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The Assessment of Soundscape Quality in Urban Parks - A Case Study in Penn Park

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Abstract

The sonic environment is an invisible but crucial part of the urban environment. Increasing density of population and diversification of social functions driven by urbanization lead to a more complex sound environment in our daily life. As an important multifunctional service area, the urban park is usually regarded as a buffer for urban noise pollution. The assessment of the sonic environment in urban parks can help park-users and park-designers get a better understanding of the health of the park environment. This study approached the urban noise pollution in urban parks with a soundscape quality assessment, from both acoustical and psychological perspectives. An urban park on the campus of the University of Pennsylvania named Penn Park was selected as a case study for soundscape quality assessment. Sound Pressure Level (SPL) was measured at ten sampled positions in Penn Park and processed in ArcMap to make the sound maps, which clearly shown the uneven distribution of the average sound energy in the park: inner part of the park with trees surrounded was the "quietest" and the part along the edge with areas of grass was the "loudest." In three months (May, June, July) when sound pressure level was recorded by the sound pressure meter, park-users' subjective responses to the sonic environment of Penn Park were investigated by randomly recruiting park visitors to complete a questionnaire about the soundscape quality. In total, 90 questionnaires were collected and analyzed on SPSS. Results demonstrated that there was a significant positive correlation between overall landscape quality, overall soundscape quality, and overall impression. Compared to mechanical sounds and human-made sounds, visitors preferred more natural sounds (birds, insects, wind) to be increased in Penn Park. Overall, the sonic environment of Penn Park was perceived as pleasant, quiet, smooth, varied, calming, directional, natural, and steady. The results of this study may have implications for the enhancement of soundscape design in other urban parks that are similar to Penn Park.

Disciplines

Environmental Sciences | Physical Sciences and Mathematics

ABSTRACT

THE ASSESSMENT OF SOUNDSCAPE QUALITY IN URBAN PARKS
- A CASE STUDY IN PENN PARK

Jiujia Guo

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The sonic environment is an invisible but crucial part of the urban environment. Increasing density of population and diversification of social functions driven by urbanization lead to a more complex sound environment in our daily life. As an important multifunctional service area, the urban park is usually regarded as a buffer for urban noise pollution. The assessment of the sonic environment in urban parks can help park-users and park-designers get a better understanding of the health of the park environment. This study approached the urban noise pollution in urban parks with a soundscape quality assessment, from both acoustical and psychological perspectives. An urban park on the campus of the University of Pennsylvania named Penn Park was selected as a case study for soundscape quality assessment. Sound Pressure Level (SPL) was measured at ten sampled positions in Penn Park and processed in ArcMap to make the sound maps, which clearly shown the uneven distribution of the average sound energy in the park: inner part of the park with trees surrounded was the "quietest" and the part along the edge with areas of grass was the "loudest." In three months (May, June, July) when sound pressure level was recorded by the sound pressure meter, park-users' subjective responses to the sonic environment of Penn Park were investigated by randomly recruiting park visitors to complete a questionnaire about the soundscape quality. In total, 90 questionnaires were collected and analyzed on SPSS. Results demonstrated that there was a significant positive correlation between overall landscape quality, overall soundscape quality, and overall impression. Compared to mechanical sounds and human-made sounds, visitors preferred more natural sounds (birds, insects, wind) to be increased in Penn Park. Overall, the sonic environment of Penn Park was perceived as pleasant, quiet, smooth, varied, calming, directional, natural, and steady. The results of this study may have implications for the enhancement of soundscape design in other urban parks that are similar to Penn Park.

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Chapter 1 Introduction

1.1 Background of the Research Topic

Hearing is one of the major ways in which humans perceive the world (L. Groeger, 2012). As what was stated in Diane Ackerman's book *A Natural History of The Senses* (D. Ackerman, 1995), sounds "thickened the sensory stew of our lives, and we depend on them to help us interpret, communicate with, and express the world around us." The sonic environment has been changing due to the rapid urban development and redevelopment (W. M. To & A. W. L. Chung, 2018). Increasing population density derived from urbanization has significantly brought multiple negative impacts on our lives, which include unwanted sounds - noises. Noise is defined as unwanted sound from the surroundings and has numerous impacts on our health (M. Basner et al., 2014). Urban parks are regarded as an important part of the complex urban ecosystem network and offer multifold services for urban communities (L. Loures, R. Santos, & T. Panagopoulos, 2007). Open green space in urban parks can promote mental and physical health by reducing residents' exposure to air pollutants, noise pollution and excessive heat as well as providing psychological relaxation and stress alleviation (M. Braubach et al., 2017). However, it was found that the sonic environment of some urban parks has been influenced by noise pollution, which reduced the restorative impacts generated by natural environments of urban parks (G. Brambilla, V. Gallo, F. Asdrubali, & F. D'Alessandro, 2013; H. Jahncke, K. Eriksson, & S. Naula, 2015). In addition to reducing the noise physically, it is necessary to investigate park-users' subjective evaluation of the acoustic environment in urban parks and assess the impacts of sounds in parks on their overall visiting experience.

In this project, the concept of *Soundscape* was used in order to describe and evaluate the environmental sounds. Sounds are recognized as ecological properties of landscapes (B. C. Pijanowski et al., 2011). *Soundscape* is defined as the "acoustic environment as perceived or experienced and/or understood by a person or people, in context ("ISO 12913-1:2014. Acoustics — Soundscape — Part 1: Definition and conceptual framework," 2014)." It is not, though frequently described as, a simple indicator for the community noise. In contrast to the environmental noise field, soundscape has an emphasis on the human perception of sounds (J. M. Downing & C. M. Hobbs, 2005). Its significant implications in urban planning and design process not only lie in reducing noise pollution but also in utilizing sounds as an effective environmental resource to create a pleasing space (R. M. Rehan, 2016). Acoustic design of the urban open space can promote the psychological restoration by optimizing the soundscape with accentuation of the characteristic properties of the area (B. De Coensel, A. Bockstael, L. Dekoninck, & D. Botteldooren, 2010).

Based on the current research in soundscape, this study combines a collection of acoustic data and an investigation on park-users' subjective responses to the sound environment to analyze and assess the soundscape in a specific urban park - Penn Park. Situated on the eastern campus of the University of Pennsylvania, Penn Park is 24-acre open space with multi-purpose athletic fields. It is regarded as a part of the urban oasis, a landscape with aesthetic values, a green infrastructure for storm water management, an accessible venue for kinds of outdoor sports, but the park's acoustic environment has not received enough attention from either the park-designers or the park-users. Through investigating and assessing the soundscape in Penn Park, this study aimed at improving visitors' awareness of the soundscape in urban parks, highlighting the importance of the acoustic environment in the park-design process, and suggesting the factors that can both effectively improve the holistic soundscape of Penn Park and mitigate negative effects of unwanted sounds.

1.2 The Structure of the Paper

Chapter 2 Literature review on the connection of sounds and human life, soundscape of urban parks, and soundscape design case studies

Chapter 3 Overview of the study site – Penn Park, from the history of site use, flora and fauna, sustainability of park design, and identified types of sound

Chapter 4 Research methodology adopted to carry out the acoustical (sound mapping) and psychological assessment (questionnaires) of the park soundscape

Chapter 5 Quantitative and qualitative analysis of the study results

Chapter 6 Conclusion and future research outlook

1.3 Research Objectives

This study aims at exploring soundscape improvement suggestions for Penn Park and enhancing the public awareness of the sonic environment by communicating the concept and characteristics of soundscape with park visitors. Through analyzing the subjectively perceived soundscape characteristics of Penn Park and assessing the average sound pressure level distributed in the park, the types of sounds were summarized and categorized for the accentuation of positive acoustical components (birds, insects, and wind) and the decrease of negative acoustical components (high-speed trains, traffic on the highway, and aircrafts) to improve the overall soundscape quality of Penn Park. The results from this study can be regarded as a reference for the future renovation or the construction of urban parks similar to Penn Park. The consideration of soundscape in the park design and the participation of park-users into the design and planning process may collectively create a healthier and more satisfying urban open public space for urban residents and contribute to the development of sustainability in urban planning and design.

1.4 Research Questions

This study aims at addressing seven questions:

1. Is there any pattern for the distribution of the average sound pressure level (SPL) in Penn Park? Which part of the park is acoustically the "quietest" and which part is the "loudest"?
2. Is there any significant difference between the sound environment (SPL) of the park in weekday and that in weekend?
3. How many types of sound in Penn Park are perceived by interviewees, what are they, and how pleasant are they?
4. Is there any reported subjectively dominant sound and what is it?
5. Is there a correlation between every two of the three selected indicators – Overall Landscape Quality (OLQ), Overall Soundscape Quality (OSQ), and Overall Impression (OI)?
6. What are the characteristics of the soundscape in Penn Park that perceived by the interviewees?
7. What is the change of people's awareness of the soundscape in this urban park after the questionnaire? How likely will people pay more attention to the sound environment in urban parks in the future?

Chapter 2 Literature Review

2.1Sounds and Human Life

2.1.1 The Physics of Sounds

Sound is the transmission of vibrational energy generated by the motion of a source through a solid, liquid or gaseous medium. The most sounds people perceive in the daily life are transmitted through the air (M. Long, M. Levy, & R. Stern, 2005). Sound transmits through the air in the form of a longitudinal pressure fluctuation. The air particles oscillate back and forth when the wave passes (J. Kang, 2007). Since the particle motion is in the same direction as the wave propagation, the waves are defined as longitudinal (M. Long et al., 2005). As other longitudinal waves, one important property of sound is the requirement of a medium for transmission (R. E. Berg, 1982). The major different between one medium and another is the velocity of wave propagation. The velocity varies when the medium changes (C. Taylor, 2000).

One important acoustical property is the sound intensity. It is a parameter used to measure the sound energy propagating through a given area during a given time. For a plane wave, the most commonly analyzed waveform, the sound intensity is defined as the acoustic power passing through an area in the direction of the surface normal and can be calculated by the following equation (M. Long et al., 2005):

$$\mathrm{I}(\theta) = \frac{E\cos(\theta)}{TS} = \frac{W\cos(\theta)}{S} \tag{2.1}$$

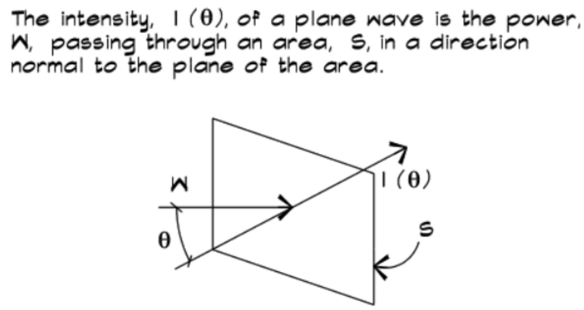


Figure 2.1 Intensity of a plane wave (M. Long et al., 2005).

