.g. Adams *et al.*, 2006; Arras, Massacci & Pittaluga, 2003; Berglund & Nilsson, 2006; Botteldooren, DeMuir, De Coensel *et al.*, 2005; Brambilla, Maffei & Zambon, 2006; Genuit, 2002; Klæboe *et al.*, 2005; Raimbault & Dubois, 2005; Raimbault & Lavandier, 2002; Schulte-Fortkamp, Genuit & Fiebig, 2007). Instead, additional acoustic measures, such as spectral distribution and temporal elements (Genuit, 2002; Raimbault & Lavandier, 2002), psychoacoustic measures (Schulte-Fortkamp *et al.*, 2007; Fastl 2006) and psycho-social judgements (Berglund & Nilsson, 2006; Dubois & Guastavino, 2007; Schulte-Fortkamp *et al.*, 2007) are also important for soundscape assessments.

Sound levels are still important, although not as a sole indicator, as they can explain 25% of the variance of visitors' assessment of the sound quality in a park (Nilsson, Botteldooren & De Coensel, 2007) and relate in part to urban soundscape annoyance (Arras *et al.*, 2003). Therefore, it can be used as an initial

gauge as to the quality of a soundscape, however the sound level alone cannot guarantee that quality. For example, in residential soundscapes and urban parks in Sweden, soundscapes with an L_{Aeq} above 50dB were considered as having a poor soundscape quality, yet there was no guarantee that the soundscapes with an L_{Aeq} below 50dB would be of a good quality (Berglund & Nilsson, 2006; Nilsson & Berglund, 2006). However, in Italy, urban parks with an L_{Aeq} above 50dB were still regarded as positive places by its visitors, probably due to factors other than sound levels and the relativity of the sound level compared to the surroundings, as silence was an important factor in overall place quality (Brambilla & Maffei, 2006).

4.2.2 **L_{den} , L_{day} , $L_{evening}$, L_{night}**

These four measures are based on the L_{Aeq} and reflect measurements taken during the day (L_{day}), evening ($L_{evening}$) and nighttime (L_{night}). The L_{den} is a corrected equivalent sound pressure level for 24 hours, incorporating the three different time frames (day, evening, night). It includes applying 5dB(A) weightings to the evening period(19.00-22.00) and 10dB(A) weightings to the night time (22.00-07.00) period. This is to account for the sensitivity humans are thought to have towards noise during those time periods.

These energy measures are supported by the European Parliament and Council Directive 2002/49/EC (2002) as potential indicators of the sonic environment's impact on humans; L_{den} is commonly used to assess overall annoyance, L_{day} and $L_{evening}$ assess the annoyance in the day and the evening, while L_{night} is commonly used to assess sleep disturbance. Position papers from the European Commission working groups set out guidelines for the use of these indicators to assess annoyance and sleep disturbance (e.g. European Commission Working Group 2, 2002; European Commission Working Group on Health and Socio-Economic Aspects, 2004). As these measures are L_{Aeq} based, they also suffer from the reservation, that used alone they do not adequately predict people's reaction to the soundscape and other measures are a necessary inclusion (e.g. Defréville, Phillippe, Lavandier *et al.*, 2007).

4.2.3 **L_{A95} or L_{A90}**

This is a measure of the sound pressure level (A-weighted) which is exceeded for 95 or 90% of the time, respectively. It is considered to be a good estimate of the background sound level (Downing, 2006), thus it has become an indicator that is considered by some as more appropriate to use in soundscape characterisation than the standard L_{Aeq} measure. In particular, the background sound level explained 28% of the variance in visitors' assessment of the sound quality in a park, three percent more than the sound level (Nilsson *et al.*, 2007).

4.2.4 **L_{A50}**

This is a measure of the A-weighted sound pressure level which is exceeded for 50% of the time. It was the best acoustic predictor, explaining 30%, of the variance in visitors' assessment of the sound quality in a park (Nilsson *et al.*, 2007). In addition, once this measure was entered into a regression model predicting soundscape quality or predicting road traffic noise annoyance, no other sound level measure added to the explained variance. It was concluded by

the researchers that it was the best acoustic indicator of soundscape quality in urban areas (Nilsson *et al.*, 2007) and in quiet areas (De Coensel & Botteldooren, 2006). L_{A50} has not been used in many other studies, so its value has not been consistently tested.

4.2.5 $L_{Ceq} - L_{Aeq}$, CoG

The spectral variations of a soundscape can help identify specific sound content (e.g. identifies sound sources), thus the third octave band spectra of the L_{A90} should be examined (Downing, 2006). These can provide clear depictions when a sound may disturb the ambient sound level, rather than just focusing on sounds that exceed a certain decibel level, which may not be appropriate for all contexts (Agnesod, Tibone, Tartin *et al.*, 2006). The spectral content as measured by the comparison of C and A weighted sound pressure level was the only additional acoustic measure, alongside L_{A50} , to be a significant predictor of soundscape quality (as rated by visitors) and the model for road traffic noise annoyance (Nilsson *et al.*, 2007). The spectrum centre of gravity (CoG) was only a very small predictor of the variance in visitors' assessment of the sound quality in a park. The psychoacoustic measure of sharpness (quantification of the balance of low and high frequencies) provides little variation within a place, but can highlight soundscape differences between places (Lavandier & Barbot, 2003; Memoli, Licitra *et al.*, 2008).

Metrics based on spectrum are commonly used to predict speech intelligibility for simple stationary background noise; for example, Speech Intelligibility Index (SII). SII has recently been extended to predict and map intelligibility in real soundscapes with moderate success (Davies, Mahnken & Plack, 2009).

4.2.6 $L_{A10} - L_{A90}$, transient events, noise events

The temporality of the soundscape can be measured using indicators of transient events, noise events, and the result of $L_{A10} - L_{A90}$ (the A-weighted sound pressure level which is exceeded for 10% of the time minus the A-weighted sound pressure level which is exceeded for 90% of the time). The temporal pattern of sound levels is important to consider as it varies throughout the day and season (Bjork, 1994; Downing, 2006; Matsinos, Marzaris, Papadimitriou *et al.*, 2008). Field measurements are therefore best if measured over a long period e.g. three weeks (Downing, 2006) or five consecutive days (Brambilla, 2002; Brambilla, Lo Castro, Cerniglia *et al.*, 2007). Measurements should at least cover the different periods in 24 hours, such as day time (9am–4pm) and night time (11pm–6am), alongside further measurements to monitor the 'transition' periods between these main periods (Lavandier & Barbot, 2003). The appropriate length of time necessary for measurements in each period may vary per type of place, e.g. only 5 minutes for thoroughfares, but 15 minutes for quiet public spaces (Lavandier & Barbot, 2003, Memoli, Bloomfield *et al.*, 2008). The psychoacoustic measure called roughness (a measure of how rapidly the loudness level changes) has also shown some ability to note subtle variations in the soundscape and can be measured in 'real time' (Memoli, Licitra *et al.*, 2008).

Noise events have been calculated as a sound that raises the level above the normal L_{A50} for 3 or more seconds (Nilsson *et al.*, 2007). Similarly, transient

events have been calculated as a sound that raises the level above the normal L_{Aeq} for more than 20 seconds (Downing, 2006). Temporal measures can provide the basis for further modelling of the resultant effects if other sounds are additionally incorporated into the soundscape (Downing, 2006). Temporal measures however only had a moderate effect on explaining individuals' assessment of the soundscape quality in parks (Nilsson *et al.*, 2007).

4.2.7 **1/f**

A $1/f$ spectrum is when amplitude is inversely proportional to frequency, especially at very low frequencies such as 1 Hertz. When the magnitude spectrum is plotted on a log-linear scale, it produces a $1/f$ pattern. The $1/f$ pattern is found in numerous scenarios, including speech, music, radio static and even abstract paintings. This measure has also been used to examine the temporal structure of soundscapes, by observing the amplitude and pitch fluctuations (De Coensel *et al.*, 2003; Nilsson *et al.*, 2007). In general, rural soundscapes tend to portray more $1/f$ characteristics than urban soundscapes (Botteldooren *et al.*, 2006).

4.2.8 **Slope**

Slope is an indicator that has been derived specifically as an indicator of the soundscape (Licitra, Memoli, Botteldooren & De Coensel, 2005; Memoli, Licitra *et al.*, 2008). The indicator is based upon the temporal history of the sound pressure, thus taking into account sudden sound events altering the L_{Aeq} , background levels, and unusual events (Licitra & Memoli, 2006). In brief, the slope indicator measures the number of peaks (sound events) in the soundscape and how large these peaks are in relation to the background sound level (Memoli, Bloomfield *et al.*, 2008). The slope indicator has been able to detect greater variation in manipulated soundscapes than some other acoustic indicators such as loudness, sharpness and fluctuation strength (Memoli, Licitra *et al.*, 2008).

4.2.9 **L_{Amax} , L_{Amin} , L_{A10} , N(Zwicker's loudness)**

A number of other acoustic and psychoacoustic measures have also been evaluated in studies (e.g. Nilsson *et al.*, 2007). These have included the highest (L_{max}) and lowest (L_{min}) sound pressure level (A weighted) noted during a recording, as well as a measure of loudness that accounts for the human ability to mask certain frequencies when listening to acoustic stimuli (Zwicker's loudness). These acoustic measures are commonly collected when describing the sonic environment and in relation to noise disturbances. For example, L_{max} is used in planning guidelines as an indicator of rail disturbance at night, although not for road disturbance at night (PPG24, 1994). Moreover, these measures have not proved as fruitful as other acoustic measures for explaining laypeople's subjective assessments of soundscape quality.

5 Classification and Categorisation of Sounds and Soundscapes

Humans use categories in their everyday life to process and conceptualise the vast array of information they hold on the world in order to conserve cognitive efforts (Rosch, 2000; Tversky & Hemenway, 1983). This also occurs in the context of everyday soundscapes (Guastavino, 2003; Maffiolo, 1999; Raimbault, 2002; Vogel, 1999; as cited by Raimbault & Dubois, 2005). As noted earlier, professionals and laypeople describe sounds differently and have different categorisation systems for sounds and soundscapes (Dubois, 2000; Lemaitre *et al.*, 2008; Raimbault & Dubois, 2005), as well as variation within groups of professional and laypeople (Dubois, 2003; Payne, 2008).

Classifications can be useful as they reduce the number of components to be studied and assessed (Parizet & Koehl, 2006). They allow comparisons to be made across a number of soundscapes, recognising similarities and dissimilarities. Classifications and categorisations can help understand assessments of soundscapes, if the structure is developed by (or is the same as) the individual who makes the soundscape assessment. Conversely, the categorisation of soundscapes can be derived from people's evaluation of a variety of soundscapes, thereby identifying places with similar evaluated soundscapes (Ge & Hokao, 2005). Attributes that the soundscapes are composed of can then be ascertained and compared, to determine what makes a positive or negative soundscape.

Classifications that are too broad, or treated as a system used by everyone, should be treated with some caution, as variations on such general classifications will exist, due to socio-demographic, cultural, and psychological differences. Additionally, if places were to be characterised as having one particular type of soundscape then temporal elements should be noted, acknowledging that the soundscape classification may change depending on the time of day or season. Again, recognition that the characterised soundscape would not be perceived by everyone would also be necessary, due to the aforementioned individual differences altering the perception of various elements.

This section firstly describes some of the methodologies that have been used for classifying and categorising sounds/soundscapes. This is followed by separate sections for the classification and categorisation of sounds, and classification and categorisation of soundscapes, as both have been used to aid researchers' descriptions and evaluations of soundscapes.

5.1 Classification and categorisation methodologies

- 5.1.1 A variety of approaches have been used for classification studies, some of which have focussed upon classifying sounds, while others have focussed upon classifying soundscapes. Some have involved researchers' pre-defined classifications, while others have determined laypeople's categorisations, using a number of different methodologies.

- 5.1.2 The reasons behind researchers' pre-defined classifications have varied owing to the different approaches taken in their methodology. Many classifications have been based upon sound sources (e.g. Schafer, 1994), others on acoustic (PPG24, 1994; PAN56, 1999; TAN11, 1997) or psychoacoustic properties (e.g. Defréville, Lavandier & Dufornet, 2003), while others used morphology (e.g. Barrigón-Morillaz, Gómez-Escobar, Méndez-Sierra *et al.*, 2005). To determine laypeople's categorisation of sounds, different types of methodologies have been used; quantitative, qualitative, and combined approaches of both qualitative and quantitative.
- 5.1.3 Quantitative methods have included the use of scales (semantic or Likert), which individuals' use to rate sound/soundscapes on a number of attributes or are used to compare pairs of acoustic stimuli. These methods are carried out *in situ* or in a laboratory using binaural samples and playback facilities. When a number of scales are used, results are analysed using factor analysis to determine key attributes which are important in the categorisation process. The sounds are then categorised using a clustering method based on each sound/soundscape's factor scores or similarity ratings. The scales used may be predetermined and chosen by the researcher or developed from a series of studies to determine the most appropriate adjectives to use. This method aids later developments of computational equations for soundscape assessments, as well as easing the matching of objective and subjective measures together. However, this reductionist approach may exclude other important aspects which also influence the categorisation process (such as context, familiarity, experience). These aspects may also be missed if questions are not asked that the individual considers important in their own categorisation process.
- 5.1.4 Qualitative methods have included open ended questions (within focus groups, interviews, soundwalks, surveys, etc) about sounds/ soundscapes which are then analysed, with content, discourse, or grounded theory analysis to determine any categorisations. This method helps identify key attributes that contribute to the categorisation system (such as context, familiarity, experience) and ensures a more realistic system is developed that is based on real contexts and situations. This contrasts to classifying sounds without a contextual basis, which could cause an abstract classification system that does not represent the real processing and categorisation of environmental sounds. However, the quality of the data may depend on participants' abilities to verbalise their cognitions and evaluations.
- 5.1.5 A combination of both quantitative and qualitative methods can help negate the disadvantages of each methodology, while benefiting from the positive attributes they contribute to understanding soundscapes. One method, the multiple sorting procedure, qualitatively generates data by presenting individuals with environmental sounds or soundscapes (real audio clips or written descriptions of identified sounds) which they sort into similar groups and label those groups. Results are analysed quantitatively and qualitatively to identify the general conceptualisation of types of sounds/soundscapes and how they are described. Using a mixed methodological approach has the benefits of both quantitative and qualitative approaches, but the assumptions behind each aspect of the methodological approaches must also be carefully considered.

5.2 Sound classifications and categorisations

- 5.2.1 A number of classifications have been created by researchers to define environmental sounds. The most common terms used are 'natural', 'human', and 'mechanical'. Such classification types depend upon the correct identification of the sound source. This means contextual and visual information may also be necessary, as some sounds can be perceived the same and have very similar acoustical properties (e.g. waterfalls and continuous road traffic).
- 5.2.2 Schafer (1994) initially classified sounds into 'natural', 'human', 'sounds and society', 'mechanical sounds', 'quiet and silence', and 'sounds as indicators'. Each of these classifications also contained sub classifications. Sounds, could appear repeatedly throughout the classifications (thus they were not considered mutually exclusive) as the classification would depend on the context (Schafer, 1994).
- 5.2.3 Another classification system using only three sound types was developed to compare acoustical and visual elements of a rural environment (Matsinos *et al.*, 2008). These were anthropogenic sounds (produced by human activities and artefacts), biological sounds (produced by organisms), and geophysical sounds (produced by natural elements). The intensity of each of these sound types could then be rated within different areas at different times. This gave some understanding of soundscapes by comparing different sound levels of each sound type in each area at different times.
- 5.2.4 Traffic noise has been classified by road type; a major road, connecting the city centre to other cities; two-way roads connecting different zones in the city; one-way connecting roads; other city streets; or pedestrian streets (in a study of Spanish cities; Barrigón-Morillaz Gómez-Escobar, Méndez-Sierra *et al.*, 2002; 2005). Each road type reportedly has different average sound levels and thus can be used as an estimate of sound levels with fewer necessary measures than when measures are calculated from a grid basis (Barrigón-Morillaz, Gómez-Escobar, Mateos-Corchado *et al.*, 2007). This may provide similar results to that of noise mapping although accuracy could be limited due to the lack of actual measures. Alternatively road traffic noise or air traffic noise can be classified by the type of vehicle/aircraft producing the sound by its spectral analysis (third octave spectra band) and temporal values (Defréville *et al.*, 2003; Berg, 2002). These studies' reliance upon traffic volume and acoustic parameters alone, limits their applicability to classifications of more complex soundscapes; although the latter classification system is hoped to be adapted and applied to other types of sounds which could then be recognised and automatically classified by software (Defréville *et al.*, 2003).
- 5.2.5 A number of factors are important in the categorisation of sounds by laypeople. In particular, sound sources and event types are used in the clustering and labelling of categorisations (Ballas, 1993; Dubois, 2003; Kawai, Kojima, Hirate *et al.*, 2004; Payne *et al.*, 2007). Affective (emotional) evaluations of sounds are also important elements in the categorisation system (Berglund *et al.*, 2002; Dubois,

2000; Payne *et al.*, 2007), while acoustic properties contribute less (Berglund *et al.*, 2002).

- 5.2.6 In a study involving a wide range of environmental sounds (e.g. office printer, traffic noise), acoustic properties only played a small role in similarity ratings between sounds (Berglund *et al.*, 2002). Zwicker's total loudness and Aure's sharpness did not contribute to similarity measures, but spectral contrast did, although not to the same extent as affective evaluations of the sounds (perceived annoyance). Again, non-acoustic properties were shown to be more important to classifying sounds than acoustic properties.
- 5.2.7 Categorisations of sounds heard in specific contexts, such as at home (Dubois, 2003; Kawai *et al.*, 2004), urban parks (Payne *et al.*, 2007) or amusement parks (Kawai *et al.*, 2004) have been developed via multiple card sorts. These generated a number of different sound types including categorisations that were context based (e.g. sounds from the surrounding buildings, household, loudspeaker) as well as frequently used general categorisations (e.g. natural, transportation). Sounds were often categorised together as they were similar sources (e.g. same type of source or made of the same source properties), or because the sounds were produced by a similar movement or action (Dubois, 2003).
- 5.2.8 Categorisations derived from discourse analysis of individuals' responses to perceived low and high frequency sounds also determined two categorisation types, again based on sound sources (Guastavino, 2006). Recognisable sound sources were broadly categorised as source events, while indistinguishable sound sources were categorised as background noise (ambient sounds).
- 5.2.9 Unless relationships between different categories of sounds are considered, within some type of categorisation framework, then assessments can only be made about individual sounds rather than the soundscape as a whole. In addition, research involving the categorisation of a wide variety of sounds is unlikely to be useful for the analysis and understanding of how people conceptualise and assess sounds within their everyday life. Such categorisations may produce broad categories and not help establish the relationships between the various sounds heard within each type of place (e.g. cafe, urban park, home). A number of research studies have stated or shown, that context is important to the assessment of sounds (and soundscapes) (e.g. Guillén & Lopez-Barrio, 2007; Ipsen, 2002; Schulte-Fortkamp, 2001; Viollon *et al.*, 2002) and thus it is also likely to be important to the categorisation of sounds. It has been suggested that research into cognitive categories should occur for each context before appropriate acoustical parameters within each context are determined (Guastavino, 2006).

5.3 Soundscape classifications and categorisations

- 5.3.1 Categorisations of soundscapes developed through research with laypeople have involved perceptual, affective, and linguistic studies. However, classification systems derived by researchers have ranged from deriving from 'objective'

acoustic parameters (e.g. De Coensel *et al.*, 2003; Lebedowska, 2005), to those derived from a consideration of the meaning and function of the sound to the potential perceivers (e.g. Raimbault & Dubois, 2005).

- 5.3.2 Classifications of ‘very quiet areas’ to ‘very loud areas’, may at first glance appeal to practitioners as they match the need to preserve ‘quiet areas’ (European Parliament and Council, 2002). However such classifications are only based on sound levels and the meaning and context of the sound is not incorporated into the classification, but instead presupposes the evaluative assessment of soundscapes as good (quiet areas) and bad (loud areas). In line with noise mapping research, such classifications may only be based on transportation noise levels, albeit if measured in relation to acoustic background noise levels (e.g. Lebedowska, 2005).
- 5.3.3 Another method involving acoustic parameters was considered from the perspective that music tends to have a spectral behaviour of $1/f$, which humans tend to prefer over other dynamics (De Coensel *et al.*, 2003). Classifications could be based around such measurements of the long term dynamics of soundscapes. The closer the temporal structure to the $1/f$ scale, the more the soundscape tends to be preferred (Botteldooren *et al.*, 2006; De Coensel *et al.*, 2003). This type of classification therefore seemingly links objective parameters to subjective evaluations of the soundscape, thus providing the opportunity to understand and produce soundscapes that may be appreciated by its perceivers. However, once L_{A50} was accounted for, the $1/f$ measure was not a significant predictor of perceived sound quality or road traffic noise annoyance in parks (Nilsson *et al.*, 2007).
- 5.3.4 Similar to the $1/f$ measure, the slope indicator was used to classify different types of soundscapes within Italy, identified as annoying and relaxing by residents (Licitra *et al.*, 2005; Memoli, Bloomfield *et al.*, 2008; Licitra & Memoli, 2006). This led to the development of a ‘scale of quietness’, with quiet areas defined as values greater than -1, actual music is close to -1, white noise and maximum length sequence is close to -2, while soundscapes that have been complained about have slope values greater than -2 (Memoli, Licitra *et al.*, 2008).
- 5.3.5 Ipsen (2002) identified three types of soundscape patterns, ranging in complexity. Ipsen (2002), firstly, describes the ‘dual soundscape pattern’ as the least complex, involving the dual organisation of time and space and considers soundscapes as dichotomous types (e.g. natural v urban, private v public, busy city street v quiet urban square). Secondly there are ‘conversational soundscape patterns’ understood as processes, which are based on dialogues between the sound and the perceiver (e.g. boat horns coming into dock, cockerels crowing in the morning). Thirdly, there are ‘synthetic soundscape patterns’, which are described as the most complex, combining images and sounds that don’t normally occur together, such as birds chirping by inner city railway lines. Identifying a soundscape in terms of one of these soundscapes seemingly depends on how the perceiver is listening and interpreting the sounds. For example, hearing the sounds of boat horns while stood in a forest by the sea,

could also be described as a synthetic soundscape, as the horn, is not sounding an alarm to the perceiver.

- 5.3.6 One categorisation framework that considers the creation and function of soundscapes within a human context, involves the comparison of ‘transportation and works soundscapes’ with ‘people presence soundscapes’ (Raimbault & Dubois, 2005). Each of these categories were subdivided into two further categories; transportation and works soundscapes divided into ‘people presence’ and ‘no people presence’ (amorphous soundscapes), while people presence soundscapes divided into ‘lively soundscapes’ and ‘relaxing soundscapes’. Each of these sub categories were further sub categorised and connected to functional characteristics that would create such soundscapes, such as specific objects (traffic lights) or types of places (e.g. behaviour settings, such as a cafe). These differentiations are empirically supported by results from free sorting of typical urban soundscapes, which established a broad categorisation between traffic and human soundscapes, with sub categories based on the presence of people and types of places, which in turn were moderated by individuals’ social activities and the urban morphology (Dubois, Guastavino & Raimbault, 2006; Guastavino, 2007).

Such a categorisation framework that links soundscapes to functional components, could aid the design and understanding of soundscape assessments (Raimbault & Dubois, 2005). This is because environmental sounds are placed into a socio-cultural context, once specific characteristics are described, beneath the initial simplified categorisation structure. Further research on each described behaviour setting or object would be necessary to identify the finer levels of categorisation and physical sources that combine to create each of the categorised soundscapes.

- 5.3.7 As with sound categorisations made by laypeople, soundscape categorisations are not derived around sound levels but include descriptions of sound sources, and involve semantic meaning (Guastavino, 2007; Raimbault & Dubois, 2005). The sorting of presented urban soundscapes (based on loudness or pleasantness), resulted in two generic categorisation types; ‘event sequences’, where individual sounds can be distinguished within the soundscape and ‘amorphous sequences’, whereby sounds are not easily distinguishable (Maffiolo, Castellengo & Dubois, 1999). These two types of soundscapes were also described differently, with event sequences being more frequently described by sound sources, attached meanings, and activities. In contrast, amorphous sequences were more frequently described by its physical acoustic properties.
- 5.3.8 Many soundscape classifications have involved comparisons across a variety of places, albeit under broad environmental types of urban (e.g. Raimbault & Lavandier, 2002) or rural (e.g. Matsinos *et al.*, 2008) or even across the two (e.g. De Coensel *et al.*, 2003). In contrast, few studies have classified different soundscapes within a specific place type (e.g. parks), or within one place (e.g. a park). Instead, it is often assumed that each place has its own soundscape that can be described, as if it has a continuous physical presence (excluding, those studies that incorporate temporal variations). As mentioned earlier, people may

perceive different soundscapes within a place, depending on what they are attending too (their attentional sets), thus different types of soundscape categorisations may exist within the same place, or type of place (e.g. a cafe). Studies that have included the identification of different soundscapes within a type of place have involved both quantitative (urban streets – Ge & Hokao, 2005; urban parks – Payne, in press; residential areas – Axelsson, Berglund & Nilsson, 2003; Berglund & Nilsson, 2006) and qualitative methods (train stations - Tardieu *et al.*, 2008).

- 5.3.9 In a study of train station soundscapes (Tardieu *et al.*, 2008), participants familiar with taking trains, freely sorted 66 aural samples of soundscapes recorded from train stations (binaurally recorded and presented through headphones). Through an examination of the language used by participants and cluster analysis, eight different types of soundscapes were identified. Four of these soundscape types were based mainly on human activities, while the other four were based mainly on sound sources. The development of the eight different soundscape types were derived from the combination of the use of human activities, sound sources, room effects, type of space and affective evaluations.

In a follow up study (Tardieu *et al.*, 2008) participants were asked to sort the same audio samples of soundscapes, into six predefined classification types based on the design and function of parts of the train station (e.g. hall, platform, shop, ticket office). The results from the two sets of study were similar, thus supporting the importance of people's recognition and understanding of how a space is used (e.g. type of place, activities that occur there), and the built design on soundscape categorisations. These conclusions were again confirmed by the descriptions of the soundscapes given by people within the actual different locations of the train station; human activities, sound sources, room effects and affective evaluations were described (Tardieu *et al.*, 2008).

- 5.3.10 Categorisations of soundscapes of eight different streets, in a Japanese city, were created by individuals evaluating recorded audio stimuli (Ge & Hokao, 2005). Eleven semantic scales were used to rate the soundscapes (noisy-quiet, gloomy-sunny, unpleasant-cheerful, warm-cool, inactive-active, inconsistent-unity, oppressive-open, indistinctive-distinctive, artificial-natural, dislike-like, unharmonious-harmonious). The terms used were based upon a broader assessment of the variety of evaluative terms that are appropriate to use for soundscape analysis (e.g. Kuwano, Namba, Hashimoto *et al.*, 1991). The results were analysed using cluster analysis and three different types of soundscapes were identified. One soundscape type (heard in a number of the locations) was predominated by large amounts of vehicles as well as human activity. Another soundscape type, was mixed with some transport, human activities and natural elements, thus there was high incongruency between all the elements. A third soundscape type, consisted of the most natural elements, but few human activities and vehicles. The study shows that the relationship between different types of sounds can lead to different categorised soundscape types, which also relate to the different functions of the place.

- 5.3.11 Soundscapes of residential areas, taken from traffic-exposed and traffic-shielded sides of buildings were each compared by laypeople and rated in terms of their similarity (0 to 100% similar), before rating each in terms of four attributes (annoying, appealing, boring and interesting; Axelsson *et al.*, 2003). Participants tended to distinguish between two types of traffic soundscapes, but also categorised different soundscapes within these two types, partly due to different attribute ratings. Three dimensions were proposed based on the produced sound clusters and examination of their acoustical properties; softness-loudness, eventfulness-monotonous and foreground-background. It was proposed that this 'diagnostic' type of categorisation system based on perceived similarities and 'perceptual-emotional' attributes (annoying, appealing, boring, interesting) could help determine a 'green labelling of soundscapes' (Axelsson *et al.*, 2003). The concept would be useful for planners although the choice of evaluation attributes would need to be considered further, as a large proportion of variance of the perceived similarities of the soundscape clusters, was still not explained.
- 5.3.12 A similar study of residential areas involved 12 'perceptual-emotional attributes' that were used to rate the soundscape in and around an individual's home (Berglund & Nilsson, 2006). The results led to the categorisation of four types of soundscapes. The categorisations did not necessarily relate to the location of the perceiver (e.g. indoor and outdoor soundscapes), but did often revolve around the amount of traffic noise present. The 12 attributes (soothing, pleasant, light, dull, eventful, exciting, stressful, hard, intrusive, annoying, noisy, loud) were suggested as having the potential to provide a 'diagnostic tool' for assessing soundscape quality.

5.4 Summary

To summarise, a variety of different methodological approaches have been used to ascertain the classification and categorisation of sounds and soundscapes. Classifications are generally research based and derived from sound levels or typologies such as traffic volume. Categorisations are developed from laypeople, and tend to be categorised by sound sources.

The relationship between different categories of sounds and their interaction also needs to be considered to aid soundscape assessments and to derive soundscape classifications. Soundscape classifications have also been derived from acoustic measures, perceptual and affective measures or categorised by place functions.

6 Soundscape Assessments

A variety of disciplines are involved in soundscape research, each with their own theoretical and methodological approaches (see section 2.2, 2.3 and 2.4). This has led to the development of a number of different tools and methods for assessing soundscapes. A number of case studies have been conducted assessing the soundscape in a range of places. These have consisted of different place types (e.g. urban square, street, park) and have focussed upon soundscapes in both public and private locations (e.g. city centres, residential areas).

A general distinction can be made between research assessing soundscapes *in situ* (where the person assessing the soundscape is listening within the actual location) or in a laboratory (where the person assessing the soundscape is listening to previously recorded soundscapes being played back in a listening room or laboratory). The types of methods used in the two settings may be similar and occasionally research is carried out both *in situ* and in the laboratory. Assessing soundscapes *in situ* provides results that reflect the complexities of real world situations. This takes into account environmental, physical, psychological and socio-cultural elements that can influence soundscape perception and assessment. Due to these complexities, *in situ* assessments and analyses make it difficult to ascertain the specific role of individual elements in soundscape assessments. Parallel to *in situ* research, are studies conducted in controlled laboratory conditions. They are not designed to incorporate and assess the level of complexity found in real world situations, but they enable the control of which specific elements are to be considered in order to ascertain which are most influential in soundscape assessments. This makes it possible to show direct relationships between experimental variables that were simulated to represent real world situations, albeit within pre-defined parameters.

Both *in situ* and laboratory methods involve subjective soundscape assessments by human participants. Different case studies use participants from a variety of backgrounds and with varying degrees of soundscape knowledge, and that is partly determined by the study's location, participant availability and demographic differences at the case study site. Each participant recruitment strategy has its advantages and disadvantages. Additionally, some studies only present acoustic stimuli or the participant is asked to focus their attention upon the soundscape. This ensures information about the soundscape is gathered; however, it may result in individuals perceiving and evaluating soundscapes differently to how they normally perceive and evaluate them, as other sensory and cognitive aspects which may normally influence soundscape perception and evaluation are deliberately omitted.

In the following sections, examples of different methods and tools used within soundscape assessments are presented via a number of case studies. The case studies have been chosen to show a broad representation of the types of places in which soundscape assessment research has been conducted. Furthermore, most known case studies from different parts of the UK are presented, alongside examples from Europe and the rest of the World. Some examples within each

section may have used more than that one method, yet they are presented under a single methodology type, due to their focus upon it and exemplar nature. The presented examples are not an exhaustive list of soundscape case studies. Moreover, other soundscape assessment tools may exist, that have not been reported or tested on specific places (e.g. soundscape recognition software such as Instrument for Soundscape Recognition Identification and Evaluation; Karatsovis & Dyne, 2008).

6.1 In the laboratory – Scales: semantic and Likert

- 6.1.1 Semantic scales involve antonymous adjectives placed at the ends of a numerical scale (often numbered 1 to 5 or 1 to 7, although other numerical scales can be used). This means that two adjectives, opposite in meaning, are at either end of a five or seven point scale. For example 'happy' and 'sad' might be at either end of the scale and the participant would be asked to rate their assessment of the soundscape according to where on the scale from happy to sad the soundscape made them feel. Likert scales involve ratings based upon one dimension, descriptor or adjective. The scale covers the range of levels for the term and is applied to the stimulus being assessed. Verbal descriptors are usually given for every incremental number on the scale (5 point and 7 point scales are again common). For example, with 'annoyance' as the dimension, participants rate the soundscape according to how annoyed the soundscape made them feel from 'not at all annoyed', 'slightly annoyed', 'moderately annoyed', 'very annoyed' and 'extremely annoyed'.
- 6.1.2 Nilsson, Axelsson and Berglund (2003) conducted an experimental study about school soundscapes, using scales which they described as 'visual analogue scales'. Ten second binaural recordings (a microphone set up to simulate human hearing) were made from indoor and outdoor areas of four schools. Two of the schools were located near to **Heathrow Airport, London, UK** and had sound levels greater than 62.5dB(A) as aircraft flew over. These were played back through binaural headphones to children and their parents (sample size = n=40), half from schools near to Heathrow and half not affected by the airport. As well as using scales for assessing pleasantness, arousal and control, tape measures were used by participants to represent their perceived loudness of the recorded soundscapes.

A very strong positive correlation between perceived and actual sound levels was found ($r=.95$), regardless of which school the children, and their parents, attended. From this, it was inferred that prior experience of similar soundscapes did not play a role in perceived loudness. A strong negative correlation between sound levels of soundscapes and pleasantness ratings also existed ($r\approx-.87$); the louder the soundscape, the less pleasant it was perceived. Some small variations were noted for some soundscapes that had the same measured decibel level. For example, indoor soundscapes were perceived as slightly louder than outdoor soundscapes, and indoor soundscapes had lower pleasantness ratings than outdoor soundscapes. These differences were considered to relate to the sources of the sounds; the only external sound influencing internal sound levels was aircraft, while outdoors the sounds of birds and children playing could also be

heard. Nilsson *et al.* (2003) conclude that this supports the need for assessment measures, other than A-weighted sound pressure levels when comparing indoor and outdoor soundscapes. This conclusion is also supported by children and adults having very similar perceptual and emotional responses to the presented soundscapes, until sound levels were above 65dB(A). Differences in these louder soundscapes might have been caused by parents' attitudes towards the source, knowledge of its deleterious effects and/or general annoyance influencing their perception of its loudness. The latter again identifies other variables that could be of importance in soundscape assessments other than measured sound levels.

This study showed the ability to include children as well as adults in evaluating soundscapes that are part of children's everyday environments. Although three emotional attributes (pleasantness, arousal and control) were originally used to assess the environment, the results produced very high correlations between all three variables, making two of them redundant. The choice of attributes used in scales to measure people's assessment of a soundscape are therefore very important to consider, before conducting such a study.

- 6.1.3 Other experimental studies involving a number of semantic/Likert scales have also identified the influence of other factors in the evaluation of urban soundscapes; in **Madrid** visual factors, noise sensitivity and environmental attitudes affected the evaluation of various urban soundscapes in (Guillén & López-Barrio, 2007). Experimental studies can also be beneficial for testing a large number of scale adjectives to assess the relationship between the adjectives and identify which types (affect, temporal, spatial, sources) explain the most variance in different soundscape assessments (e.g. traffic soundscapes; Västfjäll, Notbohm, Gulbol *et al.*, 2003). The scales limit the participants to assess the soundscape in a particular way (e.g. as pleasant, vibrant), and as such the results rely on and are limited to the adjectives used in the scales.