Where E = energy contained in the sound wave (N m/s)

W = sound power (W)

$I(\theta)$ = intensity (W/m^2) passing through an area in the direction of its normal

S = measurement area (m^2)

T = period of the wave (s)

θ = angle between the direction of propagation and the area normal

The intensity can be directly measured by a sound level meter. Due to its proportional property to sound power (W), the results shown by a sound level meter can be an indicator for the sound power on site. Given that the range of intensities can be large, the sound levels are adopted to make the indication of sound power more straightforward, among which the *sound pressure level* is the most commonly used indicator of the acoustic wave strength. Sound pressure is defined as the force (N) of sound on a surface area (m^2) perpendicular to the direction of the sound ("Engineering ToolBox," 2004). As a result of a fact that the threshold of human hearing is at about 1000 Hz, the sound pressure level is 0 dB when the sound pressure is equal to the reference pressure 1000 Hz. The sound pressure level can be calculated by the equation below:

$$L_P = 10\log\frac{p^2}{p_{ref}^2} \quad (2.2)$$

Where p = root-mean-square sound pressure (Pa)

P_{ref} = reference pressure, 2×10^{-5} Pa

In the measurement of sound pressure level using the sound level meter, most sound level meters are equipped with weighted networks that "give a response to frequency which approximated to the Fletcher – Munson curves (Figure 2.2) (A. Martyr, 2012)" The A-weighting is a standard weighting method for outdoor community noise measurements and is commonly used for noise measurements within architectural spaces and within vehicles (M. Harrison, 2004). The A-weighting can roughly present the loudness of sounds perceived by human ears and it reduces the sensitivity of the measuring instrument to both low and very high frequency sounds (M. Harrison, 2004). As a result, the dBA value to the corresponding sound pressure level measured with A-weighting can provide a more accurate human response to the intensity and discomfort level of noise (A. Martyr, 2012). In addition to the A-weighting approach, there are two other frequency weightings – "B-weighting" and "C-weighting." Both two weightings are generally used for high sound levels.

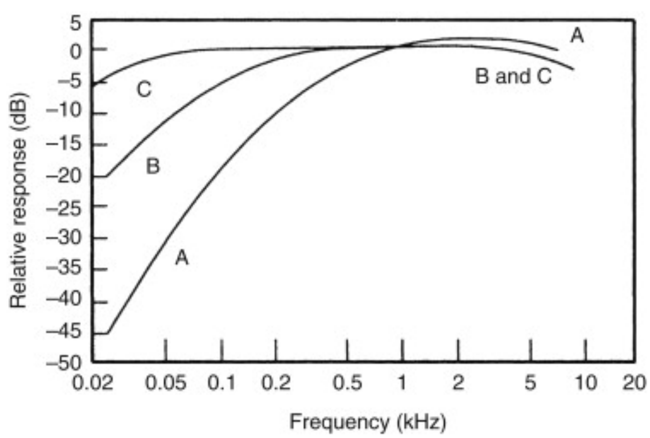


Figure 2.2 Noise weighting curves (A. Martyr, 2012).

2.1.2 Human Hearing

Sound is one of the five major ways that we use to communicate with our surroundings (C. Taylor, 2000). Human ears can process the vibrations of air at frequencies between 20Hz to 20kHz into sound waves (B. C. J. Moore, 2003). The structure of human ear is shown in Figure 2.3 (B. Gorman, 2018). There are three parts of the ear: the outer ear, middle ear, and inner ear. While the outer and middle ear are air filled, the inner ear is fluid filled (M. Long et al., 2005). Sound is firstly captured by the pinna at the outer part of the ear, then entering the ear canal and vibrating the eardrum and three small bones – hammer, anvil, and stirrup. The vibration of the eardrum is transferred into pressure waves that will reach the fluid of the inner ear (B. C. J. Moore, 2003). The fluid of the inner ear will move with the pressure wave and generate the movement of ting hair cells within the cochlea. These hair cells convert movement into electrochemical nerve impulses and the brain will finally interpret the auditory nerve impulses into sound (B. C. J. Moore, 2003).

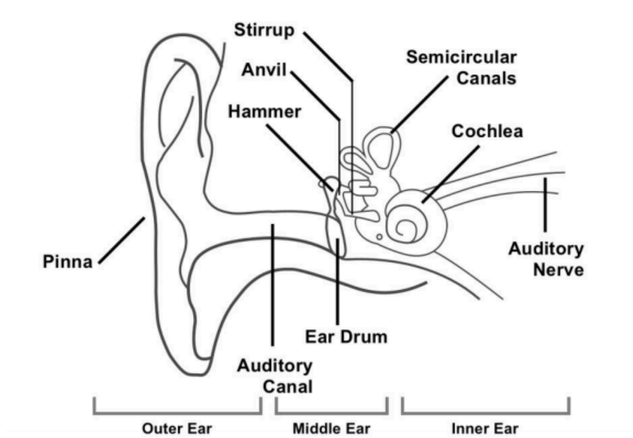


Figure 2.3 The structure of human ear (B. C. J. Moore, 2003).

2.1.3 Urbanization and Noise

With the rapid growth of urban areas in the second half of the 20th century, the number of people in urban areas was approximately equal to the number of people in rural areas in 2007, both of which were 3.33 billion people. The urban population continued to grow since 2007. Until 2017, the urban population has been 4.13 billion, which is more than almost 1 billion than the rural population (3.4 billion) (M. R. Hannah Ritchie, 2018). The rapid urbanization process and the increase of population density in cities bring a variety of environmental challenges including the noise pollution. Noise is derived from the Latin word "nausea," which is interpreted as "unwanted sound" or "sound that is loud, unpleasant or unexpected (A. Chauhan, M. Pawar, D. Kumar, N. Kumar, & D. R. Kumar, 2010)." While a sound is produced through the pressure wave, a noise also requires a subjective judgement from the listener (M. Long et al., 2005). Noise is one of the most unnoticeable and ubiquitous pollution in human everyday experience. In general, noise originates from anthropogenic activities, typically the urbanization and the development of transport and industry (N. Singh, 2004). Transportation noise is the main source of environmental noise pollution, including road traffic, rail traffic, and air traffic. Mechanized industry can cause serious noise problems and building construction and excavation work can generate considerable noise emissions (Berglund et al., 1999). The magnitude and severity of noise pollution will continue to increase with the population growth, urbanization, increasing construction of highway, rail, and air traffic, and the associated growth in the use of increasingly powerful, varied, and highly mobile sources of noise (L. Goines & L. Hagler, 2007). Noise pollution has numerous, pervasive, persistent, and medically and socially significant effects on human health (L. Goines & L. Hagler, 2007). According to the International Program on Chemical Safety, an adverse effect of noise is defined as "a change in the morphology and physiology of an organism that results in impairment of functional capacity, or an impairment of capacity to compensate for additional stress, or increases the susceptibility of an organism to the harmful effects of other environmental psychological or social functioning of humans or human organs (I. P. o. C. S. Director, 1994)." The adverse health effects can be categorized into: noise-induced hearing impairment, interference with speech communication, disturbance of rest and sleep, psychophysiological, mental-health and performance effects, effects on residential behavior and annoyance, and interference with intended activities (T. L. Birgitta Berglund, Dietrich Schwela, 1995).

2.2 Soundscape Design in Urban Parks

2.2.1 The Formation and Development of the Soundscape Concept

Human beings perceive the world in a multisensory manner (M. Lindquist, 2014). We can communicate with the outer world by either seeing, hearing, smelling, touching, and tasting. While sound surrounds and envelops us everywhere, however, visual perception is generally given the priority in the studies of human environmental perception and aesthetics (J. D. Porteous & J. F. Mastin, 1985). In the late 19^{th} century, as the development of urban areas, there was increasing attention to the unwanted sound – noise. With the rapid growth of cities in the 20^{th} century, urban dwellers became even more dissatisfied with the quality of urban environments including the urban acoustic environment and more concerned with the plight of handicapped persons in modern society. As for the blind, sound is a major means of obtaining information about the surroundings, and the composition of the sonic environment can largely determine the information gathered and interpreted by the blind (M. Southworth, 1970). In this background, the concept of *soundscape* was initially developed by the Finnish geographer J. G. Granö (1929), whose work concentrated on the change of sounds (shifting from animal sounds to mechanical sounds) in the agrarian landscape. The studies on noises and on the sound environment continued to develop after the formation of the soundscape concept. In 1969, Southworth performed a pioneering field study of the urban soundscape in a sector of central Boston including several subjects and tested perception of sounds and sights. His study strongly suggested a need for sonic planning and design (J. D. Porteous & J. F. Mastin, 1985). Following the Boston project, Ohlson (1976) and others divided the anthropocentric sonic landscape into an immediate soundscape (20-200 m from the receiver) and a distant soundscape (15-20 km from the receiver). At the same period of time, the World Soundscape Project (WSP) was established as an educational and research group by R. Murray Schafer, who is regarded as the first person developing a firm rationale for soundscape study. Aimed at discovering principles and developing techniques by which "the social, psychological, and aesthetic quality of the acoustic environment or soundscape may be improved," a group of composers, activists, social scientists, and students conducted a detailed study on the immediate soundscape of the City of Vancouver and published their results in *The Vancouver Soundscape* (B. Truax, n.d.). In 1977, as a review and summary of all the materials collected in the WSP, *The Tuning of the World* (R. M. Schafer, 1977) laid a solid theoretical foundation for soundscape study including soundscape analytical techniques, vocabulary list, and a comprehensive theory of acoustic design, followed by Truax's study on the terminological dictionary that builds the relationship between soundscape and noise research.

2.2.2 The Soundscape Definition, Categorization, and Perception

Definition

The soundscape concept was first introduced as an approach to rethink the evaluation of noise and its effects on the quality of life, but it considers our sonic environment beyond the noise control and management (B. M. Brooks, B. Schulte-Fortkamp, K. S. Voigt, & A. U. Case, 2014). It is commonly defined as "an environment of sound with emphasis on the way it is perceived and understood by the individual or by a society." Therefore, the soundscape of place requires to be understood through a holistic evaluation of the sounds with an emphasis on human perception. In 2008, a standardization of the assessment of soundscape quality outdoors was taken into consideration by an established Working Group of ISO/TC 43/SC 1. The standardized method is designed for building connections between perceived soundscape quality and acoustic, physical and visual properties of areas and being used as a guideline for both policy-maker and city planners (L. Brown, J. Kang, & T. Gjestland, 2011). Different from noisescape, soundscape should be assessed by reviewing the positive as well as the negative attributes of the sound environment (D. Hall, A. Irwin, M. Edmondson-Jones, S. Phillips, & J. Poxon, 2013).

Categorization

In general, soundscape is interpreted by means of identifying and describing different sound sources in a certain place (L. Brown et al., 2011). It is a requirement and first step of conducting a soundscape study to collect information on the actual elements that make up a soundscape (J. D. Porteous & J. F. Mastin, 1985). In Schafer's book *The Tuning of the World* (1977), he briefly categorized the sounds in our environment into six groups according to referential aspects: natural sounds, human sounds, sounds and society, mechanical sounds, quiet and silence, and sounds as indicators. B. L. Krause (1987) introduced the term "biophony" to describe the complex arrangement of biological sounds created by organisms and the term "geophony" to describe nonbiological ambient sounds of wind, rain, thunder, and so on. B. C. Pijanowski et al. (2011) extended the taxonomy of sounds developed by Krause to a broader scope with a new term "anthrophony" that was used to describe the sounds generated by human activities. R. M. Rehan (2016) integrated Wang's research (2003) on the classification of sounds with

Pijanowski's terminology for sounds to summarize all sound types into two general categories – the natural acoustics and human-made acoustics (shown in Table 2.1).

Table 2.1 Urban sound classification. Source: Rehan R.M., 2016 and Wang K., 2003.