6.2 In the laboratory – Artificial Neural Network

- 6.2.1 As a number of variables relate to people's soundscape evaluations, Artificial Neural Networks (ANNs) have been proposed as a way of incorporating the different variables and then modelling the typical response of different groups of people to a soundscape. ANNs are first trained to identify various responses made by different groups of people (e.g. data from questionnaires), so it can produce models that recreate a similar pattern of responses. The produced model is then tested by inputting people's response data again and comparing the results generated from the model with the real response results. Information used as an input to form the model can depend on the type of soundscape being modelled, along with the desired assessment type (e.g. perceived sound level, acoustic comfort), and could include measured sound pressure levels, temporal elements, demographics, individuals' activities, location within the place and evaluation of their own home's sound level.
- 6.2.2 Kang and colleagues proposed and tested an ANN model on a city centre urban square in **Sheffield, UK**, called the Peace Gardens (Yu *et al.*, 2007). The Peace Gardens' focal point is a large variable water fountain at floor level, which is

popular with children. There are plenty of seating areas (grass and benches) and a busy bus road is located a few steps above the gardens. Questionnaires were carried out in the Peace Gardens to gain 'true' results of people's soundscape assessments. These are then used to develop the model and later test the success of the model in predicting soundscape assessments. The predicted sound level evaluation and acoustic comfort rating of the Peace Gardens' soundscape derived from the ANN model correlated well with the original participants' results ($r=.63$ and $.79$). This model performed better than results derived from other statistical analyses (e.g. regression models, 53% and 61% correct prediction).

- 6.2.3 The Artificial Neural Network model therefore provides the capability of assessing people's responses to a soundscape without doing further extensive questionnaires, if data from similar soundscapes, conditions, and cultural and socio-demographic groups are known. In addition, it could be a useful tool when trying to consider people's assessment of a soundscape when certain aspects of it are to be manipulated or altered due to new buildings or changes in architectural surfaces. For example, Yu *et al.* (2007) modelled the predicted sound level and acoustic comfort evaluation of different age groups if they were in the Peace Gardens at numerous points throughout the site, thereby identifying potentially different responses that may arise due to its various acoustical features.

6.3 In the laboratory– Mixed methodology

- 6.3.1 A number of laboratories studies have used a range of different methods to assess soundscapes recorded at a particular place. One such study is by Kuwano, Namba, Kato *et al.* (2002), who used a twenty minute recording of a suburban area in **Eichstaett, Germany**, with an average sound level (L_{Aeq}) of 76.3dB. Six participants made evaluations of the same soundscape recording on three different days, presented via headphones in a soundproof room; they evaluated continuous perceived loudness, overall perceived loudness, and perceived loudness of individual sounds. Firstly, participants continuously assessed the loudness of the soundscape by moving a line representing loudness on the computer as they listened. This resulted in a good correlation between perceived sound levels and actual sound levels, although dramatic increases and decreases in sound levels often led to an over-estimate as the level increased, and an under-estimate as the level decreased.

Secondly, participants made an overall assessment of the loudness of the presented soundscape recording, using a 50 point scale. Regardless of whether participants had made continuous perceived loudness assessments before hand or not, their overall loudness assessments were similar. However, the overall perceived loudness assessments were more than 10 points louder than the averaged continuous judgements. This suggests that assessing overall loudness after an event, is not directly related to assessments made during the perception of the soundscape (Kuwano *et al.*, 2002).

Thirdly, participants were required to listen to the soundscape with the intention of memorising sounds they heard. These were then recalled and indicated on a line that represented each recalled sound's loudness. The average of these

represented sound levels was similar to participants' overall impression of the soundscape's loudness. This suggested that prominent sounds (considered to be the ones remembered by participants, which varied per individual, and weren't necessarily the loudest sounds), were important in their assessment of the overall soundscape; individual sound components influenced their impression of the soundscape as a whole. Once again, participants' perception of the sound level of individual sources was very strongly correlated with the sound pressure level of the sound ($r=.95$).

In line with general laws of memory (primacy and recency recall), participants tended to recall sounds they heard near the start and end of the soundscape recording. This is particularly important to remember when carrying out research asking participants to identify sounds they have heard within an environment. Unfortunately, this experiment contained a small sample size, albeit varying in ages.

- 6.3.2 In some regards, using different methods may hinder comparisons between results, particularly across different studies (Fiebig & Genuit, 2008). On the other hand, the triangulation of methods leads to a better understanding of the results (e.g. overall loudness assessment not explained by instantaneous loudness assessments but possibly by the memory of prominent sounds) and some researchers have called for mixed methodological approaches (e.g. Fiebig, Schulte-Fortkamp & Genuit, 2006). Additionally, similar results from different methods help validate the derived conclusions.

6.4 *In situ* – Soundwalks

- 6.4.1 A soundwalk is a practice developed by Schafer and colleagues on the World Soundscape Project in the late 1960s and early 1970s. Soundwalks have since been adapted and utilised by researchers as a method for investigating the perception and understanding of soundscapes (Adams, in press). Participants are asked to walk along a chosen route, particularly focussing upon what can be heard as they walk through the environment, thereby ensuring the soundscape is considered and assessments of the perceived soundscape can be made. Two case studies are presented that use different methods of evaluating the outcomes of the soundwalks; one focuses upon participants' verbal responses to the soundscape, the other focuses upon the psychoacoustic properties of the soundscape which an individual may experience.
- 6.4.2 Adams *et al.* (2006) conducted soundwalks with 34 residents of **Clerkenwell, London, UK**, during a summer and winter. Participants chose a 10 minute route through their local environment, listening to the soundscape, before being interviewed about their experiences. The results were analysed in relation to Schafer's terminology of keynotes, soundmarks and sound signals. Traffic was identified as a keynote sound and was evaluated negatively by many (unless heard from a distance), but it was shown that simply identifying sounds as keynote sounds was not in itself sufficient; reactions are contextual and contextual tradeoffs in terms of behaviour were constantly being made. Pleasant and unpleasant soundmarks were identified (theatre practices, market traders

calling and singing to each other, shops opening up and early deliveries). The soundmarks are therefore context-based and the assessment of them is mediated through the context of the sound to the listener.

Individual sound sources considered to be noisy and disliked were often still accepted, due to other factors. For example, if individuals perceived they had some control over the situation, they tolerated the noise or adapted their behaviour to avoid the noise (e.g., a participant's neighbour had monthly outdoor parties, but as long as the participant was warned in advance, the noisy parties were accepted as it gave the participant control over their own course of action). Additionally, negative impacts of the soundscape were evaluated by participants alongside other characteristics of their residential location that they considered important; the other characteristic (e.g. proximity to work) may override the impact of noise so the noise is tolerated. Furthermore, interventions from government through product regulations could help reduce some noisy sound sources, however, product users (for example, motor bike riders) may adapt the product beyond the designed intention of the product, thereby limiting the effect of the regulations (Adams *et al.*, 2006). Such interventions need to be considered in conjunction with the complexity of the sound making as well as the sound evaluation.

This approach to soundwalks reveals individual differences in the affective evaluation of sounds and a number of non-acoustic elements, such as prior experiences, tolerances and adaptive behaviours to noise, can influence people's assessment of soundscapes. Adams *et al.* (2006) concluded that soundwalks highlight the importance of subjective assessments for guiding policy and planning evaluations, and taking an abatement approach to noise policies (based on sound levels) risks a goal of moving towards silent environments, devoid of the buzz and vibrancy often sought and expected from a city.

- 6.4.3 Another soundwalk conducted in the UK was by Millman, Coles and Millar (2008). Eight undergraduate students from the University of Birmingham were taken on a soundwalk through a regenerated city centre development in **Birmingham, UK**, during the winter. The walk lasted an hour and incorporated an urban space called Brindleyplace and a canal towpath. Unlike many other soundwalks, the participants were allowed to communicate with each other thus interacting with and adding to the soundscape. This also meant the soundscape could be evaluated in real time rather than reflecting upon a memory of it in a post-walk interview. In addition, the relationship between the auditory experience and other sensory experiences were evaluated, providing a more comprehensive assessment of how individuals experience a place. The soundwalk was also reflected upon two weeks later during a focus group discussion carried out with the participants, using a recording made during the walk.

Participants found they were often comparing the soundscape to what they expected it to sound like, based upon prior experiences with canals in general and that specific canal at other times of the day and year. The appreciation of some sounds were influenced by the visual context; during playback of the

soundwalk recording, some sounds were evaluated less positively than during the walk. Participants concluded the canal soundscape was fairly neutral and quiet, and it was the journey through the environment that made the soundscape interesting. Additionally, in contrast to the visual and heritage elements, the soundscape was considered to have been neglected during the regeneration work along the canal, but emphasised in Brindleyplace where a fountain was included as a focal point. This particular soundwalk method was considered a useful tool for identifying the relationship between the soundscape and its surroundings and could be used when planning the redevelopment of an area, such as for identifying areas where sound elements could be enhanced to improve the soundscape.

- 6.4.4 Semidor (2007) uses the soundwalk method in a different way to the above two case studies; instead of taking participants along a chosen route through an urban area, she alone records the soundscape along a route with a dummy binaural head. A dummy head is an artificial human head with microphones in each ear, to make a binaural recording of the soundscape equivalent to that which would be heard by an individual in the environment. The data is then transformed into two spectrographs (one for the left ear, one for the right ear), which are two dimensional images of the recorded sound events, created from plotting the equivalent sound level at various frequencies across the duration of the walk. This data can provide psychoacoustic measurements such as Zwicker's loudness and sharpness as well as physical acoustic measures such as L_{Aeq} . In addition, from the spectrographs and notes taken en route, specific sound sources can be identified, highlighting how some sound sources mask others.

A study conducted one summer, used the aforementioned soundwalk method by making recordings of the soundscape as the researcher walked through the streets of **Prague, Czech Republic** (Semidor, 2006). This highlighted differences in how certain sound sources are heard by the right and left ear, depending upon the direction of the original sources. Instantaneous measures of loudness and sharpness made at the time were found to be important, as longer time frames missed much of the variation in the soundscape. This is due to the continually changing nature of urban soundscapes, and as such, the chosen sampling time of acoustical measurements is considered important for presenting a true assessment of an urban soundscape (Semidor, 2006). This ensures the identification of important sound sources (such as gusts of wind, toy drums) and their psychoacoustic effects aren't missed, as they could play an important role in an individual's assessment of the soundscape. This is likely to be the case, considering the results of the study by Kuwano *et al.* (2002; see section 6.3.1). This soundwalk method was later expanded upon and is further described below in section 6.10.4.

- 6.4.5 By combining the above three approaches to soundwalks, both verbal subjective accounts of soundscapes and objective psychoacoustic measures can be used to depict, understand and assess the soundscape in an area. Soundwalks have the advantage of allowing individuals to experience the soundscape of the area under investigation directly, they provide a useful foundation for subsequent individual or group interviews, and they raise awareness that different people can perceive

and assess shared experiences in different ways. Independently, soundwalks cannot assess the strength of the different factors that constitute a soundscape assessment, nor provide data that is conducive to statistical analysis.

6.5 *In situ* – Interviews

- 6.5.1 Interviews vary in their form and how they are analysed. They can be fully structured, semi structured, or un-structured. Fully structured interviews mean that the researcher has pre-identified, in detail, the issues to be discussed in advance of the interview, while un-structured interviews are open discussions around a topic with the participant leading the direction of the discussion. Semi-structured interviews give the interviewer a means of bringing the discussion back to the issues that are of interest to the research, while allowing the possibility of exploring unforeseen issues that may be brought up by the participant. The choice of questions and how they are worded are very important in making sure the interviewer doesn't lead interviewees' responses. Well designed interviews elicit interviewees' opinions and draw out information and factors that influence people's soundscape assessments that may be missed in questionnaires with constrained response options. Interviews are analysed at various depths of meaning, including summarising and finding themes and relationships amongst the responses, or closely examining the language used by interviewees to describe their experiences, thereby reflecting their understanding and assessment of things.
- 6.5.2 Hedfors and Berg (2003) used interviews with 18 'skilled listeners' (acousticians, musicians, and blind people) during visits to two urban green spaces. One site was a formal public garden in the city centre of **Uppsala, Sweden**, the other an open and wooded valley next to the city fringes. The interviews were analysed, to extract key themes and issues that arose through the discussions. The urban garden was described as both tranquil and stressful, due to the surrounding sounds of traffic with only occasional sounds from birds and trees inside the garden itself. Individual sounds such as a gardener running a rake through the gravel, gave an impression of care towards the site. The significance and meaning of sounds were commented on by some interviewees relating to how the sounds help form a sense of place. This included how sounds from outside the park determined activities occurring around the garden. The city garden was described as having a faster pace/tempo compared to the pastoral landscape. The contrast with the surrounding urban environment was also noted, in particular the transition in soundscapes as participants moved from one to the other. These transitions and changes in the soundscape between closely interconnected places were important for the assessment of the soundscape within the city garden – which was considered as having a weak sonic identity, due to the intrusion of surrounding traffic sounds.

The interviews were also analysed with the aim of developing a language and a tool that would be useful for practitioners when assessing soundscapes within a place. A language relating to the proximity of sounds and also a figure/ground concept identifying the prominence of some sounds (e.g. a bird) over the background sound of other sounds (e.g. distant traffic) was identified. A two

dimensional plot of the different types of qualities that a soundscape may have was created based upon the results. The two main dimensions were perceived as intensity of the 'ground' sounds (x-axis) and the perceived intensity of the 'figure' sounds (y-axis). On the diagonals, there was perceived sound pressure level and perceived clarity. This resulted in four main soundscape types, represented by the four quadrants on the plot (powerful, mild, clear and crowded). These could be used by practitioners to describe and identify sites that may need to be improved in terms of their soundscape.

Hedfors and Berg (2003) acknowledge that by using 'skilled listeners' the descriptions of the soundscape may not reflect those used by laypeople, or reflect the differentiating listening styles relating to the activities individuals are performing (see section 3.2). Positively, by using skilled listeners, ideas were developed for improving the soundscape in the city garden, based upon their knowledge about the physical properties of sound and the perception of soundscapes. Hedfors and Berg (2003) suggest that descriptions and assessments of soundscapes should not only use technical terms and measures such as L_{Aeq} , but also words expressing emotions, onomatopoeia and judgement about the congruence and suitability of the soundscape for the type of place. This may best be accomplished by combining descriptions and assessments made by skilled listeners or practitioners, with those of laypeople to gain a true assessment and understanding of a soundscape within a place.

- 6.5.3 Schulte-Fortkamp & Fiebig (2006), used interviews to provide a sociological perspective to further understand physical and perceptual data. Home owners in **Berlin, Germany**, were interviewed about a street they lived on that contained a promenade in the middle with trees. The roads are heavily trafficked at the two ends of the street, but the middle stretch has less traffic, and there is a cobblestone paved section. Questions were asked about the individuals' overall contentment with their housing, the noise condition in the apartment, their daily routines, along with their attitudes, emotions and behaviours towards certain noises. A binaural head was also used to take measurements of the physical sound condition in the apartment.

Schulte-Fortkamp & Fiebig (2006) concluded that if an individual was able to respond and act in a certain way once hearing a noise they could reduce the annoyance towards the noise. This emphasises the importance of control in evaluations of noisy situations. The identification of the sound stimulus by the individual was also very important in its evaluation, rather than just its physical properties. Attitudes towards these sound sources contributed to its evaluation. For example, sounds that added little to a collective residential identity were disliked (tourists, sightseeing buses and helicopters). Residents were particularly disturbed by the noise of traffic on the cobbled section of the street, yet they did not blame the drivers, or demand less traffic. An engineering solution would seem possible to remove this noise annoyance; meanwhile some residents took action themselves, by placing their bedrooms on the opposite side of the building. Socio-cultural aspects were identified throughout the interviews, highlighting their importance in the evaluation of sounds and the identification of

the best methods to reduce noise annoyance. Therefore, such qualitative information can provide a beneficial addition to physical measurements.

- 6.5.4 In another qualitative interview study in **Japan**, residents (n=308) described their satisfaction with their living environment in general and its noise conditions (Minoura, Hiramatsu, Matsui *et al.*, 1997). Content analysis was used to interpret the data instead of the grounded theory analytical approach, taken by the proceeding two case studies. This identified the types of sounds heard, the language used to describe these sounds, including their evaluation of them, alongside socio-cultural aspects, such as the convenience of the area to their daily lives. Most importantly, the research also identified the lack of a homogenous response to the soundscape within a fairly small area (200x300m), partly due to different soundscapes, but also due to different responses and meanings attached to the sounds by the residents.
- 6.5.5 Interviews can enable a deep and nuanced understanding of people's emotions, reactions and behaviours towards soundscapes. They can highlight the relationships between different variables that are influencing soundscape assessments, the importance of these variables, as well as relationships between soundscapes and other everyday aspects in people's lives. They work very well in combination with other methods, but in isolation they do not provide data that is conducive to statistical analysis.

6.6 *In situ* – Scales: semantic and Likert

- 6.6.1 Numerical and adjective scales are often used *in situ*, as they can quickly obtain a large amount of information from a large number of participants about their perception and evaluation of environmental sounds. Results, however, are heavily dependent on the exact wording of questions, the adjectives used in the scales and the interpretation of the question and scales in the same manner by all participants.
- 6.6.2 Guyot *et al.* (2005), used semantic scales to ask pedestrians (n=443) about heavily trafficked avenues, one way streets and pedestrian streets, in **Paris, France** and **Kalamaria, Greece**. A five point semantic scale from very unpleasant to very pleasant assessed pedestrians' evaluation of the soundscape and of individual sounds they identified (this followed on from an introductory open question). Regardless of the city, pedestrian sites were evaluated as neutral to pleasant, one way streets as neutral to unpleasant and traffic avenues as unpleasant. Even though sound levels of the different types of street had on average the same decibel level, they were evaluated differently. Factors other than sound levels therefore play a role in people's evaluation of a soundscape. In this study, the ratio of sound types within the soundscape were identified as a possible factor in evaluations, with a higher ratio of 'people' to 'traffic' sounds generally relating to a more positive evaluation of the soundscape.

There was no difference in the general identification of sound sources across the different countries, suggesting the streets had similar soundscape components. Sound source evaluations also didn't vary across the different types of streets,

suggesting that, in this study, the context was less important on the sound evaluation. Possibly, the streets were considered as similar contexts, thus pedestrians' attitudes to, and evaluations of, the sound source were similarly applied in the three street types. There was also no difference in the evaluation of the overall soundscape environment between the countries, suggesting no cultural differences in the evaluation of these soundscape types, for these two European countries (Guyot *et al.*, 2005).