The natural acoustics	Geophony	Sound of water	Oceans, seas, rivers, streams, rain
		Sound of air	Wind
	Biophony	Sound of birds	Sparrow
		Sound of insects	Flies
Human made acoustics	Anthrophony	Sound and society	Town, urban, parks
		Mechanical sounds	Machines, aircraft, constructions…

In addition to the classification according to referential aspects, categories of sound events were further grouped into three classes by Schafer (1977) to study features of the soundscape: keynote sounds, signals, and soundmarks. Keynote sounds are ubiquitous sounds not being possibly overlooked in a specific environment and are capable of producing a deep and pervasive influence on the listener's behavior and moods. Signals are defined as foreground sounds that constitute acoustic warning devices (J. D. Porteous & J. F. Mastin, 1985). Soundmarks is the sonic counterparts of landmarks, which is "unique or possesses qualities that make it specially regarded or noticed by the people in a community." (Schafer, 1977). The categorization of sounds from our environment into these three classes requires individual subjective perception.

Perception

Humans perceive the soundscapes primarily through a collection of physical pressure variations captured by the ear. Though a simple measurement of sounds level is the most common approach to evaluate the sound quality or annoyance (D. Hall et al., 2013), it is widely acknowledged that the reduction of the sound level of an urban space does not necessarily increase a listener's degree of "acoustic comfort" (W. Yang & J. Kang, 2005). The dominance of human perception in the soundscape field is regarded as a fundamental contrast between it and the environmental noise field (L. Brown et al., 2011). Social science approaches such as questionnaires are mostly adopted to supplement the physical measurement of acoustic data to analyze and present human subjective perception of the sounds (J. Y. Jeon & J. Y. Hong, 2015; J. Kang & M. Zhang, 2010; J. Liu, J. Kang, T. Luo, & H. Behm, 2013; G. Pérez-Martínez, A. J. Torija, & D. P. Ruiz, 2018; X. Zhang, M. Ba, J. Kang, & q. Meng, 2018). The awareness of the soundscape concept can be increased by these techniques and the soundscape can be comprehensively assessed from both objective and subjective views (J. D. Porteous & J. F. Mastin, 1985).

To bridge the gap between physical and subjective evaluations of sounds, a new scientific field – psychoacoustics emerged. The field of psychoacoustics describes the relationship between the physical measurement of sounds and the subjective perception of the sound quality (H. Fastl, 2006), which inspires a hybrid method with both physical representations of sounds and psychoacoustic characterization of the acoustical environment in the research of soundscape (M. Rychtáriková & G. Vermeir, 2013). Basic psychoacoustic magnitudes including *loudness, sharpness, roughness, fluctuation strength*, and *pitch* are proven to be important factors in the evaluation of sounds (H. Fastl, 2006). *Loudness* is a measure for the quality of the sound that is defined as a function of the amplitude and frequency of vibrations. *Sharpness* is related to sensation of frequency by human hearing system (H. Fastl & E. Zwicker, 2007). The more high frequencies a signal contains, the higher its sharpness is (J. Kang, 2007). *Roughness* is a "complex effect which quantifies the subjective perception of rapid (15-300 Hz) amplitude modulation of a sound and depends on the temporal variation of sounds (F. M. A. Calarco, 2015)." A rough sound usually causes an unpleasant hearing impression. The *fluctuation strength* is a similar measure to roughness indicating the amplitude modulation and depending on the temporal variations of sounds (H. Fastl & E. Zwicker, 2007). *Pitch* sensation refers to the subjective impression of the frequency content of a sound. It can be interpreted as the human perception of how high or low a tone sound is (M. Long et al., 2005). The acoustical properties of sounds can influence listener's perception, but other non-acoustic factors such as landscape effects, individual's knowledge, familiarity, memory, context, expectation, and associated meanings of the sound also play an equally important role in people's sound preference (S. R. Payne, W. Davies, & M. Adams, 2009; M. Zhang & J. Kang, 2006). A study carried out in five city parks in Xiamen, China revealed that there was a close relationship between landscape and soundscape experience in real contexts and park-users' social, demographical and behavioral factors also shown significant effects on their soundscape experience (J. Liu et al., 2013). Hall D. et al. (2011) studied the effects of perceptual, psychoacoustic and acoustical properties of urban soundscapes on the people's perception of sounds and concluded that the perceived quality of the soundscape was highly related to the individual subjective experiences such as personal preference, past history, and other social and cultural factors.

There are multiple approaches to evaluate the urban soundscape quality from the perspective of park-user's subjective responses. J. Kang and M. Zhang (2010) conducted a detailed soundscape evaluation of four typical urban open public spaces in Sheffield UK with a semantic differential analysis. The semantic differential technique was developed by C. E. Osgood, G. J. Suci, and P. H. Tannenbaum (1957) to identify emotional meaning of words and has been extended to a large variety of concepts. In the study of J. Kang et al. (2010), semantic differential technique was adopted to connect users' feelings at both linguistic and psychological levels with sound sources and identify four major factors of the assessed urban soundscape – relaxation, communication, spatiality and dynamics. F. Aletta, J. Kang, and Ö. Axelsson (2016) reviewed the main soundscape descriptors in the soundscape literature and summarized eight sorts of potential soundscape descriptors: (1) noise annoyance, (2) pleasantness, (3) quietness or tranquility, (4) music-likeness, (5) perceived affective quality, (6) restorativeness, (7) soundscape quality, and (8) appropriateness. D. Ou, C. M. Mak, and S. Pan (2017) developed a quality evaluation method for the soundscape based on two service quality measurement (SQM) models, Importance-Satisfaction (I-S) model and Improvement index (Ii) model and applied this method to a case study in Hong Kong. X. Zhang et al. (2018) employed the approach of soundscape dimensions that were analyzed in J. Kang and M. Zhang's research (2010), which are relaxation, communication, spatiality, and dynamics, to a soundscape study about the acoustic comfort in a typical city square in Dalian China and summarized the correlation of acoustic comfort with four soundscape dimensions individually.

2.2.3 The Soundscape of Urban Parks

Humans have an intimate relationship with nature. In general, natural environments can provide more of a restorative experience than built up urban environment (T. Hartig, M. Mang, & G. W. Evans, 1991). Viewing nature alone can bring various positive health benefits (R. Ulrich, 1984). Urban parks are one of the important urban open space that built with environmental elements such as green area, waterfront, sports facilities agreeable landscape. There are a variety of reasons for people visiting urban parks: rest, sports, relaxation, games, cultural events, and sightseeing (P. H. T. Zannin, A. M. C. Ferreira, & B. Szeremetta, 2006). Nonetheless, "the perception that someone has of urban green space can significantly affect whether they use that space, contribute to the collective opinion that a community has of such as space and shape the wider community's image of urban green spaces (N. Dunnett, 2002)."

A study on the evaluation of noise pollution in six urban parks in Curitiba, Brazil (P. H. T. Zannin et al., 2006) shown that measured noise levels in parks were beyond local legislation allowed limits. Another study on the investigation of the urban park soundscape in a mountainous city - Chongqing, China found that 57.2% of the respondents to the questionnaire considered the acoustic environment as severely or relatively noisy, with only 44.5% of the interviewees reporting it as comfortable or relatively comfortable (H. Li, H. Xie, & J. Kang, 2014). J. Liu, Y. Xiong, Y. Wang, and T. Luo (2018) explored the relationships between sound/soundscape perception and public visiting experience in city parks with a case study in Fuzhou, China. The results indicated that three visiting experience indicators: soundscape tranquil degree (STD), landscape aesthetic degree (LAD) and visiting satisfaction degree (VSD) were positively related with each other. To mitigate the negative effects of unwanted sounds on park-users' visiting experience, there has been studies focusing on the improvement of urban soundscape through various approaches. In addition to the acoustical characteristics of the sonic environment, other factors such as socio-cultural background, landscape quality, and urban contexts can have significant impacts on the subjective perception of the park soundscape. A cross-national comparison in the assessment of urban park soundscapes in three countries (France, Korea, and Sweden) examined the effect of socio-cultural context including language on soundscape assessments in urban parks and results shown that there were no significant differences in perceived dominance of sounds sources among three countries but perceptual responses to human sounds, birdsong, and water sounds, were significantly different across three cultural backgrounds (M. Zhang & J. Kang, 2006). Another study investigated the relationships between soundscapes and urban contexts (commercial, residential, business, and recreational) and found that dominant factors affecting soundscapes differed in accordance with the main functions of the place (J. Y. Hong & J. Y. Jeon, 2015). Additionally, people's perception of the soundscape is influenced by the composition of the sonic environment in the park. J. Y. Jeon, P. Lee, J. You, and J. Kang (2010) examined the effect of water sounds on masking urban noises and concluded that water sounds were the best sounds to use for enhancing the urban soundscape.

The level of the water sounds should be similar to or not less than 3dB below the level of the urban noise. The findings of these empirical studies can be applied to enhance the urban soundscape quality in the future.

2.2.4 Soundscape Design: Case Studies

Urban parks are one of the important components of urban life. They bring multifold benefits for the residents in cities, including environmental benefits, economic benefits, and social and psychological benefits (M. M. Sadeghian & Z. Vardanyan, 2013). However, in the planning and design process of urban parks, aesthetic value is the priority to be considered, with less attention to other environmental factors such as sounds in park surroundings (S. Liu, 2012). The sonic diversity and acoustic ecology are generally neglected aspects and less aware by park visitors (T. Elmqvist, 2013). In this section, through analyzing some typical case studies of urban soundscape design, this paper attempts to explore and summarize the innovative design techniques for engaging soundscape in cities to reduce urban noise and create enjoyable and restorative sonic environments that perceivable to urban dwellers. Some examples of soundscape design for urban open space including urban parks and urban squares are reviewed below. For each case study, the specific creative design approaches are elaborated, which could inform recommendations in the soundscape design of urban parks like Penn Park.

Paley Park, New York City, United States

By Zion Breen Richardson Associates

Located at East 53rd Street between Madison and Fifth Avenue in Midtown Manhattan, Paley Park is one of the most well-known landscape projects that incorporated masking strategies to reduce the urban noise ("Paley Park," n.d.). It was named by former Chairman of CBS, William Paley, who created and funded the project as a memorial to his father. This “vest pocket park” was designed by Robert Zion and opened in 1967 ("Paley Park," n.d.). It was conceived as “the

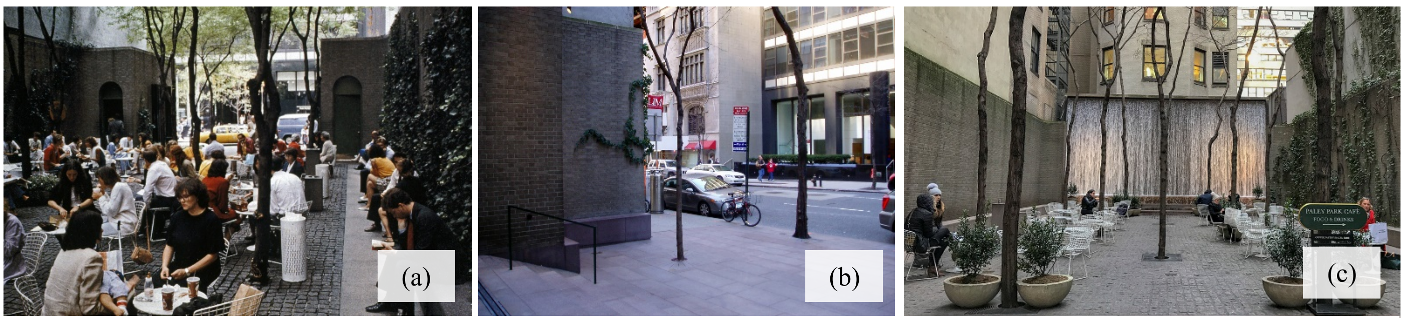


Figure 2.4 Paley Park in New York City. Source: The Cultural Landscape Foundation.

prototype for a new kind of public space, privately owned, described in a proposal by Zion & Breen Associates in a 1963 exhibition at the Architectural League of New York.” It was also featured in William H. Whyte’s film *The Social Life of Small Urban Spaces* (1980). The popularity of this park is contributed by its special design in providing a quiet place separated from the noisy street in the busy city. Surrounded by buildings on three sides, the most impressive feature of the small park is a 20-foot high wall of water placed at the back wall. The other two side walls are covered with “vertical lawns” of English Ivy. “seventeen honey locust trees, planted on a grid within the central seating area, offer dappled shade above the moveable wire mesh chairs and marble tables, set on a floor of granite pavers. Annual plantings in containers enhance the restrained plant palette ("Paley Park," n.d.).” The web of dense ivy on the walls and the canopy of honey locust trees work as a natural sound barrier while the wall of water creates white noise masking the noise from busy streets. The elevated steps at the entrance further contribute to the role of reducing noise and creating a sense of privacy in the space. Every detail of this urban park explains the success of how a pocket park generates “an atmosphere of tranquility in the city (A. M. Ward, n.d.),” and “a sense of privateness from other visitors ("Paley Park," n.d.)” in urban life by designing with sounds.