- 6.6.3 A number of studies have used semantic differential scales to evaluate people's assessments of soundscapes within urban parks (e.g. Brambilla *et al.*, 2006; Nilsson & Berglund, 2006). In **Saga Forest Park, Saga City, Japan**, 11 semantic differential scales were used to evaluate the soundscape in a number of places within a large urban park (Ge & Hokao, 2004). This identified a number of different areas in the park containing different types of evaluated soundscapes that related to the different types of activities carried out in the park. Semantic scales were also used to identify individual factors that may influence the experience people have within two urban parks in **Sheffield, UK** (Payne, 2008). Park users (n=395) made self-rated assessments of their awareness of the soundscape (seven point scale from a little to a lot) and their general noise sensitivity (seven point scale from agree to disagree with the presented statements). The perceived soundscape was also depicted via scales assessing the perceived sound level (quiet to loud) and duration (0 to 100% of the time) of different sound types. The results were able to show the perceived predominance of different sound types and the importance of park users' awareness of the soundscape in having a restorative park experience.
- 6.6.4 Another study involving semantic differential scales conducted within two urban squares in **Sheffield, UK**, studied demographic differences in soundscape evaluations (Yang & Kang, 2005b). Participants (n=1000) were people using or passing through the squares, who evaluated a number of sounds that could be heard there, using a three point 'preference' scale of favourite, neither favourite or annoying, and annoying. Significant differences existed across age groups for the rating of certain sounds as favourable. The favourability of natural sounds was greater for older participants, while younger participants were more tolerant of mechanical sounds. In contrast, few gender differences were noted. The preference towards certain sounds significantly differed between the two different squares, including the rating of natural sounds and music. This highlights how two places of a similar nature (e.g. urban squares) can have distinctive soundscapes and play a role in creating diverse soundscapes.
- 6.6.5 Caution should be taken with the particular choice of terms placed at either end of the semantic differential scale. For example, a semantic scale from 'annoying' to 'favourite' is not necessarily using bipolar adjectives and this influences the type of analysis that should be conducted. In addition, even when adjectives may seem antonymous to the researcher, they may not be viewed as such by the respondent, thus causing interpretation problems and reducing the validity of the results. Again, this has implications for the analysis of the results, as averaging the results of seemingly bipolar scales may disguise differences that arise

between different groups of people due to different styles of responding and ways of interpreting the question (Raimbault, 2006).

6.7 In situ – Categorical responses

- 6.7.1 Questionnaires sometimes involve fixed response answers that do not vary along a scale, but are categorical in nature (e.g. yes or no). This can make it very fast and simple for an individual to respond to the questions, as long as the presented options are relevant to them. Analysis of the data is fairly simple, although it is more limited than other types of data. It can be used as a quick way to check for associations between different variables.
- 6.7.2 Rozec (2003) conducted a study about the soundscape and general quality of life in 'zone 30s' (traffic calming residential areas), in **Paris, France**, compared to other streets. Questionnaires completed by residents and workers in the area (n=400) were analysed in terms of their agreement and disagreement with aspects such as the architecture, security, proximity to services, cleanliness and sound perception (originally a 4 point scale, which was reduced to a categorical response, by the researcher, for analysis). Significant relationships existed between perceiving the area as calm, clean and secure. This suggests soundscape assessments (calm) can be influenced by the perception of other environmental aspects (clean, secure). In general, people in zone 30, in comparison to those not in zone 30, perceived less traffic, less mechanical sounds and significantly more human sounds and pedestrian conversations. Overall the result of town planning, designed for safety and place identity, also helped improve the perception of sounds and the overall soundscape. This study highlights the importance of considering various aspects of the environment at once, as the improved soundscape was a beneficial 'by-product' of urban design, yet other urban designs may have a negative 'by-product' effect on the soundscape if it is not considered in original development plans.
- 6.7.3 In **Auckland, New Zealand**, the soundscape quality of a waterfront area, was assessed by students, based upon a number of previously identified characteristics (Nyunt, 2004). This included noting the type of place (e.g. green formal or informal), the surrounding surfaces and land use (e.g. open, shops), the type and age of trees in the area (e.g. evergreen, deciduous, mature, young), the number of people in the space and their activities. This method can rapidly identify and categorise the physical properties and activities that may influence the perception and assessment of the soundscape (measured with scales). This collection of information ensures the soundscape is not considered in isolation, but with other sensory and environmental elements, thus emphasising the context of the situation. Such a categorical list could be useful for practitioners when reporting on specific cases needing soundscape assessments to provide the context and understanding of a specific situation.
- 6.7.4 The use of categorical responses can provide a fast efficient methodology to identify the presence/absence of an array of related issues or elements. It can provide a broad understanding of the relationship between different variables and initial basis for assessing if soundscape interventions in an area are suitable

or not. However, the results are quite simplistic and without additional or subsequent methodological approaches, the assessment is limited.

6.8 *In situ* – Acoustical diary

- 6.8.1 An acoustical diary notes and monitors the relationship between environmental sounds in daily life and their evaluation in terms of emotions and interference with activities (Fiebig *et al.*, 2006). The diaries can be analysed in a similar manner to interviews, finding relationships and patterns between emotive responses and activities. Diaries are produced aurally, allowing a recording of the sound event that annoyed the participant as well as their response to it, with minimum interference to their daily routine.
- 6.8.2 Fiebig *et al.* (2006) used the acoustical diary with residents living on a promenade in **Berlin, Germany**, which had two one way traffic roads and a section of cobbled paving stones. In addition, acoustical measurements were collected from outside the residences for the duration of the study and a recording was made inside the homes before the study started. The combination of acoustical data and subjective data identified that low frequency noise from passing vehicles were a contributor to reported noise annoyances. L_{Aeq} measurements would not reflect all aspects of this annoyance as it does not account for the reduced sensitivity of the ear at low frequencies (Fiebig *et al.* 2006; Moorhouse, Waddington & Adams, 2004).
- 6.8.3 The advantages and disadvantages of acoustical diaries were summarised by Fiebig *et al.* (2006). The diaries allow comparisons between subjective responses and physical data. The comments help understand the importance of socio-cultural factors in the relationship between the situational context and the annoyance complaint. The sounds chosen to be recorded potentially identify attention grabbing sources and the participant's memory is not relied upon. In addition, by letting the participants decide which sounds to record, the task is less problematic, than if they are instructed to record sounds at certain times that may interrupt their daily routines. The diaries rely on individuals actively participating by remembering to record all their relevant sounds and feeling comfortable with making audio interviews, which will vary across individuals creating a possible data bias.

6.9 *In situ* – Acoustical measures

- 6.9.1 Acoustical measures are usually a part of any soundscape or noise case study, as they provide a description of the physical sonic environment. Acoustical measures, however, do not reflect the perception of the soundscape.
- 6.9.2 Psychoacoustic data of a soundscape along a tramway construction route, was collected for a week in the city centre of **Bordeaux, France**, to compare different parts of the route, as part of a study by Louwerse, Semidor and Beaumont (2002). Loudness was calculated in third octave spectra bands but this varied in a similar manner as L_{Aeq} , thus it was not considered a good descriptor of the urban soundscape. The spectral envelopes however did vary across the different types

of places (e.g. canyon versus car park), due to their morphology and varying facades, but were similar within the same sites (e.g. canyon streets). Therefore, inclusion of data on the morphological features and facades, possibly via photos, helps with analysing and assessing data, including sound propagation.

- 6.9.3 Another case study used acoustical measurements (L_{Aeq}) to assess the environmental quality in **Hong Kong's** urban parks (Lam *et al.*, 2005). These parks varied in sound pressure levels, with smaller parks generally being louder. Lam *et al.* concluded that the ability to improve the acoustical environmental quality of Hong Kong's parks would be difficult due to their size and location. However, they also comment on the park visitors being generally satisfied with the parks' noise quality, thus suggesting that L_{Aeq} alone cannot determine the perceived environmental quality of urban park soundscapes. Additionally, other studies that have used only acoustical measures (e.g. L_{A50} , L_{A90} , L_{Aeq}) to compare city street soundscapes (**Istanbul, Turkey** versus **Naples, Italy**), also suggested that subjective data would improve the analysis and comparisons (Brambilla, De Gregorio, Maffei *et al.*, 2007).
- 6.9.4 Acoustical measures allow an easy comparison between different places and may highlight certain places where soundscape interventions are necessary. They provide a quick objective assessment and do not rely upon the public's help. However, they do not necessarily reflect people's subjective assessment of the soundscape and this may vary between two different places with the same measured sound levels.

6.10 *In situ* – Mixed methodology

- 6.10.1 A number of researchers consider it important to combine both quantitative and qualitative methods to gain a complete description of soundscapes and understand how they are subjectively assessed (e.g. Fiebig *et al.*, 2006; Davies *et al.*, 2007). Using a mixed methodological approach can help validate results if they produce similar outcomes. It can also highlight issues that would be missed from using one method in isolation.
- 6.10.2 Memoli, Licitra *et al.* (2008) used physical measures (slope, sharpness, roughness, loudness) along with questionnaire surveys, to assess the soundscape of an urban park, Giardino Sonoro, in **Florence, Italy**. Measurements were made using a binaural recording at some fixed locations and as an individual walked along the garden paths for 25 minutes, as well. Recordings were made when sound art sculptures were turned on and off. As reported earlier, the slope indicator detected greater variation in the soundscapes than loudness, sharpness and fluctuation strength (see section 4.2.8).

Over the course of one summer, park users were asked to participate in the study as they arrived at the garden. Participants' noise sensitivity was self assessed, followed by their perception of the roadside noise level and how much it annoyed them, using 5 point scales ranging from not at all to very much. A section for free comments was also provided. Participants were asked to fill out the questionnaire when the sound art was turned on, and again when it was turned

off. Participants with intermediate noise sensitivity had reduced noise annoyance when the sound art was turned on, while those with high noise sensitivity levels (generally male participants) had increased annoyance levels. Memoli, Licitra *et al.* (2008) suggest that acoustical measurements, like slope, are able to help assess quietness, but sound pressure level and classical psychoacoustic measures are not satisfactory by themselves as they do not necessarily relate to the subjective assessment of sounds.

- 6.10.3 Five urban parks in **Milan, Italy**, dominated by road traffic, were assessed by Brambilla *et al.* (2006), using acoustical measurements and questionnaires with park users. Measurements [L_{Aeq} in third octave band spectra, statistical sound levels (L_{10} , L_{90} etc) and sound exposure level of specific events] were made for 30 minutes throughout the park, on different summer days, while noting dominant sounds. Simultaneously, park users ($n=232$) were questioned about their use of parks and reasons for visiting it that day, and ranked the importance of a number of park features (silence, safety, cleanliness, vegetation and clean air). The park features were also evaluated on a five point scale, from very good to very bad, along with the expectation of hearing certain sounds in the park. General annoyance and overall satisfaction with the park and its soundscape was also evaluated on a five point scale.

The most frequent reason given for visiting parks was for 'quiet' (25%). However, for 40% of the participants, silence was the least important park feature from presented options. These differences highlight terminological differences between silence and quiet and the importance of using terms consistently within a study to allow comparisons. For example, quiet may be a more important park feature than silence and other park aspects. The overall quality of the park was often rated higher though than the overall quality of the soundscape. Brambilla *et al.* (2006) concluded that a holistic approach is necessary, as the use of acoustical measures alone does not reflect a true assessment of a place and its soundscape.

- 6.10.4 A European Commission research project, entitled SILENCE, researched the reduction of urban transportation noise levels, including soundscapes and its potential use in urban design (Semidor, 2007; Semidor & Venot, 2007; Semidor & Venot-Gbedji, 2007). As part of the project five sites in different European cities were analysed using a soundwalk method; Queen Square and 'The Centre' **Bristol, UK**; La Rambla, **Barcelona, Spain**; Roi Baudouin Park, **Brussels, Belgium**; and the historic city centre of **Genoa, Italy**. This research involved making binaural acoustic recordings, collecting descriptions of sound sources, human activities, architecture and morphological characteristics, taking photographs of the sites, in combination with resident/user surveys (e.g. identified sound sources, pleasantness rating of these sound sources, overall perceived noisiness, description of overall sound quality). Recordings and notes were made about the site at numerous times and days throughout a week, to account for the variations in soundscapes that occur over time.

A series of acoustic images representing overall sound levels, frequencies and duration of sound source events were identified and compared for both the left

and right ear. The notes and photos were used to aid the identification of the sources within the acoustic image. A visual representation of soundscapes was made by placing acoustic and photo images upon a geographical map of the soundwalk route, accompanied with information of human activities occurring there. The combination of the physical soundscape description with the subjective assessments of the soundscape quality, led to recommendations for improving the soundscape. The combination of methods also provides a more holistic understanding of the soundscape in relation to other sensory aspects and embedded meanings. Carrying out simultaneous surveys with residents and users of a place increases the link between a location's physical features and the characteristics that influence users' perceptions and evaluations of the soundscape. This would also enhance the recommendations made, by providing specific guidance on features that could be changed in certain locations rather than stating a general need for reducing sound levels from the surrounding traffic.

- 6.10.5 Defréville, Can and Lavandier (2007) conducted a soundwalk through **Paris, France**, walking past a market, down a street and ending in an urban park. Participants (n=10) were asked every 90 seconds to rate the prominence (importance), proximity (distance) and presence (duration) of certain sound types in the environment on an 11 point scale. Overall pleasantness and perceived loudness of the soundscape were also rated on an 11 point scale. Perceived loudness explained a lot of variance in overall pleasantness for the street sections of the soundwalk, but explained very little for the park and market pleasantness environments. Therefore, as with measured sound pressure levels, perceived loudness is not necessarily a good indicator of other evaluative aspects of a soundscape. In contrast the prominence of many sound types, especially of cars and other transportation, were predictors of unpleasantness, (as was subtracting a weighting for the proximity of birds). Caution however should be taken with the level of statistical analysis that can be conducted on small sample sizes. The importance of the proximity of bird sounds rather than prominence, indicates that some sounds do not need to be prominent, but as long as they can still be perceived and catch an individual's attention (Defréville *et al.*, 2007) then they can be beneficial to the assessment of the overall soundscape.
- 6.10.6 Raimbault *et al.* (2003) studied a number of town squares and main thoroughfares within **Nantes and Lyon, France**. Acoustical measurements, and questionnaires with passers-by *in situ* (n=296), were used to assess the soundscape. The questionnaire involved open ended questions (type of activity, assessment and knowledge of the location, and overall soundscape) and semantic differential scales assessing the soundscape (seven point scales, e.g. quiet-loud, steady-unsteady). Fifteen minute acoustical recordings were made in the morning, midday and afternoon, in the seven locations, enabling measurements such as L_{Aeq} , statistical sound levels, number of emerging peaks compared to the time rate, L_{max} and L_{min} . Psychoacoustic measures such as Zwicker's Loudness, sharpness and roughness were also calculated.

Through correspondence analysis, three factors were identified from the semantic differential scale results, explaining 91% of the data variance. The

three factors related to pleasantness and sound level, sound dynamics (temporality and spatial arrangement) spatial dimensions and clarity. Types of places were similarly evaluated; the two streets (one in Nantes, one in Lyon) were evaluated as loud and monotonous, while the two squares (one in Nantes, one in Lyon) were evaluated as varied and pleasant. Similarly, three factors were identified using only the acoustical data. One factor, identified that sound levels differentiated between the streets, while the squares were distinguishable by emergence parameters. Differences between squares and streets in the two different cities were identified with another acoustical factor, consisting of background noise levels and sound level magnitude. Lyon, a city 5 times bigger than Nantes, had louder background noise levels (Raimbault *et al.*, 2003).

6.10.7 Together, acoustic measures and subjective measures can identify similarities and differences between otherwise similar or different types of place. The combined measures can further differentiate between types of places within different cities, within which individual differences in evaluations can arise. The combination of both objective and subjective measures therefore enables a thorough assessment of a soundscape along with the attendant complexities. This in turn aids a more accurate understanding of the soundscape, helping to predict responses to changes in the soundscape.

6.11 Mixture of *in situ* and in the laboratory

6.11.1 Some case studies have involved work carried out both *in situ* and in the laboratory. These often involve making recordings of the soundscape and possibly the landscape while conducting work *in situ*, and then using these in the laboratory, with similar or different methods. Conducting research in both these environments enables a more thorough exploration of the factors that may influence soundscape assessments and how assessments are altered by different design modifications. Using both methodological approaches allows researchers to benefit from the advantages of each as well as slightly counteracting the disadvantages of each; more nuanced results can be obtained and results become validated if the outcomes are similar.

6.11.2 Davies *et al.*, (2009) conducted a number of *in situ* and experimental study of urban spaces (pedestrian streets, shopping malls, urban square, urban park and roads with high traffic volumes) in **Manchester** and **London, UK**. Soundwalks were conducted and binaural recordings of the soundscape along the soundwalk route were taken. Participants in the soundwalk were asked a series of questions about the soundscape in each key space entered (e.g. What can you hear? What do you think is in the background? How do you value this space?). In laboratories, participants were presented with 30 second binaural recordings or 8 second binaural recordings and asked to evaluate the soundscape on semantic differential scales (including the adjectives calmness, relaxation, comfort, reassurance, vibrancy, arousal, informative, intrusiveness and pleasantness). Additionally, in a separate aspect of the study, participants listened to the soundscape recordings while their cognitive responses were monitored in fMRI scanners. These identify physiological areas in the brain that are specifically active during the listening and evaluation process.

The soundwalk transcripts were analysed and identified three components used to describe the sonic environment, each with their own terminology. Firstly, sound sources are frequently listed (e.g. traffic lights), followed by sound descriptors (e.g. flapping, clatter), in addition to soundscape descriptors (e.g. constant). This series of components was described as reflecting the foreground and background distinction of the sonic environment (e.g. Schafer, 1994). In particular, two dimensions were proposed for soundscape descriptors; one to describe the interaction of sources (cacophony-hubbub) and one to describe the evolutionary and dynamic nature of the soundscape (constant-temporal). These terms were described as two different components of vibrancy, which itself was a factor derived from analysis of the soundscape evaluation ratings made in the laboratory, alongside a calmness/relaxation component. The differences between soundscapes rated high and low on the calmness/relaxation component and vibrancy component were monitored on the fMRI scans.

Using a combination of *in situ* and laboratory studies, quantitative and qualitative, a triangulation of results emerged on the elements that are important to people's description and assessment of soundscapes, in particular the emotional response to sound. These combined results also highlight the potential that can be achieved from interdisciplinary research (the project involved acousticians, social scientists, artists, and health scientists).

6.11.3 Ge and Hokao (2005) conducted an *in situ* and experimental study of eight streets in **Saga City, Japan**. The streets varied from the loud Main Street (≈ 65 L_{Aeq}dB, shops, traffic, buildings) to the quieter alleys behind it (45 L_{Aeq}dB, green areas, cultural spots). The morphology (e.g. buildings), transportation, activities and sounds heard in the streets were noted by the researchers. Additionally, people (n=75) in the streets were asked to rate the sounds they could hear in terms of 'preference' (like-dislike) and congruence with its surroundings (unharmonious-harmonious). As with many other studies (see Kang, 2007), natural sounds were generally preferred and transportation sounds were disliked. Nuances were identified in the strength of the dislike for traffic sounds, as they were disliked a lot in quiet streets, while in busy traffic orientated streets, they were only slightly disliked. The congruence of traffic sounds with the busy street was higher than in the quieter street, thus the context of the street type, seemingly played a role in the evaluation of the sounds.

Videos of the streets were played to University student participants in a laboratory. The participants were presented with 11 semantic scales, using adjectives that had been developed from a prior study of verbal emotional impressions of sounds (e.g. noisy-quiet, gloomy-sunny, inactive-active). These scales were then used to assess the audio-only presentation of the streets and also the audio-visual presentation of the streets. The overall preference and pleasantness of the street soundscape was similar regardless of the presentation type (audio or audio-visual). However, ratings of other adjectives varied depending on the presentation type (in particular with 'noisy-quiet' and 'inactive-active'). The amount of variation also depended on the type of street soundscape (Ge & Hokao, 2005). An awareness of this diversity in the evaluation of the

soundscape, what makes it preferred, and how this is or isn't influenced by visual factors is important when designing and adapting soundscapes.

Further analysis of the results identified three different types of street soundscapes, dependent on how they were evaluated. These were then depicted by the evaluative ratings, the morphology of the street and individual sound components; for example one street type mostly involved artificial elements, and was the least preferred, another contained more natural elements with fewer people and buildings and was the most preferred albeit rather gloomy (Ge & Hokao, 2005). Using this combination of noted sound components, soundscape types, audio-visual interaction, usage and morphology of the streets can help identify which elements could be adapted to improve the soundscape.

This style of research helps identify the diversity of soundscapes within a type of environment (street) and the elements that could be adapted to effectively improve the subjective impression of the soundscape, while maintaining their own identities. Additionally, the study was able to incorporate a number of elements that are also considered important in the soundscape assessment (vision, morphology). Comparisons between the *in situ* and laboratory results would have been beneficial in order to examine the success of the laboratory in producing similar reactions to a real situation.

6.12 Summary

- 6.12.1 Many different methods and tools have been used to assess soundscapes in a number of places. Each approach has its own advantages and disadvantages and using a number of methods in one case study can help overcome some of these aspects. Collectively, case studies help understand soundscape assessments and the range of issues involved which should be considered when researching soundscapes.
- 6.12.2 From the case studies presented above, a number of aspects have been identified as important when understanding and assessing soundscapes, these have included: individual and demographic similarities/differences; people's behaviour; physical aspects of the soundscape; other sensory and environmental elements; and the general location and context. Each of these is briefly defined in the following paragraphs, with reference to the case studies described above. This list of aspects reflects the (relatively) small number of case studies presented here. The overall soundscape literature review (presented in sections 2 to 5) identify other elements that are also important to soundscape assessments.
- 6.12.3 When soundscape assessments involve a subjective component, differences between individuals have been noted. These consist of an individual's knowledge and prior experience of the soundscape (Adams *et al.*, 2006; Nilsson *et al.*, 2003), which in turn may influence the meaning taken from it (Schulte-Fortkamp & Fiebig, 2006) and the attitude towards the source, both of which can play a part in assessments (Guillén & López-Barrio, 2007; Guyot *et al.*, 2005; Nilsson *et al.*, 2003; Schulte-Fortkamp & Fiebig, 2006). An individual's noise sensitivity is also

considered and controlled for in some studies (e.g. Guillén & López-Barrio, 2007; Memoli, Licitra *et al.*, 2008). Demographic and cultural differences in soundscape assessments can also arise, including between different age groups (Yang & Kang, 2005b), although similarities also exist between children and adults (Nilsson *et al.*, 2003). Gender differences in soundscape evaluations may only be small (Yang & Kang, 2005b) and there may be little cultural differences between similar European countries (Guyot *et al.*, 2005). People's assessment of the soundscape may also vary depending on individuals' behaviour (e.g. use of the space, Ge & Hokao, 2005), and their perceived control over the noise, which may include some form of adaptive behaviour (Adams *et al.*, 2006; Schulte-Fortkamp & Fiebig, 2006).

- 6.12.4 The soundscape sometimes perceived as a collection of the individual sounds of which it is comprised, thus the overall soundscape assessment is related to the assessment of those sound types (Ge & Hokao, 2005; Kuwano *et al.*, 2002). This therefore depends upon the identification of the sounds (Schulte-Fortkamp & Fiebig, 2006), the prominence of the sounds (Kuwano *et al.*, 2002), and potentially the ratio of certain sound types compared to others (Guyot *et al.*, 2005). Moreover, the soundscape varies over time thus the soundscape that is assessed is only for that moment in time and can heavily depend upon an individual's memory (Kuwano *et al.*, 2002) and/or the segment of the soundscape that was recorded (Semidor, 2007).
- 6.12.5 The soundscape is not something that is perceived in isolation, but is perceived and assessed alongside other sensory and environmental aspects. In particular, audio-visual interactions are emphasised in some of the case studies described above (Ge & Hokao, 2005; Guillén & López-Barrio, 2007) and a number of specific experiments have been carried out researching the influence between these two senses (e.g. Carles *et al.*, 1999; Viollon *et al.*, 2002). As well as vision, other sensory and environmental elements are important including perceptions of cleanliness, security (Rozec, 2003), as well as the morphology (Ge & Hokao, 2005) and building facades and features themselves (Nyunt, 2004). In general, the whole context of the soundscape is important in its assessment (Adams *et al.*, 2006; Ge & Hokao, 2005; Nyunt, 2004), including in the comparison of similar place types (Yang & Kang, 2005b), and in the transition from, or moving between, one place's soundscape to the next (Hedfors & Berg, 2003).

7 Soundscape Design: Case Studies

When soundscapes are assessed and deemed to be of a poor soundscape quality, interventions and modifications to a place may be considered appropriate to improve the soundscape. In contrast to the number of interventions used to control noise, this review found relatively few reported interventions to improve soundscapes, or to design a place while considering its soundscape.

A number of examples of soundscape designs for urban civic squares, urban green spaces, urban residential areas and recreational areas are reviewed below. Where possible, for each case study, the concept behind the design intervention is depicted, the resultant design is described, and an evaluation of the design is provided if it has been assessed. The examples presented are not an exhaustive list and other processes and tools have been developed to design soundscapes; these are not presented here however as they have not been tested in a particular location. Additionally, case studies for Wales, Scotland and Northern Ireland were sought but no reported examples were found.

7.1 Urban civic spaces – streets, squares, stations

7.1.1 Neville Street underpass, Leeds, UK By Arup Acoustics (2008)

Leeds City Council and Yorkshire Forward wanted to regenerate a pedestrian route from the city centre to south Leeds' residential areas. This included a busy road underpass below the main railway station, which was dominated by road traffic noise and "considered dirty, aggressive, noisy and very unpleasant" (Arup Acoustics, 2007). The aim was to make the walk through the underpass more attractive by enhancing the soundscape.

The soundscape in the underpass was recorded before any alterations were made. Potential soundscape alterations to the underpass were modelled and played back to clients and artists in the sound lab, allowing assessments of potential design alterations, before they were made. Acoustic panel absorbers are to be placed on the wall of the underpass and a sonic art installation by Hans Peter Kuhn is to be put in place. The installation will produce compositional soundscapes in between the sound of passing traffic. The aim of the sonic art installation is to redirect pedestrians' attention towards more positive aspects of the soundscape, rather than traffic sounds (Arup Acoustics, 2007). The acoustic panel absorbers are to reduce the overall sound level of the underpass, these are also to be decorated to make the underpass more attractive.

The soundscape design is yet to be completed, thus it cannot be formally evaluated.

7.1.2 **Sheaf Square, Sheffield, UK** By Arup Acoustics (2008)

Sheaf Square is the open space in front of Sheffield train station; originally it was a car park and taxi rank for the train station. The square is adjacent to a very busy inner city ring road, thus the space was exposed to high noise levels from road traffic. The square was redesigned to be turned into a more welcoming space for pedestrians and a space to relax for users of the station. The designers were aware of the importance of the soundscape in creating a space that people would want to rest in and the need, therefore, to counteract the noise from the traffic.

The square was turned into a pedestrianised area with an upper area that has a slope and steps down to a lower area. A noise barrier was erected that runs alongside the road, thereby separating the traffic from the square visually and acoustically. The noise barrier is a tall silver curved screen that conjures up associations with Sheffield's 'steel city' history. The barrier is also a water wall with water cascading down it from top to bottom, ending in a pool of water at the base of the barrier near the entrance to the station. Next to the barrier is the main pathway sloping down towards the train station and on the other side of the pathway is another water feature. This involves a series of shallow water beds that drop down from one level to another with the water flowing over the edges mimicking the sound of passing trains, thus linking the identity of the space to the train station. At the bottom of this water structure there is a large water fountain which provides additional masking of the majority of the road traffic sounds.

Noise level maps show the reduction of the sound level with the inclusion of the noise barrier. The sound level is again altered with the addition of the water features which produced an increase in the sound level around the water fountain (Arup Acoustics, 2008). However, the water sounds mask the background traffic sounds, thus improving the soundscape quality of the space. The space is well used and is a vast improvement on the prior design suggesting that the overall design and soundscape consideration within the design process was a success.

7.1.3 **Warwick Bar, Birmingham, UK** By Liminal (2006) and Prior and Crow (2008)

Liminal is a company consisting of an architect and a sound artist/composer. Along with Kinetic AIU architects, Liminal were brought into the design process of the regeneration of the new cultural quarter, Warwick Bar, in Birmingham. Warwick Bar was historically important to industries as a number of canals and rivers are located there, including the Grand Union Canal. The artists were expected to work with the architects from the start of the design process, applying a 'broadbrush' approach rather than identifying specific alterations or sonic installations (Public Arts Online, 2007). They also had to report upon the engagement process between the artists and the designers. Liminal's approach is to consider the current soundscape and work with it, rather than through a desire to control or preserve soundscapes (Public Arts Online, 2007). They

aimed to identify sounds that were present that should be kept and enhanced, as well as sounds from the past that could potentially be reinstated (Liminal, 2006).

Old Ordnance Survey maps were studied to understand the history of the place and identify sounds relating to Warwick Bar's history. Liminal used a soundwalk with project managers and architects, whereby all the sounds that could be heard at four key points on the site were noted. Conversations about the sounds heard en route by people visiting the location were also recorded. Soundwalks for the public were created and were made available on portable audio devices which people listened to as they walked around the site. The recordings consisted of sounds from the area that would have been heard in the past, present day sounds, and interviews of people discussing historical aspects of the past – both factual and experiential.

Aside from the development of the audio files - created as part of a soundwalk during an Arts festival - there was no specific input into the soundscape design of the area. Liminal proposed a 'biological sound design', which involves incorporating specific plantings, encouraging wildlife, and using the canal to attract various human activities and their positive soundscapes (Liminal, 2006). In addition, Liminal's work reportedly triggered the architects to consider the soundscape in their own development plans for the area (Public Arts Online, 2007). For example, noise maps of the current area were compared with modelled noise maps relating to different potential architectural designs and layouts. The success of Liminal's involvement and their sound considerations, with the architects and designers on the project was to be documented and evaluated, but owing to different timings of the project (due to funding issues) this was not thoroughly conducted (Public Arts Online, 2007).

7.1.4 **'Harmonic Bridge', Millennium Bridge, London, UK, 16th June-16th July, 2006**
'Wave Phases at Chesil Beach', National Maritime Museum, London, UK, 1999
By Fontana

Bill Fontana is a sound artist who uses environmental sounds, their settings and various sculptures to create an artistic soundscape that can make people reconsider the relationship between environmental sounds and their settings. He was interested in the way relocating sounds from different contexts might alter the meaning of the sounds when recreated in a different setting and their interaction with the new setting (Fontana, 1987). By using familiar sounds and replaying them through hidden speakers, any juxtapositions between the familiar sounds, their new spatial situation and context, forces passersby to consider the presence of the sounds in their new location (Fontana, 1987).

The Harmonic Bridge involved vibration sensors placed on the array of cables on the Millennium Bridge, a suspension footbridge in London. The sensors translate the vibrations into acoustic frequencies, with each type of cable creating a different type of sound, which also varies depending on the wind, the number of people on the bridge (load), and the energy created from pedestrian footsteps (Tate Modern, 2009). The resultant sounds were replayed for a month into "a

spatial matrix of loudspeakers” located within the nearby Tate Modern and main concourse of the Southwark London underground station (Fontana, 2009). This constantly changing soundscape concurrently adapted the sonic installations, yet its perception also depended on the physical structure of the Tate Modern and Southwark station concourse (Fontana, 2009).

The installation at the National Maritime Museum was, in 1999, initially a live recording from the sounds of the waves on Chesil Beach, near Weymouth, Dorset, UK. Depending on the tidal phases, the soundscape of the waves on the pebble beach vary in intensity. The recordings were placed in the pathway up to the museum and in the lobby; thereby visitors who had just arrived from the busy road were greeted by the sound of waves, linking them to the current soundscape of the beach (National Maritime Museum, 2008).

The sounds of the beach at the National Maritime Museum offset the noise from the traffic, providing an increased positive soundscape, creating an identity to the museum’s entrance that instantly takes visitors away from the city soundscape. The Harmonic Bridge also marked the museum’s entrance, this time linking the entrance to the unheard sounds from the bridge that some visitors may have just walked on.

7.1.5 **Market Hall, Frankfurt, Germany** **By Ipsen (2002)**

A change to the soundscape was considered a possible way to raise awareness of environmental issues by a group of artists. In a market hall square in the city centre of Frankfurt, different sounds of water were played into the area. The artists hoped that, by altering the soundscape passersby would consider the use of water in a city compared to their usual urban routine (Ipsen, 2002).

The success of the sonic installation was measured by comparing the length of time people stayed within the market hall. The artists determined that at least 30% of the passersby stayed for a longer period of time than when no water sounds were played. People they interviewed in the square were said to commented on the relationship between urban and natural environments, suggesting awareness had been raised about such issues (Ipsen, 2002). However, the extent of the introduction of the natural sounds, or any changes in their awareness to environmental issues was not assessed. It was suggested that because people remained for longer periods of time than they may otherwise have done, the soundscape may have been evaluated more positively when the water sounds were played than when no natural sounds were heard within the area (Ipsen, 2002).

7.1.6 **Open public spaces, South Korea** **By You and Jeon (2008)**

A piece of experimental research was conducted to ascertain the changes in the evaluation of open public spaces after the introduction of sounds and landscape manipulation designed to alter the perception of the current soundscape. The

aim was to assess the soundscape before and after the intervention. Eight open public spaces were chosen, at a range of distances, from a number (0, 1 or 2) of construction sites and were located by roads with different traffic volumes (low to high). Nine sounds were introduced as maskers to test their effect on the evaluation of the open spaces' soundscape. These were the sounds of a waterfall, rainfall, a stream, a lake, birds in a forest, seagulls in a port, insects, church bells, and wind.

Sound levels were recorded on a binaural model head and torso simulator, 1.5 metres high, 15 and 33 metres away from the road. Two sites were chosen that had high sound levels at low frequencies owing to traffic noise, although one site was more harmonic than the other due to additional noise from the construction site. Recordings of these soundscapes were combined with each of the masker sounds, producing 7 second soundscape stimuli. The new recordings were presented to 12 participants, between 20-30 years old, along with an image of the site. They compared two recordings at a time, and stated which they preferred. The masker sounds of the incongruent stream and lake were the most preferred while rainfall, seagulls in a port and wind sounds were the least preferred. This pattern of results was the same for both sites, regardless of the presence or absence of construction sounds. However, the preferred sound level of the maskers 'stream' and 'lake' varied depending on the type of noise at the site. Alongside construction noise, the combined soundscape was most preferred when the introduced masker sound was 3dB(A) quieter than the sound of construction noise. Alongside road traffic noise, the combined soundscape was most preferred when the introduced masker sound was at the same level or 3dB(A) less than road traffic noise. Preference for the masker sound decreased when it was presented above the sound level. The preferred sound maskers, the stream and lake, were also installed into the actual site to test the effect on psychoacoustic evaluations *in situ*. This confirmed that the loudness of the road traffic noise and construction noise was perceived as quieter when it was combined with slightly quieter masker sounds of nature.

Although this study did not actually include the permanent installations of sounds into a location, the study was able to identify the benefits of adding certain types of sounds into a place to improve the impression of the soundscape. Interestingly, the sound levels of the introduced sounds did not need to be louder than the noise they are masking to have a positive influence on the soundscape. This is extremely beneficial when increasing the sound level overall could have damaging health consequences.

7.1.7 **Bus stations, South Korea** **By Park, Song, Song, Jang and Kim (2004)**

In Korea, the government is trying to consider soundscapes, with The Ministry of Environment trying to compile a database of 'beautiful sounds'. Park *et al.* (2004) aimed to improve the soundscape in large bus stations by introducing 'appealing sounds'. Originally, the bus stations had measured sound levels between 55 and 75dB(A), with an average 10dB(A) fluctuation at each bus station over time. The waiting rooms had similar 62dB(A) levels, with the pedestrian walkways having

similar levels. The arrival halls' sound levels varied from quieter or louder than the walkways, depending on the bus station. The soundscapes were evaluated less positively than the overall sound evaluation, by 10 acousticians, using 25 semantic differential scales.