Sheaf Square, Sheffield, United Kingdom

By Regeneration Projects Design Team (RPDT) of Sheffield City Council & Si Applied and Keiko Mukaide

Sheaf Square is a public area located outside Sheffield Station, previously used as a car park and was surrounded by a road network ("Sheaf Square," 2017). In 2006, as part of the City Center Master plan of Sheffield, this place was transformed into a square available to pedestrians and served as an entrance to the city center ("Sheaf Square," 2017). It was built with remarkable water installations, one of which is the *Cutting Edge* sculpture, a stainless steel sculpture and waterfall designed by Si Applied and Keiko Mukaide that “takes a cylindrical shape at its southern end and gradually morphs into an evocative blade-like cross section that at the opposite terminus (A. Newman, n.d.).” This sculpture not only screens off the traffic noise by breaking the visual contact with the roads, but also creates masking effects through water sounds ("Sheaf Square," 2017). “Water is pumped from a large plant room under the main water feature to the crest of the sculpture from where it flows over a very accurately levelled weir and down the polished face of the sculpture. As well as creating an attractive shimmering effect the filtered and sterilized water has the added advantage of keeping one face of the sculpture clean and graffiti free.”

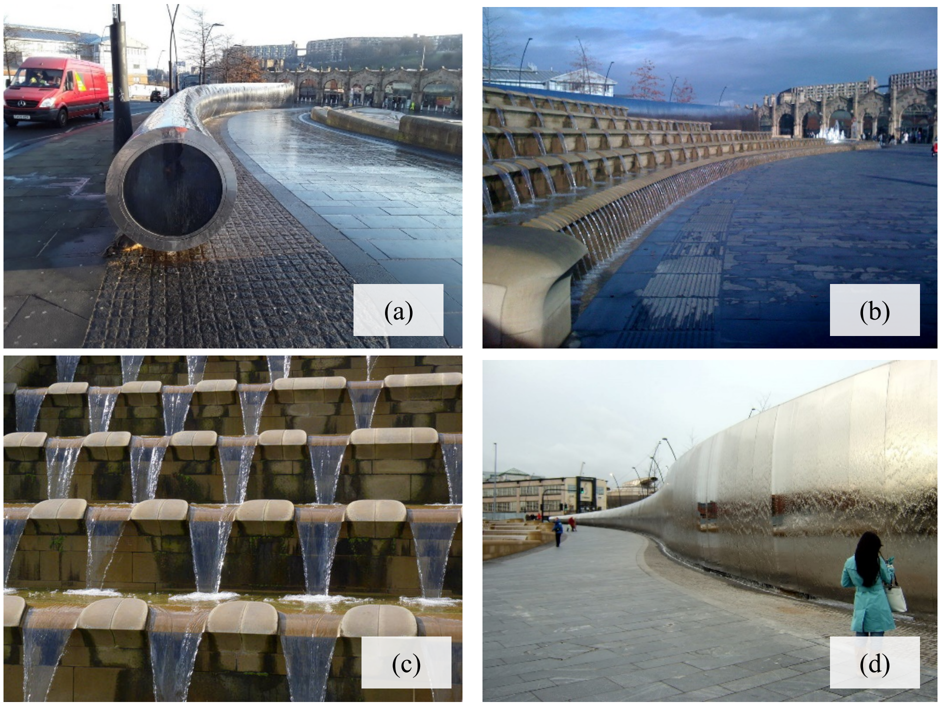


Figure 2.5 Sheaf Square, Sheffield. Source: Atlas Obscura.

Soundscape Malmö, Malmö, Sweden

By Gunnar Cerwén, Department of Landscape Architecture, Planning and Management, Swedish University of Agricultural Sciences, SLU, Alnarp, Sweden

"Soundscape Malmö" was a Movium Partnership project carried out in 2010-2011 (G. Cerwén, n.d.). A vegetation covered wall – the arbour was installed for two major purposes: screening noise from a nearby busy street named Amiralsgatan; and adding forest sounds through loudspeakers inside the "room" (G. Cerwén, 2016). The arbour was placed with its rear side as close to the street Amiralsgatan as was practically possible, about 12 meters to achieve the strongest possible contrast between being inside the arbour and being outside (G. Cerwén, 2016). Additionally, to minimize the incoordination between the installation of "noise screen" and the background landscape elements, the structure was built with an arbour and covered with pre-fabricated walls of ivy. "Inside the arbour, recorded forest sounds were played through six small (4″ coaxial) speakers. These were mounted in the wooden frames of the construction at around 1.6

m height.” The forest sounds were chose for their correspondence with the overall experience. A connection can be built by the visual expression of the arbour and the corresponding forest sounds. “The sound that was played back consisted of a collage of several different sounds typically found in forests: the sound of wind in trees, the sound of a brook in the mid-distance, and birds (predominantly nightingale and blackbird). The collage was composed so as to offer variations over shorter periods of time as well as longer periods of time. The total playback time was approximately 20 min, which was looped with a subtle fade-in and a subtle fade-out (G. Cerwén, 2016).”

Figure 2.6 Soundscape Malmö, Malmö, Sweden. Source: Gunnar Cerwén (2016): Urban soundscapes: a quasi-experiment in landscape architecture, Landscape Research, DOI: 10.1080/01426397.2015.1117062

Buitenschot Land Art Park, Amsterdam, Netherlands

By H+N+S Landscape Architects & artist Paul De Kort

Schiphol is one of the busiest airports in the world located south of downtown Amsterdam. The primary reason for rebuilding this place as a landing strip is that this area is considered as a “polder,” a typical low-lying area, which is prime for landing airplanes. But at the same time, the feature of this kind of topography amplifies the sound of planes across the area (H. Hansman, 2015). Designed by H+N+S Landscape Architects and artist Paul De Kort, this 80-acre green space serves as a sound barrier to deflect ground noise from planes. Different from the sounds on highway, this low-frequency, long-wavelength ground noise cannot be deflected by traditional sounds barriers (H. Hansman, 2015). Netherlands Organization for Applied Scientific Research conducted a study on the noise from the airport in 2008 and found that the farmer's furrows can effectively decrease the noise level by their multiple ridges. This is the origin of the design idea. "The basic element consists of 3-metre-high embankments which are 1, 10 meters below the land surface and distribute the noise. The 1-meter broad paths between the ridges also serve as walking paths. In Park Buitenschot a second principal direction for the ridges is introduced exactly perpendicular to the sound waves. This relates to the linked ridges up to the Haarlemmermeer polder grid in a surprising way, generating an intriguing interplay of lines ("Land art + Soundscape, Buitenschot park," n.d.)." Following tests after the design proved that this park successfully decreased the decibel level of the ambient noise and the volume at each location did not exceed the desired level (H. Hansman, 2015).

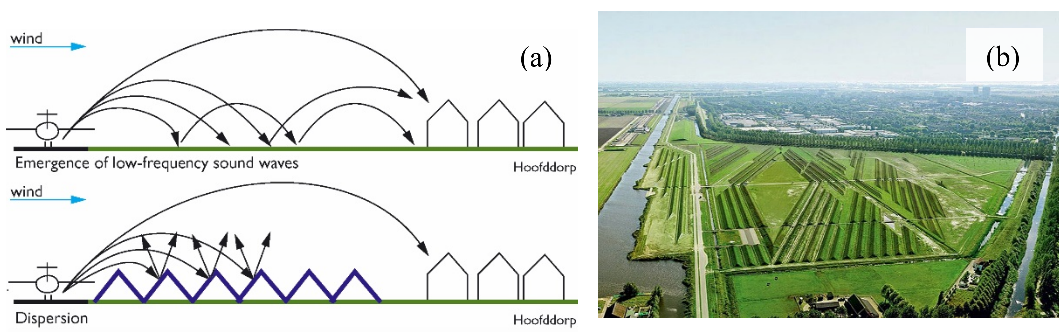


Figure 2.7 Buitenschot Land Art Park, Amsterdam, Netherlands. Source: H+N+S Landscape Architects

Sea organ, Zadar, Croatia

By architect Nikola Bašić

The musical architecture Sea Organ (morske orgulje) is located by the coast of Zadar, Croatia, and is the world's first musical pipe organs that is played by the sea. Under the steps carved in white stone, there are 35 musically tuned tubes with whistle openings on the sidewalk. The music will be triggered by the waves and motions of the sea ("Sea organ in Zadar, Croatia - Nikola Basic," n.d.). The waves create random harmonic sounds and the composition changes with the mood of the sea. The architect Nikola Bašić won *European Prize for Urban Public Space* in 2006 for this project.

“The steps are made up of seven parallel flights, each one ten meters wide. The seven flights are juxtaposed in such a way that at each change of flight there is a difference of one step; that means that the steps both at the junction with the parade and at the water's edge the flights present a staggered silhouette. The first three are the longest; they consist of six steps and descend about two metres, which is the highest level of the cruise ship arrival platform. From the fourth flight, the height of the parade gently approaches the water level, so that each new flight loses one step. The last flight, which has reached the definitive level of the parade, has only two steps above the water. But the proper adaptation to the topography of the parade is not the only explanation for the variations in the dimensions of the flights of steps. There is another which establishes a clear formal analogy with the variations in dimension and arrangement of the parts of a musical instrument. A series of polyethylene tubes of different diameters run along the inside surface of each flight of steps, connecting the submerged part with a gallery that runs along beneath the parade. With the variable force of the waves, the water penetrates the lower end of the tubes and is carried into the subterranean gallery, which collects it and returns it to the sea. In this process the air of the interior of the conduits is pushed to orifices that connect the gallery with the surface of the parade, generating sound vibrations which, given the variations in the diameter and length of the tubes, cover a broad range of musical tones (J. T. Foster, 2015).”

Figure 2.8 Sea organ, Zadar, Croatia. Source: ArchDaily.

SoundScape Park, Miami, United States

By West 8 Urban Design & Landscape Architecture

As a part of the Miami Beach City Center Redevelopment Plan, Miami Beach SoundScape Park is a 2.5-acre urban park in the cultural and civic heart of Miami Beach. The park was designed by the Dutch urban design & landscape architecture firm West 8 and was open to the public in January 2011. It was considered as "both an urban oasis and a gathering place for cultural and special events ("SoundScape Park," n.d.)" and "a unified expression of recreation, pleasure, and culture ("Miami Beach SoundScape," n.d.)." The park has a variety of unique features. "Firstly, several pergolas embrace the park edges; their shape inspired by the puffy cumulous clouds inherent in South Florida's tropical climate. Their hand-fabricated painted aluminum structures not only provide shade but also support the spectacular blooms of bougainvillea vines; highlighting a threshold of color at the parks points of entry." "Soft, undulating topography is reinforced visually by a white concrete mosaic of meandering pathways, and white concrete seating walls that provide options for informal seating. These two critical elements of the park design convey an illusion of a park much larger than its 2.5-acre envelope. While 'veils' of palm and specimen tree planting conceal and reveal views further reinforcing the experience ("Miami Beach SoundScape," n.d.)." One prominent feature that distinguished SoundScape Park from other urban parks is the “unprecedented, distinctive, and ambitious audio-visual program, which provides a free space to sit, view, and hear performances at concert level quality in the park ("Miami Beach SoundScape," n.d.).” The classical soundtrack of the New World Symphony increases the relaxation that can be obtained from visiting this urban park.

Figure 2.9 SoundScape Park, Miami, United States. Source: ArchDaily.

Through reviewing case studies of the soundscape deign in urban parks, it is illustrated that each park adopts a unique approach to deal with the unavoidable urban noise and innovatively engages the concept of soundscape in the landscape design and planning process. There are a few design recommendations that can be derived from these cases studies for enhancing the soundscape quality in urban parks:

1. By virtue of masking effects, adding water element to the park design is a common but effective approach in reducing the discomfort brought by street noise;
2. Aesthetic objects including plants and sculptures can be incorporated into the park design as sound barriers;
3. According to the information indicated in case studies above, the selection of preferred sounds, which might be sounds from nature or music, could add the relaxation and restorative effects of visiting the park. The introduction of preferred sounds can be achieved by artificial ways such as playing recordings with speakers;

4. The topography of the site can be taken into consideration before sketching the design plan in order to minimize adverse impacts of noise from the beginning;
5. The characteristics of the park surroundings can be leveraged to create the unique soundscape specifically for the park;
6. The harmony between visual effects and acoustic effects generated by incorporating the corresponding sounds to the landscape can have impacts on park-users' overall visiting experience.

Chapter 3 Overview of the Study Site: Penn Park

3.1 Basic Information about Penn Park

Penn Park is 24-acre open space with athletic fields and recreational facilities that owned and operated by the University of Pennsylvania ("Frequently asked questions about Penn Park," 2012). Located at the eastern side of Penn's academic campus, the creation of Penn Park extended the campus eastward for 14 acres more. One of the major functions of Penn Park is connecting Penn campus to the Center City of Philadelphia, which is fully illustrated by the commuting infrastructure web braided by three running train trails (Amtrak's Northeast Corridor rail line, SEPTA Regional rail line, and West Philadelphia Elevated/Philadelphia High Line), one waterfront highway (I-76/Schuylkill Expressway), and two street bridges (Walnut Street Bridge and South Street Bridge). The idea of "creating a coherent space out of a mess of transportation infrastructure" and transforming the old giant parking lot for mail trucks into new open green space is embedded in the university's goal of providing more park space and accessible outdoor sports facilities for the university community (J. Green, 2011). In addition to two acres of open spaces that are not specified for athletic use (the South Lawn and the Picnic Grove), Penn Park contains multiple sports amenities that are accessible for both Penn community and the public: two multi-purpose NCAA regulation athletic fields – Ace Adams field and Dunning-Cohen Champions field, a multi-purpose NCAA regulation women's softball field, and 12 tennis courts with an elevated observation deck. To link Penn campus to the surrounding transportation facilities and Center City, meandering pathways in the park are designed to lead commuters and park-visitors to Walnut Street, Smith Walk on campus, and the parking lot of Penn Facilities & Real Estate Services through the Paley Bridge, the Weave Bridge, and the Walnut Bridge ("Frequently asked questions about Penn Park," 2012).

Figure 3.1 Penn Park Map. Source: Penn Facilities & Real Estate Services

3.2 The History of Penn Park

The creation of Penn Park was enabled by an opportunity emerging in 1992, when Sheldon Hackney, the then-Penn president put forward a long-sighted plan of expanding Penn campus eastward rather than westward to avoid exacerbating the tension between the University and West Philadelphia neighbors during the process of campus growth (S. Zweifler, 2013). This very first idea of envisioning Penn' growth along the bank of Schuylkill River became a vital step for Penn President Amy Gutmann to form the Eastern Campus Advisory Committee as well as create a new campus development plan with Sasaki Associates. With an industrial land use history, a 14-acre area south of Walnut Street in current Penn Park was used to be the parking facility for the U.S. Postal Service (shown in Figure 3.1). In June 2003, Penn Trustee approved a resolution for the land acquisition and signed an Agreement of Sale one year later. In June 2006, as a blueprint for the campus sustainable development in the next 30 years, *Penn Connects: A Vision for the Future (1.0)* was released with a special focus on “replacing a 24-acre industrial zone with a vibrant, mixed-use neighborhood (*Penn connects: a vision for the future*, 2006).” Lead by the inspiring idea of connecting University City and Center City, Penn made successful achievements in the Penn Connects Phrase I (2006-2010), one of which was the Weave Bridge entrance of Penn Park. As a response to emerging sustainability goals, Penn Connects 2.0 Phrase II (2011-2015) enhanced the planning and design vision for the campus. Penn Park was completed in September 2011 at the beginning of Penn Connects 2.0. A time-lapse video of Penn Park provided by Penn Connects project presents the translation process of depicted visions into a real urban green landscape (http://www.upenn.edu/video/download/pennpark/draft4.mp4). This new open space transformed from an industrial site not only creates Penn community and the public opportunities for relaxation, informal play, and sports activities but also builds a tight connection between the university and the city both visually and emotionally.

Figure 3.2 Photos of Penn Park.

(a) (b) View of the U.S. Postal Service parking lot (Penn Park today) in 1965. Source: Artstor.

(c) Night scene of Penn Park today. Source: Flickr.

3.3 Sustainability in Park Design

One major sustainability challenge of the park design is the target of park's role in connecting the low-elevated site and surrounding train rail lines, bridges, and highway. Landscape architect Michael Van Valkenburgh Associates, Inc. worked with the engineering company Arup in designing and building three pedestrian bridges to increase the accessibility of this open space to Penn community and other city dwellers ("Project - Penn Park," n.d.). As one of the design goals and features, not only are three bridges cost effective and easy to build, but the steel structure of bridges successfully generates a visual harmony with the background of existing CSX rail line crossing the site, which "minimizes the visual weight of the bridges against the landscape. "

Another sustainability challenge is the stormwater management on site. Regulated by the Philadelphia Water Department (PWD), runoff from land development and redevelopment projects on Penn's campus must be managed to meet specific criteria devised in Stormwater Regulations in 2006 (*A stormwater master plan for the University of Pennsylvania*, 2013). As one of the overall environmental sustainability initiatives proposed in Penn's Climate Action Plan (2009), the Stormwater Master Plan for the University of Pennsylvania recommends a series of actions to reduce the negative stormwater runoff impacts generated by the impervious surfaces on campus (*A stormwater master plan for the University of Pennsylvania*, 2013). The design of Penn Park was challenged to address the stormwater management despite of the limited available space for stormwater attenuation. Given that a large portion of the park is planned for athletic venues built with artificial turf and landscape landforms, an underground detention system was developed for capturing a maximum of 300,000-gallon runoff water and reusing the captured water for irrigation during the growing season. It was proved to be successful by the heavy rainfall brought by Hurricane Irene in Philadelphia, 2011. In addition to the impressive performance in stormwater attenuation, Penn Park's sustainable design that is in alignment with initiatives of the university's Climate Action Plan saved significant amount of energy and budget through underground electrical infrastructure.

3.4 Flora and Fauna

From the information provided by Penn Facilities & Real Estate Services on Penn Plant Explorer website (https://www.facilities.upenn.edu/services/landscape/penn-plant-explorer), the list of plants in Penn Park is shown in Table 3.1:

Table 3.1 The list of plants in Penn Park. Source: Penn Plant Explorer.

Northern catalpa (*Catalpa speciosa*)	Purple cliffbreak fern (*Pellaea atropurpurea*)
Common hackberry (*Celtis occidentalis*)	Trumpet vine (*Campsis radicans*)
Swamp white oak (*Quercus bicolor*)	Purpletop (*Tridens flavus*)
Weeping willow (*Salix alba*)	Black oat grass (*Stipa avenaceum*)
White pine (*Pinus strobus*)	Canada wildrye (*Elymus canadensis*)
Dawn redwood (*Metasequoia glyptostroboides*)	Blue atlas cedar (*Cedrus atlantica*)
Eastern larch (*Larix laricina*)	Love grass (*Eragrostis spectabilis*)
Partridge pea (*Cassia fasciculate*)	Little bluestem (*Schizachyrium scoparium*)

Based on the bird survey conducted by Chloe Cerwinka, Landscape planner from Penn Facilities & Real Estate Services, there were 48 identified bird species in Penn Park from April 2018 to November 2018 and April 2019 to June 2019. The list of bird species in Penn Park is shown in Table 3.2.

Table 3.2 The list of bird species in Penn Park. Source: Penn Facilities & Real Estate Services.

American Goldfinch	American Kestrel	Eastern Phoebe	Black-throated Green Warbler	Eastern Kingbird	Yellow-bellied Sapsucker
European Starling	Ring-billed Gull	Chimney Swift	Bronzed Cowbird	Dark-eyed Junco	Yellow-billed Cuckoo
American Robin	Barn Swallow	Blue Jay	Belted Kingfisher	Double-crested Cormorant	Unidentified Flycatcher
House Sparrow	Northern Cardinal	Red-winged Blackbird	Black-and-white Warbler	Cooper's Hawk	Trumpeter Swan
Northern Mockingbird	White-throated Sparrow	Common Yellowthroat	Tree Swallow	Common Grackle	Red-eyed Vireo
Rock Pigeon	Chipping Sparrow	Cedar Waxwing	Red-tailed Hawk	Cedar Waxwing	Merlin
Mourning Dove	House Finch	Canada Goose	Peregrine Falcon	Carolina Wren	Laughing Gull
Gray Catbird	Song Sparrow	Fish Crow	Northern Flicker	Carolina Chickadee	Great Blue Heron

The plant species and bird species listed above are common species in Penn Park that were identified by professional landscape architects, which are highly to be noticed by park-users during a typical visit in a year (April to November for bird species). The collection of information about flora and fauna in Penn Park is intended to assist the understanding and analysis on the soundscape composition and soundscape quality of this park in the following chapters.