Nine sound sources were sampled to be played back into the various locations within the bus station. These were wind in leaves, cuckoo bird, rain, wave, stream water, popular Korean music, popular English music, news announcements, and a combination of classical music and birds. Each of these sounds was replayed at each of the various locations.

The same 25 semantic differential scales were used to evaluate the soundscape when the sound compositions were played into the various locations. These identified that the complex sound of classical music and birds produced the most positive responses compared to the normal ambient background sounds. The sound of English music was also rated favourably on many attributes. In contrast, the sounds of waves and rain only produced a slightly positive evaluation of the soundscape and on some evaluative attributes it actually produced a negative evaluation. Therefore, although natural sounds tend to be evaluated preferably, in the bus station they were not rated as favourably, possibly due to their incongruence with the surrounding environment. Therefore, caution should be taken with the introduction of certain sounds as they may not necessarily improve the soundscape.

- 7.1.8 **Gylling, Østjylland, Denmark, 1995**
Boulevard Laurent Daniel Casanova, Villepinte, Paris, France, 2000
Anyang, South Korea, 2006
West Avenue K and G, Lancaster, California, USA, 2008
Various roads in Hokkaido, Wakayama, and Gunma, Japan, 2008
By various

Musical roads have been designed so that cars driving at a certain speed play a tune that can be heard within the car due to the vibration produced from the wheels. Musical roads have involved adding raised discs of various sizes and shapes or cutting grooves into the asphalt of various depths and of various distances apart. These create different frequency sounds when driven over and with careful positioning of the grooves or raised discs a musical composition is 'played'. The roads have been created for a variety of reasons including commercial marketing, tourist attractions and keeping drivers alert and awake.

On Boulevard Laurent Daniel Casanova in Villepinte, Paris, composer Gaëllic Guillerm created a 28-note melody based on Cm7 minor key with 4 notes using corrugated patches on the road that varied for the left and right wheel (Kempa, 2006). In Denmark, sound artists Streen Krarup Jensen and Jakob Freud-Magnus used raised discs to create a tune along a road which they called 'the Asphaltophone' (Stalker, 2009). In Japan, the engineer Shinoda and the Hokkaido Industrial Research Institute designed roads to have tunes that were locally relevant (Noise Addicts, 2008). This included popular regional tunes, 'Memories of summer' and a popular theme tune 'Alvin and the Chipmunks', being played

when driven over at an optimum speed of 28 and 31mph (Gigdoggy, 2008; ITN, 2007). There are musical notes drawn onto the road and colourful signposts to alert the drivers to the oncoming 'musical road' (Noise Addicts, 2008). The Japanese site near Gunma involves 2559 unevenly spaced grooves in the road over a 175m stretch of road and costing £10,000 which was installed to attract tourists to the region and its infrequently used roads (ITN, 2007). In Anyang, South Korea, the road was created for safety reasons on a downhill curved stretch of road where a number of accidents had happened, with the tune 'Mary had a little lamb' being 'played' when driving at the speed limit of 62mph (ABC News, 2007). In Lancaster, USA, the overture of William Tell was 'played' when cars drove down the road with an optimum speed of 55mph (Gigdoggy, 2008). The installation was paid for by the American Honda Motor Co. Inc, who used it to market their latest car model (The Musical Road, 2009).

The quality of the tune heard within the vehicle varies across the streets and is also variable depending on the driver's speed and if the window is open (Noise Addicts, 2008). The 'tune' sounds very different from outside the vehicle. Initially, there was a positive response from the local residents in Lancaster, USA, and in Villepinte, France, but after a couple of months both road structures were smoothed over owing to a number of complaints from residents becoming annoyed from constantly hearing the sound (The Musical Road, 2009; Kempa, 2006). The musical road in Lancaster was then recreated at a site further away from any residential houses (The Musical Road, 2009). Additionally, damage may be caused to the tyre tread over a long period of time causing skidding in wet weather due to reduced traction (Stalker, 2009). Therefore, the success of musical roads is mixed, with a general decline in their positive evaluation over time especially when placed near to residential areas.

7.2 Urban green spaces - parks

7.2.1 Thames Barrier Park, London, UK

By Greater London Authority, Groupe Signes and Patel Taylor

Thames Barrier Park, is on the edge of the River Thames, adjacent to the Thames Flood Barrier. The entrance to the park is by the Docklands Light Railway and a major road. A short distance away is London City Airport. Originally, the site was a piece of brownfield land until designated to become the first riverside park built in London since 1950 (Garden Visit, 2009). The park was designed to provide a green space for local residents and for visitors viewing the Thames Barrier Park as part of an urban development project. The soundscape of the park was considered during the design process.

The 22 acre park was opened in 2000 and contains pathways, numerous trees, Yew and Maygreen hedges, plenty of wildlife, a 32 jet water fountain, a sports court, and a children's playground (Thames Barrier Park, 2009). The whole park is built onto a plateau so that visitors are protected from the road traffic sounds (Mayor of London, 2007). Additionally, to reflect the past history of the immediate area - the London docks - a green trench runs through the centre of the park. As the trench is at road level there is a water fountain at the start of it

which masks the noise of the road traffic from visitors, as well as acting as a visual, play feature and providing a positive sound (Mayor of London, 2007).

The park won the Best Open Space in Britain Award in 2008 (Times Online, 2008) thus inferring the success of the overall design of the park. It was also listed by Arup as an example of good sound conscious urban design, describing it as having an “effective, visually and attractive safe edge acoustic screening of open spaces” (pp14, Mayor of London, 2007). By considering soundscapes from the outset of the design process and integrating the soundscape design with other sensory experiences, it is seemingly a good example of soundscape design.

7.2.2 **Museum of Garden History, Lambeth Palace Road, London, UK, and St Thomas’ Hospital Garden, London, UK**
By Memoli, Bloomfield and Dixon (2008)

A three step action plan was proposed for improving people’s perception of two urban parks adjacent to busy roads in London, UK. First, this involves making a characterisation of the place by describing its soundscape via noise indicators, any cultural and place specific information, alongside observations of people’s behaviour. The soundscape expectations from the place’s potential users should also be understood. Secondly, optimization of the soundscape takes place via some form of intervention or modification of the landscape and its acoustical and visual features so that it matches its users’ expectations. Indicators may potentially then help assess the success of the altered soundscape in relation to users’ perceptions. Thirdly, the intervention is evaluated to assess its success in creating a positive enjoyable soundscape (Memoli, Bloomfield *et al.*, 2008). The two parks have different sections within them but both had a fountain (one was deactivated), planted areas, concrete areas, and some benches. Each of the parks could be separated into two areas by their sound pressure levels [60-65 and 65-70dB(A)], measured by 45 and 15 minute recordings taken at various points throughout the parks. Slope indicator values (see section 4.2.8) were able to further differentiate between the parks’ different areas. In the Museum of Garden History the slope indicator near the fountain was slightly more positive than by the roadside, as the fountain masks some of the road traffic sounds. Analysis of sonograms also distinguished different soundscapes at different locations within the park. For example, at one location, event peaks are clearly distinguishable from the general low level background noise, which are caused by the junction with traffic lights on the neighbouring road. The sonogram also identifies the dominance of traffic sounds in the frequency of 200 hertz (Hz) and 2 kilohertz (kHz).

The combination of the slope indicator and sonograms were described by Memoli *et al.* (2008) as useful for characterising the soundscape and identifying areas that could be manipulated to enhance the positive nature of the soundscape. For example, for the fountain to mask the traffic sounds it would need to be designed so that the water flow rate and surfaces it lands on are at a similar frequency to the road traffic. Differences between the slope indicator values related to people’s behaviour patterns; the slope indicator value became more favourable when children were playing in the area. It was concluded that indicators that

weren't necessarily source dependent were useful, as are multi-disciplinary research teams to interpret and collect the range of appropriate data (Memoli, Bloomfield *et al.*, 2008).

The project on these two parks is currently ongoing, possibly with plans to include sonic art installations and the reactivation of the water fountain. The success of the interventions will then be evaluated using the slope indicator and observations of people's behaviour, thus they cannot be formally evaluated here. The three step plan of characterization, optimisation and evaluation is a useful approach for soundscape designs, as successful and unsuccessful processes can be identified and used for future modification plans.

7.2.3 **Giardino Sonoro Limonaia dell'Imperialino (Sonic Garden), Florence, Italy**
By ARPAT, Licitra and Memoli (2006) and Memoli, Licitra, Cerchiai *et al.*, (2008)

An intervention was proposed within an urban garden in Florence. It was located next to a very busy road, situated half a metre higher than the garden. The aim was to create a quiet urban area and aid the development of a measure to assess the 'quality of quietness' by linking perceptual and physical aspects. The idea was to introduce sculptures incorporating sound and light to create a more pleasant soundscape. Active control techniques were implemented, using the new source sounds as a contrast to the road traffic noise, as well as masking the road noise by increasing the sound level with the addition of a different sound type.

Three sound sculptures were placed at the same distance from the roadside; rosefield, flying dolphins and sonic wall. The rosefield consisted of three loudspeakers placed at the ends of tall cylindrical tubes, facing the walkways of the park. The flying dolphins were a sculpture created by plexiglass structures suspended on rods that moved around in the wind. Each dolphin had a speaker directed towards a concave element of the dolphin, so that passersby heard the reflected sound, rather than directly. The sonic wall was a mesh wall consisting of loudspeakers, covered over by vegetation, to produce "sound parallel to the terrain" (pp3, Licitra & Memoli, 2006). Three different types of sound compositions were generated and played back through the sculptures. One involved human voices, singing or story telling combined with classical or baroque music. Another involved a mix of classical and baroque music. The third composition had some classical and baroque music mixed with recordings of an urban street with traffic. The sculptures were not always turned on and did not look as if they should be sound-specific designs.

The success of the sculptures in improving the perceived quietness of the park was assessed using a slope indicator. Accordingly, quietness of the park improved when the sculptures' sound was turned on. The sound composition that achieved the greatest 'quietness' varied depending upon the sculpture, except for one sculpture which produced the same result regardless of the composition played. The composition which included some road traffic sounds produced the least 'quietness' response. The frequency of the sound

compositions suggested their success could be partly due to breaking up the flat spectrum from the road traffic noise.

A questionnaire was also conducted with public visitors to the garden to help evaluate the sculptures' success in enhancing the soundscape quality and its quietness. The perceived noise and annoyance of the road traffic was assessed, taking into account participants' noise sensitivity. The perceived noise and annoyance from the traffic however did not differ depending on whether the sound sculpture was turned on or off, particularly for those with extreme views on noise and annoyance (e.g. not at all, or very annoyed). People with intermediate noise sensitivity were positively affected by the sound sculptures, with a large decrease in their perceived annoyance from the road traffic, when the sculpture was turned on.

Overall, the success of the sound sculptures is mixed with indicators suggesting an improved quietness, but with people reporting little change in their annoyance towards road traffic sounds. The mix of methods used in evaluating any soundscape intervention is therefore recommended in order to gain a full understanding of the success of the intervention and the way in which it works (or not).

7.2.4 **Nauener Platz, Berlin, Germany**

By Schulte-Fortkamp, Volz and Jakob (2008), Rossmannith and Willecke (2009) and Volz, Jakob and Schulte-Fortkamp (2008), to be completed June 2009

Nauener Platz is an urban park that was part of a regeneration project for a residential area in central Berlin. A soundscape based approach was taken when redesigning the park to be an attractive place, with a positive social life for both young and old visitors. Soundwalks and interviews were carried out with potential public users of the park (e.g. residents and workers in the area), to get their understanding and assessment of its soundscape. A map of the park was annotated with the sounds that could be heard in the different areas to help analyse the space and compare it with people's use of the park. Acoustic parameters as well as factors relating to individuals' assessment of the soundscape and sound characteristics were used to help design the space.

The park has a busy trafficked road along one side, which previously dominated the soundscape within the park. Bushes were planted to act as a visual and acoustic barrier that would be particularly beneficial for the park bench users, by reducing perceived and objective sound levels. The barriers had to be at a low level to ensure passersby could see into the park, thus enhancing the safety of the park by deterring crime due to the openness of the space. 'Audio Islands' were designed and installed. These were different shaped seating benches/sculptures, each designed to attract either young or old visitors and had directed speakers placed inside them. People sitting on the audio islands have individual controls to choose which of a few sound recordings they wish to listen to (e.g. the sound of water on a beach), or none at all. An acoustic curtain was also installed and the sound intensity increases as the installation is walked through, whilst on a terraced grass area, the sound of the sea can be heard.

The project is due to be completed in June 2009, but it is unknown if any post evaluation is planned. The use of individual controls for the audio islands allows a diverse array of sounds to be used, thereby potentially satisfying an array of people's different sound preferences. The appropriateness or success of using non-contextual related sounds, such as the sea, within an urban park without a water feature, needs to be evaluated. The longevity of the audio installations however is not known.

7.3 Urban residential

7.3.1 Gainesville, Florida, USA

By Siebein, Kwon, Smitthakon & Gold (2006)

A sustainable urban village was proposed for part of Gainesville and in the initial site analysis and design process a soundscape study was conducted. The project involved a number of different areas incorporating architects, planners, urban designers, and transport specialists to create an integrated solution to infrastructure and sustainable urban development. The site was next to the University and had a number of heavily congested roads which surrounded a mixed land use area of residential apartments, commercial premises and public services.

Seven different methods were used in the soundscape study. These included soundwalks at various times of the day and week, with the consultants noting the array of sounds heard, their frequency, and duration. Sound pressure levels were monitored and average day night levels calculated, as well as recordings and analysis of specific sound events noticed during the soundwalk. Focus group discussions were had with the design team, residents and stakeholders to identify categories of sounds and potential interventions to improve the soundscape. The information was displayed on an acoustical map of the site and possible interventions and sound source combinations were modelled. Five different acoustical zones were identified in the area (e.g. transport artery, residential, commercial, natural), which were then tackled using appropriate solutions for their specific attributes.

The focus groups between the involved parties identified a number of elements that could be altered to improve the general physical and social qualities of the area, which in turn affect the soundscape. These included more entertainment (e.g. restaurants and retail providing social sounds), ecological solutions to storm water (e.g. natural areas providing natural sounds) and the provision of more environmentally friendly transportation solutions (e.g. cycling, walking, and quiet buses providing less transport noise). In addition to the transportation, infrastructure and architectural alterations, acoustical interventions were also proposed. These were grouped into three types: remove, buffer or mitigate the negative sounds in the area (e.g. from the busy trafficked roads); preserve and/or enhance existing positive sounds; and add sounds that could aid the urban design of the area.

For the three types of acoustical interventions, negative sounds were removed by switching buses to electric, reducing mixed traffic flow, and encouraging different forms of transportation. Buffer zones were created by separating pedestrian and bicycle routes from the traffic roads, with the use of acoustical barriers, planting and landscaping to help define space. By providing distance between traffic sounds and other activities, and locating similar activities together (e.g. cafes, parks) the positively evaluated sounds are preserved such as natural sounds and audible conversations. In addition, by designing related spaces near to each other, and with careful planning, desired sounds can flow between the spaces, attracting more people to the activities. Alternatively, quiet areas can be created by blocking the flow of sounds between the different spaces.

The cooperation between the different departments involved in the project, the identification of three different strategies to improve the soundscape, and the involvement of numerous relevant parties, seemingly provided a beneficial way to plan for the soundscape in a realistic manner, complementing the overall project of the development of the site. However, the evaluation of the strategies used and resultant proposals have not occurred, or have not been reported.

7.4 Recreational sites

7.4.1 Imagination playground, lower Manhattan, New York, USA By ARUP Acoustics, construction starts May 2009, to be completed by 2010

A car park in New York is to be turned into a children's playground and the clients (Rockwell Group, New York City Department of Parks and Recreation) wanted the soundscape to be considered, as they were aware the site could be quite noisy (Woodger, 2008). Arup Acoustics made recordings from a number of playgrounds throughout New York so that the soundscape of the new playground could be compared to others available. The recordings highlighted the loudness of all the playground sites in New York. Recordings of the current playgrounds and the potential soundscape of the playground being designed were shown to the client within the sound lab. Using the sound lab, alterations were made to the design and the effect this had on the soundscape was modelled and monitored to try and improve the soundscape of the new playground (Woodger, 2008).

Existing playgrounds provided a baseline context of New York playgrounds for comparison with the design of the new playground. Without these comparisons, the current design would initially have seemed very noisy to the client (Woodger, personal communication, 13th February 2009). The designer of the playground also found it very useful to use the sound lab as a tool to consider the soundscape and hear how the layout and design of the playground could be altered to enhance the soundscape, by excluding traffic sounds or including positive sounds (Woodger, personal communication, 13th February 2009). As the park is yet to be built and used at the time of press, an evaluation of its success cannot be made (see imaginationplayground.org).

7.4.2 **Mount Ontake National Recreational Forest, Japan**
By Yamada (2006)

Forests in Japan provide a large portion of the natural environment and forest soundscapes account for 25% of the 100 soundscapes that the Japanese Ministry of Environment consider necessary to protect. Recreational pathways into forests however are often designed for the more active climbers and are not easily accessible for many who may want to stroll through the forest. A project by Yamada (2006) was therefore established to create forest trails with varied soundscapes that are appropriate for a variety of park users. The project was set in a national recreational forest in central Japan, which is in a sub-frigid zone, and the forest contained predominant sections of fir trees (new and old), birch, larch, understory vegetation and bamboo shoots.

Aerial Geographic Information Systems were used to identify 15 different zones, each containing different types of vegetation or mixed vegetation. Streams ran through the area, which were on gentle terrain. The sound intensity of the stream was recorded and spectral analysis of the soundscape within each section of the forest was calculated. This was used to create a sound weight value to differentiate between the different types of soundscapes for each zone. Additionally, the sound frequencies of the different vegetation types were calculated, as was their slope value. The presence of animals and insects in the different types of vegetation was considered (e.g. more birdsong in coniferous forests than broadleaf), along with the amount of wind necessary to create sounds amongst the leaves. The acoustic properties of the forest sounds were then matched with the frequency of human hearing and calculations made for each area based upon the type of vegetation it contained. Three walking routes through the forest were devised with the distances traversed through each vegetation type measured, and Land Use Diversity Index and sound weightings calculated.