Chapter 4 Research Methodology

4.1 Acoustical Assessment – Sound Mapping

In this project, the A-weighting sound pressure level (SPL) was used as the method for acoustic measurement, and specifically, LAeq (continuous equivalent sound pressure level) was calculated to analyze the quality of acoustic environment. The LAeq refers to the constant noise level whose sound energy value is equal to the average energy of noise level fluctuation over an entire measurement period of time (A. J. Torija, D. P. Ruiz, & Á. Ramos-Ridao, 2012). It is a commonly used indicator for the noise pollution and has been widely applied to the calculation and assessment of industrial and community noise.

Given the major identified sound sources around the park, ten sampled positions were selected for the sound recording and measurement to ensure a detailed, accurate, as well as comprehensive evaluation of the park soundscape. The location of each sampled position is indicated in Figure 4.1. The coordinates of ten sampled positions were found on Google Map, which were used for sound mapping in ArcGIS.

Figure 4.1 A map made with Google Earth showing the ten sampled positions in Penn Park

One weekday and one weekend day of May, June, and July, respectively, were randomly selected for the acoustic data collection at ten sampled positions (including sound recording and measurement of the sound pressure level). Penn Park opens from 6 a.m. to 12 a.m. each day all year round. Therefore, for each selected weekday and each selected weekend day of three months, the acoustic data were collected during three time intervals of a day: morning 8 a.m. to 10 a.m., afternoon 2 p.m. to 4 p.m., and evening 6 p.m. to 8 p.m. At each sampled position, the A-weighting sound pressure level was recorded by a sound level meter (The BAFX Products Advanced Sound Level Meter - BAFX3608). To minimize the disturbances caused by weather conditions, all measurements were completed on days without rain and wind (wind speed < 10 m/s). During the sound measurement, the sound level meter's microphone was positioned at a tripod approximately 50 inches above the ground to reduce the effects of acoustic reflection and disturbances of ground. The meter was set in slow mode (displaying current average dB value in 1 second) and A-weighted mode to record the sound pressure level for every 1 second. The recording for each sampled location was in a duration of 5 minutes. The mean value of the 5-minute recorded data was calculated to obtain the corresponding LAeq, which was then converted into an available format for sound mapping in ArcMap.

All LAeq data of ten sampled positions in all surveying date were arranged into spreadsheets with all the coordinates and then were added to ArcMap. XY data were displayed and exported to a shapefile. After being projected to the commonly used coordinate system in Philadelphia - NAD 1983 (CORS96) State Plane Pennsylvania South FIPS3702 (US Feet), a method called inverse distance weighting (IDW) interpolation was adopted to create interpolated sound maps from SPLs in ArcMap. Data were displayed in equal intervals in the range of 50 – 74 dBA. In total, there are 18 sound maps showing the sound variations across the whole park for three time periods of a day (morning, afternoon, evening), two days of each month (weekday and weekend), and three months (May, June, July).

4.2 Acoustical Assessment – Sound Identification

In addition to measuring sound pressure level using the sound pressure meter, other formats of data were also used for the overall assessment of park soundscape. The sound recorder on the mobile phone was turned on at the same time when the sound pressure level of the ambient acoustic environment was measured. All information from the recordings were synchronized with the data in the sound pressure meter. Meanwhile, at each sampled location, the researcher observed the sonic environment and kept textual records about all the identifiable sound types. In terms of each identified type of sound, the researcher also assessed whether the sound was dominant or not and then decided the sound as “primary dominant” or “secondary dominant” for the purpose of displaying more detailed information about the characteristics of the soundscape. The audio and textual records are intended to provide assistance with the analysis of dramatic sound variations due to special events and the identification of all perceivable regular sounds in the park overall selected three months. Along with the acoustic data, other important background information including meteorological conditions (temperature, wind speed, moisture, etc.) and the number of people at each sampled position were also recorded for reference.

4.3 Psychological Assessment – Questionnaires

Recruitment of participants

To ensure the research method of this study is in alignment with ethic principles stated in the University of Pennsylvania IRB Mission, a protocol was submitted and reviewed by the Institutional Review Board. The protocol was determined to meet the eligibility criteria for IRB review exemption in March 2019. The approved recruitment script was used to randomly intercept and recruit park visitors in three months (May, June, and July of 2019). In total, 90 visitors were randomly selected to participate in the subjective assessment of soundscape quality in Penn Park via questionnaires in this project. The average number of recruited participants each month is 30. The manner in which participants were recruited was a random intercept-format. The recruitment was completed at the same selected time intervals of a day when acoustical data were recorded by the sound level meter, but the recruitment location was not limited to the area around the sampled positions. Before filling in the questionnaire, participants were given a detailed explanation of the purpose of this study and explanation of the potential risks in answering the survey to ensure the participation of recruited visitors was on a completely voluntary basis. Any uncompleted questionnaire was discarded. Thus, there were 90 valid questionnaires for the analysis.

Design of the questionnaire

The questionnaire designed for the analysis on subjective perception of the soundscape quality in Penn Park is composed of four major sections (the complete questionnaire is attached in Appendix):

- The first section is the socio-demographical information collection, including gender, age, ethnic origin, education background, occupation, and association with UPenn. These variables were collected for reference only. The relationship between the socio-demographical variables and other soundscape indicators was not analyzed in this project.
- The second section is the visiting information collection, during which process participants' basic information about how they usually use the park were recorded. The questions covered the frequency of visiting the park, the length of stay, the purpose of visiting (commute, relaxation, eating, studying, recreation etc.), and the time period in a day of visiting. Answers were provided for participants to make the selection.
- The third section is sound identification & sound assessment. In this section, participants were firstly asked to identify three types of sound they perceived at the location where the recruitment was completed and evaluated their psychological responses to those sounds using a scale from 1 to 5 (most unpleasant to most pleasant). Following the first question, participants were asked to report a subjectively dominant sound. Three indicators, which are Overall Landscape Quality, Overall Soundscape Quality, and Overall Impression, were selected for participants to evaluate by ten numbers, where 1 represents the lowest quality and 10 represents the highest quality. Lastly, a matrix is offered for identifying characteristics of the overall soundscape in Penn Park. Eight pairs of sematic attributes are selected for the evaluation with a 7-point bipolar rating scale from -3 to 3. Participants were guided to use the scale and circle the number which best indicates their agreement to

each attribute for the soundscape (-3 is the "most unpleasant", 3 is the "most pleasant", while 0 is neutral, meaning neither pleasant nor unpleasant). Eight selected pairs of semantic attributes are: pleasant - unpleasant, quiet - noisy, smooth - rough, varied - simple, calming - agitating, directional - everywhere, natural - artificial, steady - unsteady. The selection of these semantic attributes is based on previous studies (Kang, & Zhang, 2009; Martínez et al., 2018). These attributes are representative for both the sound characteristics and human psychological responses.

- The fourth section is the last but an optional part. All questions are open questions, and there are no definite answers to them. Questions are designed to investigate the change of awareness of the acoustical environment after the questionnaire, collect information about participants' favorite soundscape components in the park, and obtain their suggestions on design improvements of the soundscape in urban parks.

Chapter 5 Results

5.1 Acoustic Data

5.1.1 Characteristics of the Sounds in Penn Park

From the audio recordings of May, June, and July, a variety type of sounds has been identified by the author at ten sampled positions in Penn Park. Those identified sounds are summarized into the categories mentioned in Schafer's book *The Tuning of the World* (1977) and listed in Table 5.1:

Table 5.1 Identified types of sounds in Penn Park (May to July of 2019).

Natural sounds	**Mechanical sounds**	**Human-made sounds**
bird chirping, wind blowing, leaves rustling, insects buzzing	train brake scratching, train horn blaring, vehicle whizzing, helicopter whirring, airplane buzzing, bike whizzing	football playing, yelling, laughing, chatting, singing

According to the textual and audio records of all three months, identified sounds can be categorized into three general groups ("Geophony", "Biophony", and "Anthrophony") based on Pijanowski's terminology for sounds (2011) (shown in Table 5.2). Although most of the identified types of sound at each sampled location were consistent in three months, there was a slight variation that can be noticed in the composition of the soundscape in Penn Park. In May, mechanical sounds were shown to be the dominant component of the acoustical environment, the main reason for which was the construction along the west edge of the park. The sound of air and the sound of bird were consistently steady. However, one important change of the acoustical environment is the appearance of insect sounds in June, which was not perceivable in May. The sound of insects became dominant at several sampled locations in June and July (#2, #4, #6, and #10) and increased the diversity of sound in Penn Park. Except for the special events when the freight train on the highline passed over the park, the mechanical sounds were steady without dramatic variations. Similarly, human sounds did not have substantial changes in three months. The distribution of human sounds was largely determined by the location of sports venues and the schedule of sports events, though it was noticed by the author that the number of park-users evidently increased in July, which was likely to be a consequence of the seasonal change.

Table 5.2 The identified sound types of the soundscape at ten sampled positions.

Sampled Positions #	Identified Sounds at Sampled Positions					
	Geophony		Biophony		Anthrophony	
	Sound of Air	Sound of Water	Sound of Bird	Sound of Insects	Mechanical Sounds	Human Sounds
1	Yes, and secondary dominant	No	Yes, but not dominant	Yes, but not dominant	Yes, and primary dominant	Yes, but not dominant
2	Yes, but not dominant	No	Yes, and primary dominant	Yes, and secondary dominant	Yes, but not dominant	Yes, and secondary dominant
3	Yes, but not dominant	No	Yes, and secondary dominant	Yes, but not dominant	Yes, and primary dominant	sometimes, and not dominant
4	Yes, but not dominant	No	Yes, and secondary dominant	Yes, and secondary dominant	Yes, but not dominant	Yes, and primary dominant
5	Yes, and primary dominant	No	Yes, and secondary dominant	Yes, but not dominant	Yes, but not dominant	sometimes, and not dominant
6	Yes, and secondary dominant	No	Yes, and primary dominant	Yes, and secondary dominant	Yes, but not dominant	Yes, but not dominant
7	Yes, and secondary dominant	No	Yes, but not dominant	sometimes, and not dominant	Yes, and primary dominant	sometimes, and not dominant
8	Yes, but not dominant	No	Sometimes, and not dominant	No	Yes, and primary dominant	Yes, and secondary dominant
9	Yes, and secondary dominant	No	Yes, and primary dominant	Yes, but not dominant	Yes, and secondary dominant	Sometimes, and not dominant
10	Yes, and secondary dominant	No	Yes, and primary dominant	Yes, and secondary dominant	Yes, and primary dominant	Sometimes, and not dominant

5.1.2 Sound Maps

Sound maps of 18 time periods are shown in Figure 5.1. Ten sampled positions are indicated by numbers on the sound maps. The average sound pressure level of Penn Park in both weekday and weekend of May, June, and July falls within the range of 50-74 dBA. The comparison of the area with low LAeq in Penn Park between weekday sound map and weekend sound map for three months demonstrates that the average sound pressure level of the park in weekend day is relatively lower than that in weekday. Specifically, it is clear to see that the average sound pressure level of the park in the morning and evening of May weekday ranged over 59.0 dBA, while the park in the morning and evening of May weekend had an average sound pressure level lower than 59.0 dBA. Another feature of the park soundscape illustrated by the results is that in both May and June, the afternoons were the quietest time period in a day (58.8 dBA and 59.0 dBA, respectively) compared to mornings (61.9 dBA and 60.0 dBA, respectively) and evenings (60.7 dBA and 60.6 dBA). According to the audio recordings, it can be noticed that there were few external disturbances in the sonic environment of afternoons in May and June and the sounds were relatively steady, which are in alignment with the results of sound pressure level on the sound maps. However, different from the results of May and June, the afternoons in July were not the quietest time period during a day (59.6 dBA in weekday and 59.4 dBA in weekend). There was one abnormal data on the sound map of July weekend afternoon. Based on the information shown in Table 5.3, the LAeq of sampled position #3 reached as high as 72.5 dBA. The dramatic increase in the sound pressure level was explained by the passing CSX freight train and a cleaning vehicle. The external sound sources had immediate impacts on the average sound pressure level in the park. The comparison among the results of three months does not reveal any change in the seasonal pattern of the sound distribution in Penn Park since this study only focused on three months in one year. Whereas, by analyzing the differences between the sound pressure level in weekdays of May, June, and July, it can be summarized that the sound environment of Penn Park on the weekday of May had the highest average sound pressure level (62.0 dBA), which was associated with the construction sound along the southwest edge of the park from recordings.

Through examining the average sound pressure level of each sampled position in all three months, it is demonstrated that there were substantial differences among the soundscape at each location. Sampled position #6 and #4 are the two quietest locations in the park with the sound pressure level of 56.3 dBA and 57.5 dBA, respectively, while sampled position #1 is the loudest location (62.5 dBA), followed by #7 (62.3 dBA) and #10 (61.1dBA). In addition, regardless of the data influenced by special events, there is a noticeable pattern in the spatial variation of the average sound pressure level value across the park: the area surrounded by sampled position #7, #8, #9, and #10 had the highest average sound pressure level (61.1 dBA) and when moving towards northeastern, the area cropped by sampled position #4, #5, and #6 had the lowest average sound pressure level (57.5 dBA). The findings can be explained by the landscape characteristics of different sampled locations. The area surrounded by #7, #8, #9, and #10 is a triangular area encircled by three railways and a highway and main habitats are areas of mown grass and natural grassland. Few trees are available along the edge of the park to buffer the sounds from railways and highway. However, the habitats of the area between #4, #5, and #6 are natural grassland, turf, and a cluster of trees (mainly in #6 picnic area). Trees have become natural barriers to minimize the sound pressure level on site.

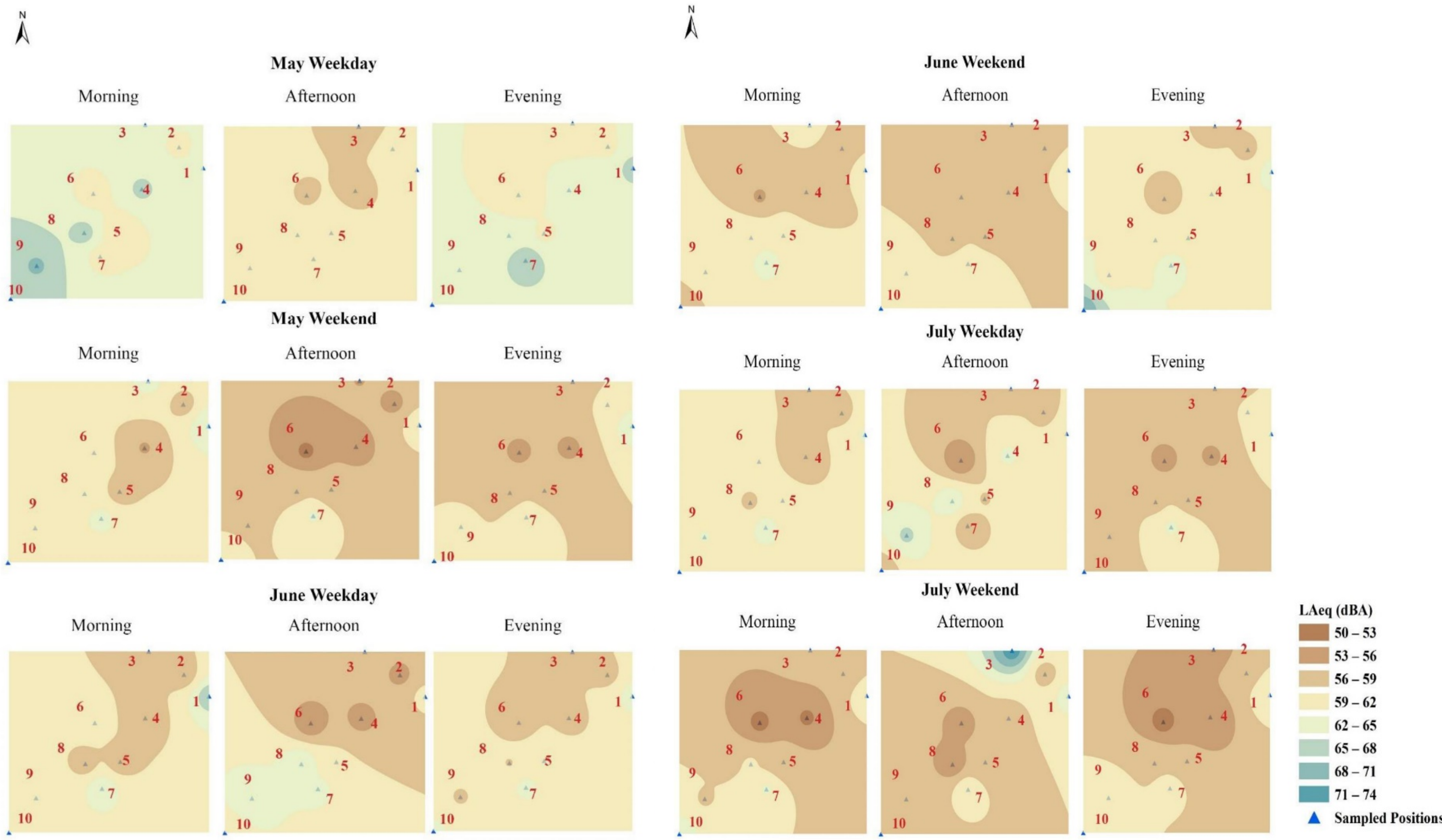


Figure 5.1 The sound maps showing distribution of the average sound pressure level (dBA) in Penn Park

Table 5.3 The average sound pressure level (dBA) at each sampled location in Penn Park

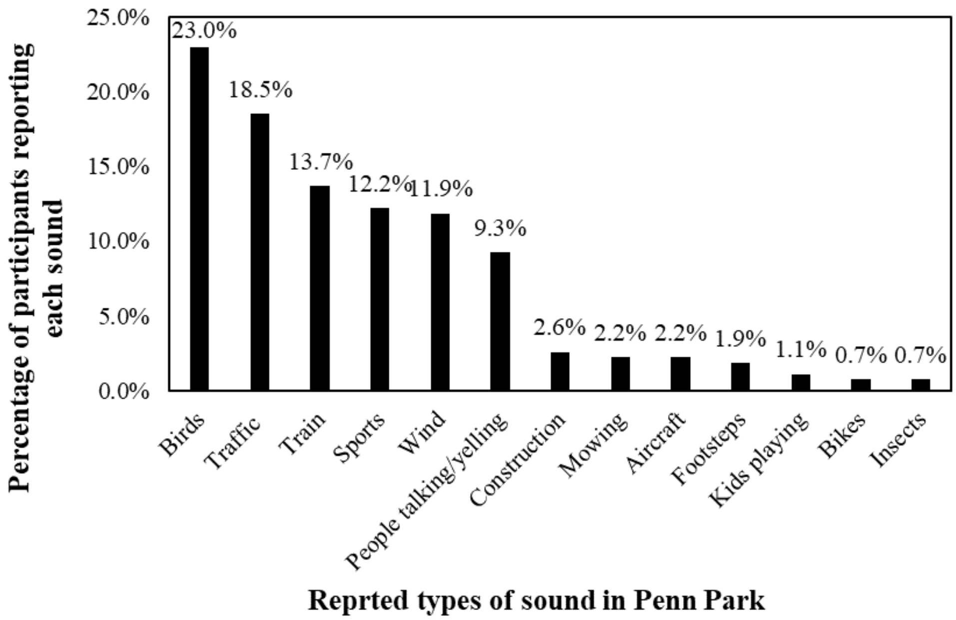
Sample position	Sound Pressure Level (LAeq, dBA)																	
	May						June						July					
	Weekday			Weekend			Weekday			Weekend			Weekday			Weekend		
	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening
1	63.0	61.0	65.8	65.0	61.2	64.1	66.9	59.7	63.1	60.3	61.3	63.1	62.3	60.2	62.1	61.5	63.1	62.0
2	61.6	59.5	61.6	58.0	55.5	59.3	57.3	55.4	58.3	56.1	56.9	58.4	58.4	58.4	59.3	56.0	57.6	58.0
3	62.2	57.8	59.8	62.8	56.0	57.4	57.0	57.8	57.8	60.4	56.4	58.3	58.6	58.0	56.5	57.6	72.5	54.3
4	65.7	58.0	63.1	55.8	55.0	55.4	57.1	55.1	58.2	56.8	56.2	59.7	57.6	62.5	55.6	52.6	57.6	53.2
5	59.1	61.3	61.5	57.7	56.8	57.4	57.4	59.3	61.4	60.8	58.4	60.5	59.2	58.9	58.1	56.6	56.1	56.2
6	60.5	58.6	59.4	59.7	52.4	55.4	60.2	53.6	57.8	55.6	56.4	57.5	59.1	53.0	55.1	52.1	54.9	51.8
7	61.0	59.5	67.5	62.8	62.4	62.1	64.5	62.7	62.6	63.1	61.8	63.0	63.3	57.5	62.5	62.3	61.6	60.6
8	66.3	61.6	62.8	61.4	58.6	56.8	57.8	64.9	58.9	61.2	57.5	60.5	58.6	64.6	58.3	59.2	54.0	58.7
9	68.3	61.1	62.3	59.9	59.0	59.6	60.4	64.0	58.9	60.3	61.0	61.1	62.1	65.5	58.2	58.9	57.3	61.1
10	67.5	60.3	63.5	59.2	59.5	59.1	61.1	60.5	62.5	57.6	61.4	69.6	59.3	57.0	57.3	63.7	58.9	61.8
Mean	63.5	59.9	62.7	60.2	57.6	58.7	60.0	59.3	59.9	59.2	58.7	61.2	59.8	59.6	58.3	58.0	59.4	57.8

5.2 Psychological Responses

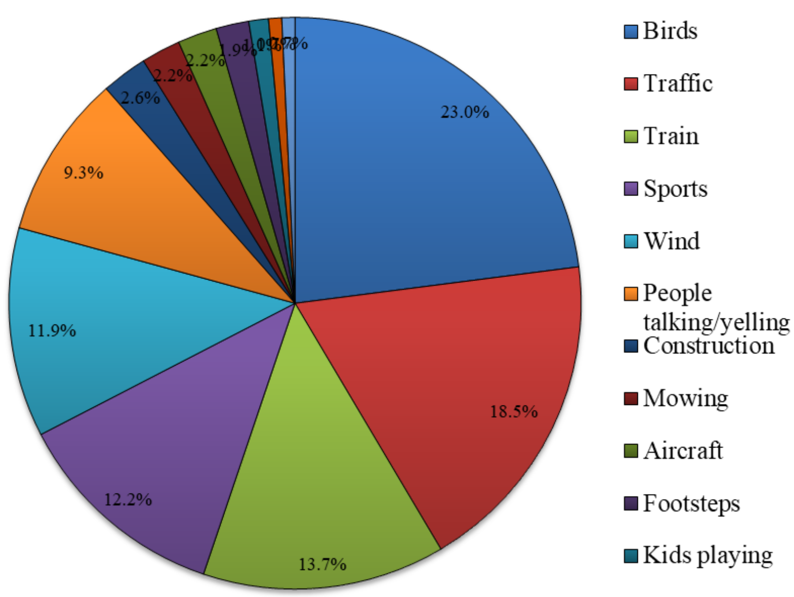
5.2.1 Identified Types of Sounds by Visitors in Penn Park

At the beginning of the third section of the questionnaire, participants were asked to report three types of sound they noticed at the recruitment location and rate each sound using a scale with number from 1 to 5, where 1 stands for "most unpleasant" and 5 stands for "most pleasant." The results of the identified types of sound in Penn Park by participants are shown in Figure 5.2. In total, there were 13 types of sound identified. The sound of birds was the most frequently reported type of sound (23.0% participants), followed by the sound of traffic from the street (18.5% participants) and the sound of train (13.7% participants). Penn Park has served favorable habitats for birds, and the number of birds (especially American Robin and European Starling) significantly increased with the rising temperature in late spring and early summer, which is likely to be the primary reason for the high percentage of participants reporting the sound of birds. In addition, Penn Park is surrounded by the I-76 highway and two street bridges. The sound of traffic is a background sound in the park that can be easily noticed. The influence of the sound from railways was random. The identification of the train sound is largely determined by the time when participants fill in the questionniare. Some participants heard the trains passing by while some participants did not. The passing trains can cause dramatic variation in the soundscape of the park.