Using the devised weightings, comparisons were made between the quality of the soundscape of similar length routes dependent upon the amount of variation along the route. The various routes could then be adapted if necessary by studying the surrounding area's vegetation, to create a walk that incorporates the highest quality soundscapes and Land Use Diversity Index. What is considered the best quality soundscape would again vary depending on the aim of the walk – complexity and variation (mixed vegetation) or a quiet calmness (large coniferous forest). The proposed routes also considered other elements rather than just the soundscape, including the terrain which can promote or hinder certain walking paths through a forest, as well as needing an awareness of different visitors' preferred activities and goals for visiting the area.

Decisions on which types of vegetation should be planted could incorporate soundscape decisions, although different regional weightings would be necessary to account for the different climate types (Yamada, 2006). The method seems an appropriate way to plan recreational walks through a forest and potentially the method could be adapted to devise routes through urban green spaces to maximise the quality of the soundscape route available.

7.5 Summary

- 7.5.1 Only a few case studies, involving the modification and designing of soundscapes, have been reported for the UK and the rest of the world, and of those available, their success has often not been formally evaluated. The presented examples range from artistic interventions (e.g. Harmonic Bridge, Musical roads), through council, policy and consultancy interventions (e.g. Gainesville, Neville Street), to experimental studies (e.g. Mount Ontake). The underlying rationale behind most of the case studies' focus on or consideration of sound was to improve a soundscape that was negatively affected by the sound of traffic.
- 7.5.2 Approaches to soundscape design varied, ranging from the use of usual noise control elements, such as barriers (Gainesville, Nauener Platz, Sheaf Square) and absorbers (Neville Street), to the use of natural elements that already exist in the location (Gainesville, Mount Ontake, Warwick Bar). Some case studies introduced sounds to the soundscape (Bus Station, Giardino Sonoro, Harmonic Bridge/Chesil Beach, Nauener Platz, Open Public Spaces), in particular, water sounds (Market Hall, Open Public Spaces, Sheaf Square, Thames Barrier Park). Others were, or incorporated, specific sonic art installations to alter the soundscape or detract attention from existing features of the soundscape (Giardino Sonoro, Harmonic Bridge/Chesil Beach, Musical Roads, Neville Street, Warwick Bar).
- 7.5.3 A number of case studies additionally used design alterations to the location to improve the soundscape and perception of the soundscape. This included altering visual aspects of the place (Giardino Sonoro, Nauener Platz, Neville Street, Sheaf Square), altering the layout of the area (Sheaf Square, Thames Barrier Park), pedestrianising the area (Sheaf Square), and recommending social entertainment facilities (e.g. Gainesville). These approaches aid the soundscape by changing the perception of the place and altering its function, thereby changing the sound sources in the area which may decrease the infiltration of sounds from the surrounding areas or removing the negative sound sources. Five reported studies (Gainesville, Imagination Playground, Nauener Platz, Sheaf Square, Thames Barrier Park) involved improving the place in general and, as such, soundscape considerations were integrated into the design process from the start. This allowed the soundscape to be considered alongside other experiential elements of an environment and enabled an understanding of the interaction between different sources creating the soundscape and their (un)importance to the place.
- 7.5.4 The case studies also varied in their use of introducing (in)congruent sounds to the soundscape. The outcome of these results were mixed, with the experimental studies suggesting that sometimes congruent sounds were preferred (Bus Station) while in other locations incongruent sounds were preferred (Open Public Spaces). Some of the case study examples did try to include design elements that were appropriate to the history of the place (Sheaf Square, Thames Barrier Park, Warwick Bar) or use sounds to help form the identity of the place (Harmonic Bridge/Chesil Beach, Musical Roads).

7.5.5 Hardly any of the case study examples were formally evaluated, with a few not evaluating the success of the soundscape design at all. The studies that were evaluated used a number of different methods to determine the design's success. These included the experimental comparison of subjective ratings (Open Public Spaces), observations of people's behaviour (Market Hall), recognition and awards for good designs (Thames Barrier Park), increased awareness of the soundscape (Warwick Bar), level of complaints about the soundscape (Musical Roads), and objective and subjective measures (Giardino Sonoro). Different evaluation tools are likely to be necessary dependent upon the type of soundscape intervention being evaluated. Additionally, using a number of evaluation methods in conjunction with one another, will produce a more accurate understanding of the success of the soundscape design, and aid future interventions.

8 Interviews with Soundscape Researchers and Planners

Interviews were carried out with five individuals identified as experts in researching and/or having practical involvement in the design and management of soundscapes. Three interviews were conducted face to face, while two interviewees responded via email. All interviews were carried out in January and February 2009. Interviewees were asked a series of questions (presented in the appendix, section 13), from which their responses have been collated and are depicted below. A brief biography of the interviewees is presented below, in alphabetical order, before subsequently being referred to by their surname.

- Mr Max Dixon, is principal strategy adviser on noise at the Greater London Authority, UK. He is a town planner and environmental policy analyst and was main author of “‘Sunder City’, the London Mayor’s Ambient Noise Strategy”, published in 2004 and its progress report in 2006. He has also collaborated with academics on the use of indicators within urban spaces (e.g. Memoli, Bloomfield & Dixon, 2008).
- Dr. Daniele Dubois, is a psycholinguist and senior researcher at the Centre National de Recherche Scientifique (CNRS), University of Paris, VI, France. She works with the organisation Lutheries-Acoustique-Musique. Her research involves studying how individuals perceive and evaluate sounds and how this is influenced by cognitive processes. In particular, she is interested in the language used to describe sounds and soundscapes in order to comprehend how individuals understand and interpret soundscapes and what influences these appraisals.
- Professor Jian Kang, is an acoustician and architect at the School of Architecture, University of Sheffield, UK. He has been involved in soundscape research for some time, studying both indoor and outdoor public spaces. His focus was upon modelling sound propagation but, more recently, he has also been involved with large scale international surveys incorporating the public’s perception of soundscapes. He is a Fellow of the Acoustical Society of America and Member of the Technical Committee on Noise and Technical Committee on Architectural Acoustics (ASA), a Council Member and management committee on the Building Acoustics Group of the UK Institute of Acoustics. He also leads the new COST action (European cooperation in science and technology) entitled Soundscapes of European Cities and Landscapes.
- Professor Dr. Brigitte Schulte-Fortkamp, is a Professor in psychoacoustics and noise effects at the Institute of Fluid Mechanics and Engineering Acoustics, Technische Universität, Berlin, Germany. She introduced the soundscape concept, 15 years ago into the field of Community Noise and is involved in national and international surveys on soundscapes. She is a Fellow of the Acoustical Society of America and Chair of the Technical Committee on Noise (ASA), Chair of the Technical Committee on Noise of the German Acoustical Society and member of its advisory board (DEGA), and a

member of the Executive Board of European Acoustic Associations (EAA). She is also a management member in the new COST action (European cooperation in science and technology) entitled Soundscapes of European Cities and Landscapes.

- Mr Neill Woodger, is a consultant at ARUP Acoustics. He has worked with numerous clients in the development of both indoor and outdoor spaces and the soundscape that will be produced from various building and landscape designs. Much of his recent work has been carried out in North America, although he is now based in London, UK.

8.1 The approach and disciplinary perspective taken by the interviewees was varied, although all mentioned involving subjective aspects in soundscape assessments. Indeed, subjective assessments are important, as they are part of the concept definition of soundscapes (Dubois, Schulte-Fortkamp). The interviewees' backgrounds varied and this highlights the interdisciplinary nature of soundscape work, which all interviewees agreed is necessary. For example, Dubois, Kang and Schulte-Fortkamp take an academic interest in human responses to the soundscapes of real world physical environments. Woodger focuses on physical design interventions and the influence this has on soundscape assessments made by laypeople/the client, and Dixon provides a practical, policy perspective, including incorporating soundscape considerations into transport, planning and urban design.

8.2 In contrast to the agreement amongst the interviewees on taking an interdisciplinary approach to soundscape research and the need for subjective analysis, there was little agreement upon *the* most valuable method and tool for understanding and assessing soundscapes in urban areas. As Dubois pointed out, the most worthwhile method and tool is highly dependent on the theoretical framework used for each study, and by each expert, hence the variation between interviewees. Most interviewees mentioned specific tools and methods that can be used, including spectrographs (a visual representation of the temporal and spectral composition of a signal, see section 6.4.4), slope indicator (see section 4.2.8), multiple card sorts (see section 5.1.5) and semantic differential scales (see section 6.1.1) (Dixon); artificial neural networks (see section 6.2.1) and semantic differential scales (Kang); soundwalks (see section 6.4.1), interviews (see section 6.5.1), and psychoacoustic data (see section 6.4.4) (Schulte-Fortkamp); and the sound lab at Arup Acoustics (Woodger). The sound lab is a technical simulation of soundscapes within a laboratory, using pre-recorded calibrated ambisonic (three dimensional) soundscape samples that can be altered and modelled according to design plans. Subjective responses to soundscapes are then sought from the client, on alternative design choices which alter the soundscape. A set procedure is followed to ensure ecological validity. Both Dixon and Kang however, stressed that further research was necessary to develop tools that are operational and to determine which are the most worthwhile for soundscape assessments.

8.3 There was an emphasis by some interviewees on the holistic and interdisciplinary approach that is necessary in understanding and assessing

soundscapes. For example, Dubois emphasised that “there is no best method per se”, as it depends on what aspect of the soundscape is being studied and by which discipline. Dubois stated that she first focuses upon understanding individual and collective human representations of soundscapes, prior to relating these subjective appraisals to physical attributes. Dubois adds that it is the integration of these methods and their subsequent results that provide the “adequate (non reductive) description of soundscapes”. Dixon, was in agreement, stating that discussing a ‘best’ method/tool and a ‘best’ soundscape was not appropriate, as methods and outcomes needed to be related to specific local factors.

- 8.4 For some of the interviewees, similar tools would be used for designing soundscapes as those used for assessing soundscapes in urban areas; artificial neural network model (Kang); psychoacoustic information and combined disciplinary knowledge (Schulte-Fortkamp); and the sound lab (Woodger). A focus upon the importance of the subjective nature of soundscapes was again emphasised by a number of interviewees calling for the involvement of the public in any soundscape design work. The manner in which this would be achieved varied, with innovative forms of capturing behaviour through mobile devices, as well as conventional public participation engagement procedures being suggested (Dixon). Other suggestions included monitoring users’ activities and interaction with the soundscape, and linking physical attributes to perceivers’ categorisation of sounds and place types (Dubois), and incorporating focus group interviews (Schulte-Fortkamp). Similarly, the sound lab (Woodger) emphasises the role of the client comparing soundscapes with other soundscapes that originate from similar place types and user activities, to achieve a focus upon eventual users’ soundscape perception.
- 8.5 There was some variation between interviewees in relation to the use of different methods and tools depending on the context. Some considered that similar tools could be used across different contexts, as they could be modified to suit the context being studied. The tools would potentially be influenced by aspects such as the ambience, area, social characteristics, seasons, and research aim (Schulte-Fortkamp). For example, the sound lab can be used in different contexts, by using soundscape samples from places relevant to the current situation (Woodger). Similarly, the artificial neural network can be used for different contexts by altering the variables (such as those identified above) and the importance of them in the model (Kang). Others considered that different indicators and different methods would be necessary for different types of urban areas, especially when simplifying the tools for practitioners, although the aspiration to find a unified indicator should not be entirely abandoned (Dixon).
- 8.6 Applying methods and tools in the correct manner was also emphasised (Woodger). This is an important point to make considering the diverse range of disciplinary backgrounds in researching and designing soundscapes, therefore a common understanding of the methods and their content was considered important (Schulte-Fortkamp). The assumptions embedded in the methodologies and tools need to be understood, to ensure their successful application, interpretation of results and awareness of their limitations. For example, for simulations, without a true understanding of the tools’ application

(e.g. technical calibration) and correct presentation of soundscapes to participants/clients (e.g. suggesting alternative meanings and values to the sounds to what they expect/think they are listening to) the perception and assessment of the designed setting and its soundscape may be negatively affected (Woodger). Therefore, an awareness of factors that can affect participants' stimuli perception is also important to be able to present audio stimuli in a successful manner (Woodger), and produce a realistic soundscape assessment as close as possible to a real world situation, particularly in terms of listener state and simulated activity (Dixon).

- 8.7 A common understanding of tools and language was also emphasised in relation to the various ways the term 'context' can be interpreted. Dubois stated that there are numerous levels of context, such as the context of the situation, the question being asked, who is asking it, who is paying for the research and redesign, alongside which individual will experience the soundscape. Moreover, Dubois states that 'context' should be redefined, with people as the focus, because it is they who rate the soundscape quality and this will depend on who they are, what they want to do and for what purpose (economic, political, individual). The method used then depends on these people-related factors, such as their noise sensitivity and complaint levels, their ability to avoid or control the noise and the impact the soundscape has on their health (Dubois). This is alongside further methodological issues, such as what language should be used in any method and the feasibility of the method in terms of economic, political and practical terms (Dubois), which can be limited by available resources (Dixon).
- 8.8 Similarly, Dixon referred to 'context' in both people orientated aspects (e.g. expectation, individual personalities, listening states of the individual and their activity influencing the meaning of, and attitude towards the sound) as well as physical related aspects (e.g. different land uses, visual characterisation). Therefore, the concept of 'context' could be viewed as being generated from the individuals, the physical layout, and design, which also influences the soundscape. In accordance with this, different tools or methods could be necessary for different contexts, depending upon what level of context was being discussed, how it is defined and how the research/design is framed. However, the basis of the inquiry may then become dependent on other factors that are not related to 'context', such as those described above (section 8.7) (Dubois).
- 8.9 The benefits of managing soundscapes were considered to be well reported and include elements such as improving society, people's well being, comfort and general quality of life (Dixon, Dubois, Kang, Schulte-Fortkamp, Woodger). A more sophisticated understanding of relationships between health, psychological restoration and soundscapes was still desired (Dixon). Additionally, Woodger emphasised the importance of understanding the bi-directional influence of soundscapes and human interactions. For example, the noisy streets of New York prevent conversations on the street and few sonic clues are provided from houses as to what is happening within them (Woodger), thereby discouraging neighbourly interactions and emphasising the separation between public and private territory.

- 8.10 The management of soundscapes was considered to be different from managing noise levels, as the latter do not incorporate other physical aspects of the sound, or non physical aspects relating to human representations and responses to these physical aspects (Dubois, Schulte-Fortkamp). Again, the definition of soundscapes was recalled, which includes both positive and negative aspects (Kang), unlike noise levels which only focuses on lowering sound levels (Schulte-Fortkamp) and are generally considered in relation to removing negative aspects. Noise levels were considered by some as a subset of soundscapes, with the former only focussing on one aspect, a quantitative aspect, compared to the more inclusive concept of soundscapes which considers quality and meaning (Dixon, Woodger). Moreover, case studies whereby soundscape methods and tools were unsuccessful in designing soundscapes were identified as those that relied upon reducing noise levels (Dubois), or just used noise parameters such as L_{Aeq} (Kang). This was because they weren't considered appropriate (Kang), as they did not incorporate all aspects of the soundscape concept. Work aiming to reduce noise levels was not belittled though, instead it should be considered as an important subset of the soundscape approach, as in addition to health issues, it can help "unmask positive sounds" (Dixon).
- 8.11 Opinions varied on whether tools were available to manage soundscapes, with some interviewees believing there were plenty of tools available (Schulte-Fortkamp, Woodger), especially in terms of inquiring about soundscape perception and assessment (Dubois). Others though, considered further research into tools as necessary, in particular, indicators or indexes (Dixon, Kang). The latter opinion was because tools were considered a technique while it is the output that it provides, what it means, and how it is interpreted that is important (Kang). Such tools and indicators were suggested as more useful for practitioners and policymakers to use, rather than a description of a soundscape and how it alters when certain sounds are added (Kang). Soundscape research has often involved the description of a soundscape without the development of a tool or indicator, which would help assess one situation compared to another (Kang). However, one interviewee suggested that describing everything via numbers and modelling each sound component is too complex, in contrast to comparing soundscapes on attributes that are identified as important for that setting and its particular users (Woodger).
- 8.12 Queries were raised over the term 'management of soundscapes' as it was considered to imply that it was constantly being monitored, rather than the 'natural' result of good design of all the elements creating the soundscape, such as surrounding architecture, vegetation, ground surfaces, water, and type of location (Woodger). In reference to this, Woodger considered that "soundscapes can't be superimposed on top of architectures and landscapes, as they are a consequence of those landscapes. The soundscape is a consequence of planning, landscape and all those decisions". Importantly this raises the point as to when soundscapes should be considered, emphasising best practices in considering soundscapes from the outset. This includes factoring soundscape assessments into the decision processes of planning applications (Dixon, Woodger), as well as educating architects, landscape designers and planners about soundscaping (Dixon, Woodger), given that many urban design professionals still have a visual bias (Dixon).

- 8.13 Modifications to soundscapes would be necessary for some current locations and settings, but the soundscape should still be considered as integral to the whole design, rather than as a separate entity to be overlaid onto the present sensory environment (Woodger). Dixon also warned that ‘retrofit’ modifications of soundscapes, such as adding permanent electro-acoustics (the use of amplified speaker systems), needs to be done very carefully, especially if incorporating sounds out of context. An example of a recommended direct intervention by an interviewee, did involve audio installations to create a soundscape at Nauener Platz, Berlin, Germany (Schulte-Fortkamp).
- 8.14 Dixon suggested instead that designers should, as far as possible, “work with the inherent properties of machines, passive alternatives, artificial and, increasingly, natural materials, particularly through enriching the flora and fauna spaces, including more use of green walls and roofs”. For example, part of the Quaggy River in Lewisham, London, UK, has been uncovered and renaturalised from previously culverted and concrete channelled sections, converting adjacent areas back into semi-natural green space (see QWAG, 2009). This acts as a flood plain, reducing flash flooding, with the added benefit of being an urban park at other times, where the sound of water and wildlife in reed beds can be heard, in an otherwise predominantly urban environment (Dixon).
- 8.15 In relation to the above example, Dixon envisioned an indicative hierarchy of soundscape design, similar to the ‘source-pathway-receptor’ sequence of classical acoustics. In such a hierarchy, the source creating the sound is first controlled (e.g. fewer and quieter cars), secondly, the sound pathway is modified (e.g. using barriers), and only as a last resort use building sound insulation (e.g. secondary glazing) or electro-acoustics. Dixon also proposed that work needs to move beyond imposed design, towards ‘biomorphic self-regulation’, developing new forms of soundscape intervention which draw upon the behaviour of natural systems. For example, “Bernie Krause’s ‘niche hypothesis’ is a powerful explanation for how component sounds in climax ecosystems have become spread across the sound frequency spectrum, and how acoustic space is shared through time” (Dixon). “If people have evolved to be more comfortable in ‘broadband soundscapes’, could ‘differential sound frequency charging’ at product certification stage support the evolution of soundscapes that are dominated less by oppressive flat line drones, along with new ways of ‘negotiating the acoustic commons’?” (Dixon). This is an interesting hypothesis, requiring further investigation.
- 8.16 Woodger emphasised the importance of having varied soundscapes, ranging from quiet to hectic soundscapes, with each being appropriate for their setting; “they are all different soundscapes, and they all have their place”. This is similar to Dixon’s emphasis on relating good soundscapes to the ecological niche theory, whereby a comprehensible, yet complex soundscape is meaningful, recognisable and suitable for its location. Comments about designing a ‘best’ soundscape also reflected this need for diversity. For example, a set criterion was cautioned against (Kang); and “it doesn’t necessarily mean there is a right or wrong... depending on what your objective is, there is an acoustic that could help or not help that objective” (Woodger). The ‘best’ soundscape would also depend upon

such factors as an individual's actions, listener state, aims and overall (sensory) experience, thereby the 'best' soundscape would vary per person, although collective agreements would arise. Therefore, the whole sensory experience is important, rather than considering the soundscape as an isolated aspect, that is treated as a separate set of physical numbers (Woodger). It is people's responses to the whole environment that has a bearing on soundscape assessments and as such should be considered in soundscape designs (Woodger).

- 8.17 The multi-sensory nature of soundscape assessments was also noted by two case studies whereby the response to the sound is actually based upon other sensory and behavioural elements rather than the sound *per se*, thus the design modification to improve the soundscape was non-acoustic (Dubois). One such identified case study, recommended improving the visual features in an urban park to enhance a feeling of withdrawal from the surrounding urban soundscape (Maffiolo, Mzali, David *et al.*, 2000). The other identified case study recommended reducing the noise annoyance of a train compartment door by reorganising the space of the compartment, as the sound only became 'annoying', rather than 'unpleasant' when it was accompanied by people opening the door to move through the compartment (Mzali, Dubois, Polack *et al.*, 2000).
- 8.18 Governmental bodies in France (various departmental levels, from national to individual cities) and Germany [Senate of Berlin, Bundesbauministerium Berlin (Federal Ministry)], have both introduced the concept of soundscapes (Dubois, Kang, Schulte-Fortkamp). In France, a few soundscape projects were developed 5-6 years ago (Kang), although the focus is often still on physical measurements, in part due to the expertise and knowledge at the political level (Dubois). In Germany, their soundscape focus is upon the construction of parks and roads, alongside Action Planning for the Environmental Noise Directive (Schulte-Fortkamp). In New York, USA, there was little focus on soundscapes or noise legislation, as the focus was upon crime rates (Woodger). Now with the regeneration of places and people feeling safer to complain about noise from neighbours, there is some focus upon soundscapes, especially in relation to quality of life (Woodger).
- 8.19 In the UK, national organisations vary in their consideration of the impact of noise and, even more so, soundscapes on landscapes (e.g. Commission for Architecture and the Built Environment, Campaign to Protect Rural England, Natural England, Civic Trust). Unfortunately, many bodies hardly discuss soundscapes (Dixon). Dixon stated that in the highly centralised UK system, national policy needs to present a lead to others in including soundscape considerations, to provide a basis for developing practical tools and then wider interest will follow (Dixon). Soundscapes should not be considered as an isolated aspect but substantially integrated into additional policies (other than PPG24) such as Planning Policy Guidance Note 17: Planning for Open space, Sport and Recreation, as well as aspects relating to sustainable planning, such as increasing biodiversity (Dixon). Mainstreaming the soundscape concept into processes and thought patterns of landscape designers and architects (Dixon), thereby ensuring they consider the implications of their designs on the soundscape, will improve the soundscape from the outset, rather than considering it afterwards, when it is a by-product of other processes (Dixon, Woodger).

8.20 To summarise, key soundscape researchers and practitioners emphasise the importance of understanding the perception of soundscapes and how it is subjectively assessed. Due to this, the public should be involved in design and soundscape assessments and an array of suitable methods to achieve this was suggested. An interdisciplinary approach was supported by all five interviewees, although there was limited consensus on the most worthwhile methods and tools for understanding and assessing soundscapes, with differences deriving from the different theoretical stances of the interviewees. There were some differences as to whether there are currently enough tools and measures for assessing and improving soundscapes. A 'best' method/tool and a 'best' soundscape were not considered appropriate discussion points, as the definition of 'best' would be influenced by so many factors. The suitability of the term 'managing soundscapes' was also queried and problems arose with the term 'context', however, everyone agreed the definition and assessment of 'soundscapes' differs to 'noise levels'. Both soundscapes and noise levels need to be considered within research, practice and policies to improve society's health, well being and general quality of life. Additionally, it was suggested that soundscapes should be considered from the outset, in any design and planning process, as it is one aspect of a multisensory experience.

9 **Gap Analysis in the Evidence Base**

The preceding review of the current state of knowledge and understanding of soundscapes, the methods and techniques used in assessing soundscapes, example case studies, and interviews with key individuals, outlines the strength and depth of the field. There are however, a number of key gaps in the knowledge and understanding of soundscapes and their potential incorporation within policy and planning guidelines for assessing and designing soundscapes. A number of key themes are presented below which each represent gaps in soundscape knowledge or research. This list is not meant to be exhaustive and their presence here does not imply a complete lack of information on this topic, just relatively little considering its suggested importance from the review of present soundscape knowledge and interviews with experts.

I. From multidisciplinary to interdisciplinarity

Soundscape research involves a variety of disciplines and stakeholders, which reflects the broad scope of the concept (see section 2.2.1). It is therefore surprising that there have been so few interdisciplinary research projects [interdisciplinarity being defined as disciplines operating jointly, discipline boundaries being transgressed, and there is some need for a shared perspective (Cooper, 2002)]. The multidisciplinary nature of the research has led to a large array of methods being used to research soundscapes [multidisciplinarity being defined as disciplines operating in parallel or in series, discipline boundaries remain unpermeated, and a shared perspective is not strived for (Cooper, 2002)]. This can be beneficial in understanding the array of aspects involved with soundscapes, but the best way to integrate these methods and produce successful interdisciplinary projects is unclear. In addition, disagreements arise due to the multidisciplinary nature of soundscapes research; therefore, there is little agreement as to what are the n most important factors for a given soundscape. Deciding upon the key attributes for characterising, understanding and assessing soundscape aids the progression of research into a planning and policy guidance tool.

II. Research gaps

A number of research gaps exist within the study of soundscapes and many research areas have so far only involved small research projects, in particular with studies relating to various aspects of soundscape perception, cognition and classification. Research areas that have specific knowledge gaps include the effect of the soundscape on speech intelligibility in outdoor areas; identification of the main perceptual dimensions involved in soundscape research (e.g. loudness, spaciousness); identification of perceptual dimensions that can be objectively measured (e.g. roughness, slope); the relationship between the physical layout of the built environment and various objective and subjective measures; the relationship between the evaluation of soundscapes and individuals' activities; and a holistic understanding of the sensory interaction in individual's experience and assessment of the soundscape.

III. Assessing soundscapes

Most case studies assessing soundscapes within a place have involved a description of the soundscape and some form of objective and/or assessment of the soundscape. The case studies have been carried out by different researchers in different locations using different methods and tools, making comparisons between different types of locations hard to evaluate, as there is no form of standardisation. Any variation between different places' soundscapes could therefore be due to a number of reasons including the methods or tools used, and regional or cultural differences. This also means that the robustness of the methods and tools in assessing soundscapes across different types of places hasn't been evaluated.

Subjective assessments about soundscapes have generally been in relation to their perceived physical attributes (e.g. loudness, busyness) or the affective impression it makes upon the individual (e.g. annoyed, happy). There have been fewer evaluations made about how the soundscape impacts upon individuals' activities, due to its distracting nature or masking important aspects of the activities (e.g. speech intelligibility, warning alarms). There is also little information about the impact of the soundscape on health, including negative aspects similar to those noted in noise research (e.g. stress, cognitive impairments), and positive aspects from desired soundscapes (e.g. cognitive restoration).

IV. Tools and indicators

Soundscape assessments have largely been carried out using generic research methods and few specific tools and indicators have been developed for designing soundscapes. It has been suggested by some that there is a need for identifying indicators that provide some type of output that aids design considerations for improving or maintaining the soundscape. Monitoring the successful use of current soundscape tools in different types of places and across different countries is also lacking.

Different methods and different tools are used by different researchers due to researchers' different epistemologies, assumptions and knowledge, although similar methods have been used in the laboratory and *in situ*. The most practicable methods and tools to aid the design of certain aspects of the soundscape need to be clearly understood, although these may also vary depending upon the aim of the project.

V. Soundscape interventions

There are fewer examples of soundscape interventions than there are of descriptions and evaluations of present day soundscapes in specific places. Any soundscape interventions that have occurred have tended to be small scale, in one particular place, rather than on a large scale such as an area of a city. Additionally, the interventions tend not to be formally evaluated before and after the intervention, thus the success of the intervention in both the short and long term is not known. The impact of the soundscape intervention on people's behaviour, multisensorial experience, and overall evaluation of the place is also a neglected area of research.

VI. Research and practice

There is little connection between current research and design and planning practice. This is partly due to the lack of examples of soundscape interventions, particularly on a large scale, such as their inclusion into city master plans. It is also due to the emphasis upon assessing soundscapes and not the methods and tools that have been used, and whether they are appropriate or adaptable for use by design and planning professionals. This has meant that procedural methods have not been developed, although further tools and indicators, as identified above, may also be necessary to develop a practical procedure. Ultimately, design decision support tools are lacking for practitioners, which is necessary considering practical soundscape design will not, in general, be carried out by expert researchers.

10 Research Proposals

- 10.1 The gap analysis of the evidence base points to a number of potential research proposals. From the point of view of Defra, perhaps the most important absence is the lack of a rigorous, practitioner-level method for assessing an urban soundscape. Developing such a method would be a significant step forward for the UK. However, establishing a practical method is not straightforward. The case studies and interviews analysed in this project reveal that there is no clear consensus in the soundscape field on which soundscape concepts and techniques should be the focus of future research. This is partly because the experts have different aims in mind for assessment and partly because soundscapes are complex, with many factors which could be taken into account. One way forward is to envisage the development of a soundscape assessment tool as an iterative process.
- 10.2 In the first iteration, the aim of the assessment tool should be to allow a local authority to characterise their existing urban soundscapes and to assist in identifying soundscapes of high or potentially high quality. The method must have the following characteristics: it must be simple to use, it must make sense to those using it, it must link to research evidence, it must fit existing & likely policy, and it must be capable of being developed. When dealing with noise, acoustic engineers and policy makers are used to using objective metrics like noise level to assess sound. However, development of objective metrics for soundscapes is still at an early stage. Therefore, a realistic assessment method in the near future should be based on qualitative methods. For example, version one of the assessment method could consist of:
- a soundwalk of the area to be assessed;
 - a list of soundscape types against which the soundscape under test could be classified; and
 - guidelines on identifying features of a high quality soundscape.

There is probably enough research evidence to support the use of these techniques. The last element, identifying features of high quality, is the most difficult part, and would depend on the user of the method having some experience or training. “High quality” would need to take into account what people do in the soundscape under examination, i.e. what is the principal use of the space, or what soundscape is thought appropriate for the most common activities in the space? This would clearly be aided by building up a database of such assessments. This kind of qualitative tool could be developed and refined with a field trial involving local authority practitioners. It should be possible to make it reasonably simple and meaningful, offering a common framework for practitioners to acquire knowledge on ‘their’ soundscapes, while allowing for flexibility, for example in identifying features of local importance. Such a tool would seem to fit well into a policy environment where identification of quiet areas is already mandated. Developing this kind of assessment tool would be best done in an interdisciplinary project. This is because experience suggests this is the best way to capture the most important features of a soundscape, and to

best characterise the relationship between the acoustic events of the soundscape and the subjective responses of people within it.

- 10.3 Future iterations of the soundscape assessment tool could supplement the qualitative techniques with quantitative methods. This could first be based on subjective rating scales and eventually on objective metrics which predict the subjective ratings. The rating scales used should be based on evidence that they rate the way people experience soundscapes. This would allow a more precise comparison of different soundscapes, numerically-based mapping and (when accurate simulation is achieved) swift assessment of many different design possibilities. Version two of the assessment tool would thus require a robust trial of quantified subjective rating scales and their link to an overall quality rating, across a representative range of soundscape types and use/activity types. This is a feasible project in the near future, but would require more research effort than the qualitative tool described for version one. Version three would require the development of new objective metrics for measuring soundscapes. There is some fundamental research currently aimed at producing soundscape metrics, but there is not yet enough evidence to be able to proceed with a project to develop an objective quantitative assessment scheme.

11 Conclusion

- 11.1 Research into soundscapes covers a vast array of topics and concepts and as such, many disciplines have contributed to the field. This has generated a large range of approaches for the consideration, research, and design of soundscapes. In addition, the complexity of soundscape research is highlighted by the array of components that each discipline considers necessary for soundscape discussions.
- 11.2 This report highlights the complexity of soundscape research by reflecting the number of approaches that can be taken and should be considered before a 'definitive' assessment of a soundscape can be made. The language used by people to describe and categorise soundscapes identifies the number of factors involved in perceiving and conceptualising soundscapes, including singular sound sources, the interaction of sound sources, other sensory stimuli, and contextual and individual factors. The descriptions and categorisations also convey the importance of the meaning, experience, expectation, and context of the perceiver in their assessment of a soundscape. These attributes need to be considered alongside more traditional acoustics and psychoacoustic measures of the sonic environment. The combination and consideration of all these elements are likely to be important in the production of tools suitable for soundscape assessments.
- 11.3 Examples of soundscape assessment and design case studies have been presented, which highlight the array of methods currently in use to assess and design soundscapes, both objectively and subjectively. Interviews with five key individuals in the field of soundscape research and practice were conducted. All interviewees emphasised the need for an interdisciplinary approach, although this comes with difficulties in interpreting definitions, descriptions and deciding upon suitable methodologies for understanding and assessing soundscapes.
- 11.4 Six key themes were identified each representing gaps in soundscape knowledge or research; moving from multidisciplinary to interdisciplinary, research gaps, assessing soundscapes, tools and indicators, soundscape interventions, and research and practice. From this, a research proposal was created involving the initial development of a qualitative soundscape tool for practitioners. Later versions of the tool were proposed that would include quantitative elements, including subjective ratings and given time, objective metrics.
- 11.5 This report has covered an overview of the origins of the soundscape concept alongside its contemporary use. Different theoretical approaches, models, and frameworks have been identified in soundscape research. Research on the perception, description, and classification of sounds were explicitly described, and through this, attributes relating to, and important for, soundscape assessments are additionally noted. Case study examples were presented, to showcase the array of methods that are currently used to assess and design soundscapes. These provide a basis for a further exploration of developing tools for assessing and designing soundscapes in practice. Six key themes were identified as representing gaps in soundscape knowledge and research from which a research proposal was produced with a comparative field study of urban areas, to develop a tool within an interdisciplinary framework.

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13 Appendix - Interview questionnaire

**Questions about soundscapes, in particular, soundscape tools.
Part of a project by the University of Salford for the
UK Department for Environment, Food and Rural Affairs**

1. How would you describe the approach and disciplinary perspective you take towards studying soundscapes?
2. What method(s) and tool(s) do you consider the most worthwhile for **understanding** and **assessing** soundscapes in urban areas and why?
3. What method(s) and tool(s) do you consider the best for **designing** and **enhancing** soundscapes in urban areas and why?
4. In relation to questions 2 and 3, do you consider a need for different methods and tools to be used for different contexts, or can one general method/tool be applied to all contexts?

Depending on your response, please answer question a **OR** b below.

- a. If the methods/tools depended on the type of context they were used in:
 - i. what factors would influence this choice?
 - ii. would there be an underlying relationship between these methods, if so, what would that be?
 - b. If there was one general method/tool to be applied in all contexts, how would it manage the:
 - i. variety of attributes that soundscapes consist of in different contexts?
 - ii. varied meanings associated with aspects of the soundscape in each context?
5. Can you think of any specific examples where soundscape methods and tools have **successfully** been put into design practice? Please provide details.
 - a. Conversely, can you think of any specific examples where soundscape methods and tools were **unsuccessful** in designing a soundscape? Please provide details.

6. What do you consider to be the main purpose of managing soundscapes in urban areas?
 - a. Would the management of soundscapes differ to the management of noise levels? If so, how?
 - b. Which aspects/dimensions/characteristics of a soundscape ought to be managed?
 - c. Do we currently have the tools to manage these aspects of the soundscapes?

7. The UK Department for Environment, Food and Rural Affairs (Defra) are interested in how soundscape concepts and methods could be applied to sound management in urban areas. Are soundscapes discussed and considered by governmental bodies/departments/ ministries within your own country?

If no, why do you think they have not discussed soundscapes? Please state the country.

If yes:

- a. Please state the country and relevant bodies/departments/ministries if known.
 - b. What soundscape research are they doing, if any?
 - c. Do they consider the design and management of soundscapes?
 - d. Do they consider both the removal of negative aspects and the preservation of positive aspects?
8. Any other comments?

Thank you very much for taking the time to answer these questions for us.