Identified sounds fall into three genral sound categories: natural sounds, mechanical sounds, and human-made/human-related sounds (Figure 5.3). Although the parcentage of participants reoprting three categories of sound is approximately the same, the mechanical sounds were the most frequently reported sound category by participants (39.3%) and the human-made sounds were the least frequently reported sound category (25.2%).



(a)



(b)

Figure 5.2 Identified types of sound and the percentage of participants reporting each sound in Penn Park (a) in bar chart, (b) in pie chart

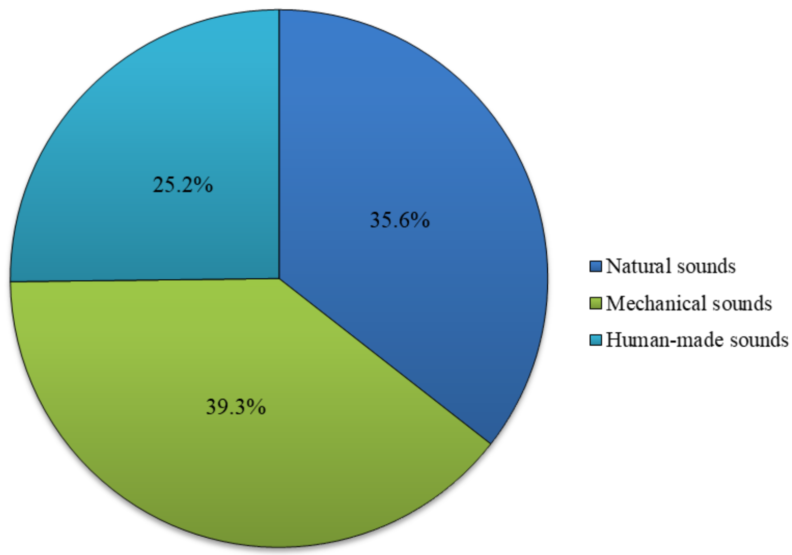


Figure 5.3 The percentage of participants reporting each category of sounds

At the beginning of the third section of the questionnaire, participants were asked to report three types of sound they noticed at the recruitment location and rate each sound using a scale with number from 1 to 5, where 1 stands for "most unpleasant" and 5 stands for "most pleasant." To evaluate the pleasantness of each identified sound, the average value of the scores for each sound was calculated. The higher the average value, the more pleasantness the sound was perceived. The results are shown in Figure 5.4. It can be found that three types of natural sounds: the sound of birds, the sound of insects and the sound of wind have the highest average value for pleasantness (4.4, 4.0, 3.9, respectively), which implies a strong connection between the human perception of sounds and nature. Mechanical sounds (traffic, train, construction, mowing, etc.), however, are all rated as the least pleasant sounds.

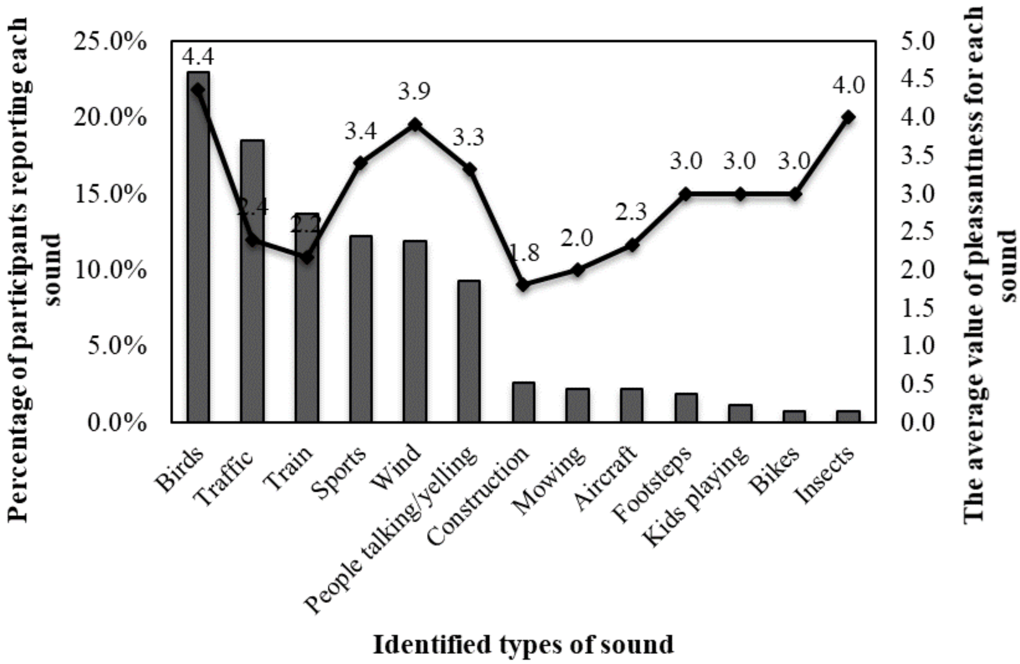


Figure 5.4 The assessment of pleasantness for each reported sound

5.2.2 Reported Subjectively Dominant Sounds

To further explore whether the frequently reported sound has dominant effects on people's subjective perception of the acoustical environment, participants were asked to report if there was a subjectively dominant sound in the surrounding acoustical environment and what type of sound it was. Figure 5.5 shows the percentage of participants corresponding to each type of identified subjectively dominant sound. Approximately 40% of the participants reported that there was no identified subjectively dominant sound in surroundings. Traffic sound was the most frequently reported sound as subjectively dominant (25.9% participants), followed by the sound of train (11.1% of participants) and the sound of birds (9.9% participants). The subjective dominance of traffic sound may be attributed to the steady vehicle flows on the highway and two streets along the edge of the park. Nevertheless, the acoustical background dominated by traffic sounds was covered by train sounds when different trains (Amtrak train, SEPTA train, and highline freight train) passed by. The train sounds can bring significant impacts on park-users' perception of the acoustical environment and the identification of the subjectively dominant sound.

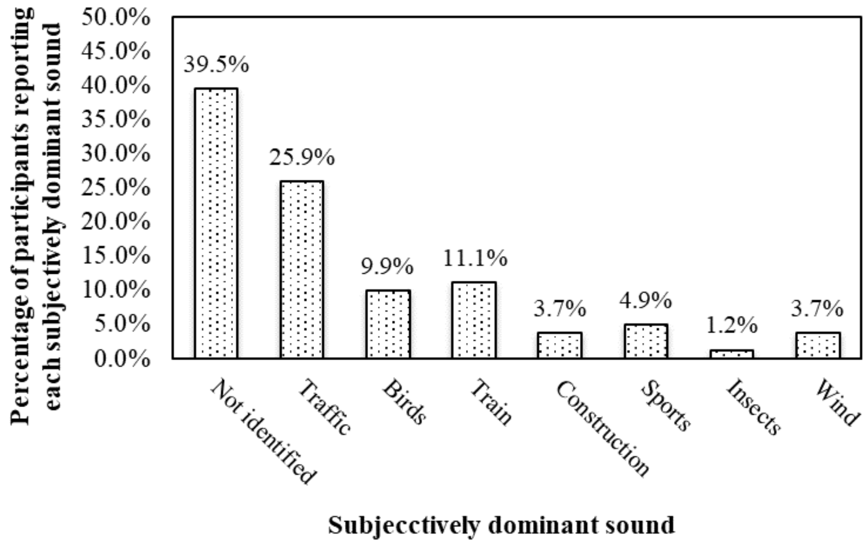


Figure 5.5 The percentage of participants corresponding to each reported subjectively dominant sound

5.2.3 Relationship of Three Indicators

Three indicators were selected for participants to evaluate: (a) Overall Landscape Quality (OLQ), (b) Overall Soundscape Quality (OSQ), and (c) Overall Impression (OI). OLQ was rated by how acceptable and enjoyable the landscape was, OSQ was rated based on the features of sounds, subjective feelings about the perceived sound, and OI was rated based on the landscape quality, soundscape quality, and other factors participants considered important. Data analysis on the interrelationship between three indicators was carried out in SPSS. Pearson's correlation was conducted to examine the relationship between overall landscape quality, overall soundscape quality, and overall impression. Table 5.4 and Figure 5.6 show the results of analysis on correlations. A complete list of correlations is presented in Table 5.4 and a scatterplot of OLQ, OSQ, and OI is presented in Figure 5.6. Table 5.4 clearly indicates that there is a significant positive relationship between overall landscape quality and overall soundscape quality, r (88) = .519, p <.001. Overall landscape quality is more strongly positively related to overall impression, r (88) = .742, p <.001, than overall soundscape quality, r (88) = .700, p < .001, which is in alignment with the results displayed in Figure 5.6. These findings demonstrate that the improvement of the overall landscape quality and of the overall soundscape quality can effectively increase the park-users' overall impression on the park, though the change of overall landscape quality can lead to more significant impacts on the overall impression than the change of overall soundscape quality. This finding might be related to the priority of people's visual perception rather than the audial perception of urban parks. Nevertheless, the enhancement of soundscape quality can be regarded as a complementary approach to strengthen the positive influence of landscape on park-users' overall impression.

Table 5.4

Pearson's correlation (Pearson's r) between reported value for "overall landscape quality", "overall soundscape quality", and "overall impression"

		Overall Landscape Quality	Overall Soundscape Quality	Overall Impression
Overall Landscape Quality	Pearson Correlation	1	.519**	.742**
	Sig. (2-tailed)		.000	.000
	N	90	90	90
Overall Soundscape Quality	Pearson Correlation	.519**	1	.700**
	Sig. (2-tailed)	.000		.000
	N	90	90	90
Overall Impression	Pearson Correlation	.742**	.700**	1
	Sig. (2-tailed)	.000	.000	
	N	90	90	90

**. Correlation is significant at the 0.01 level (2-tailed).

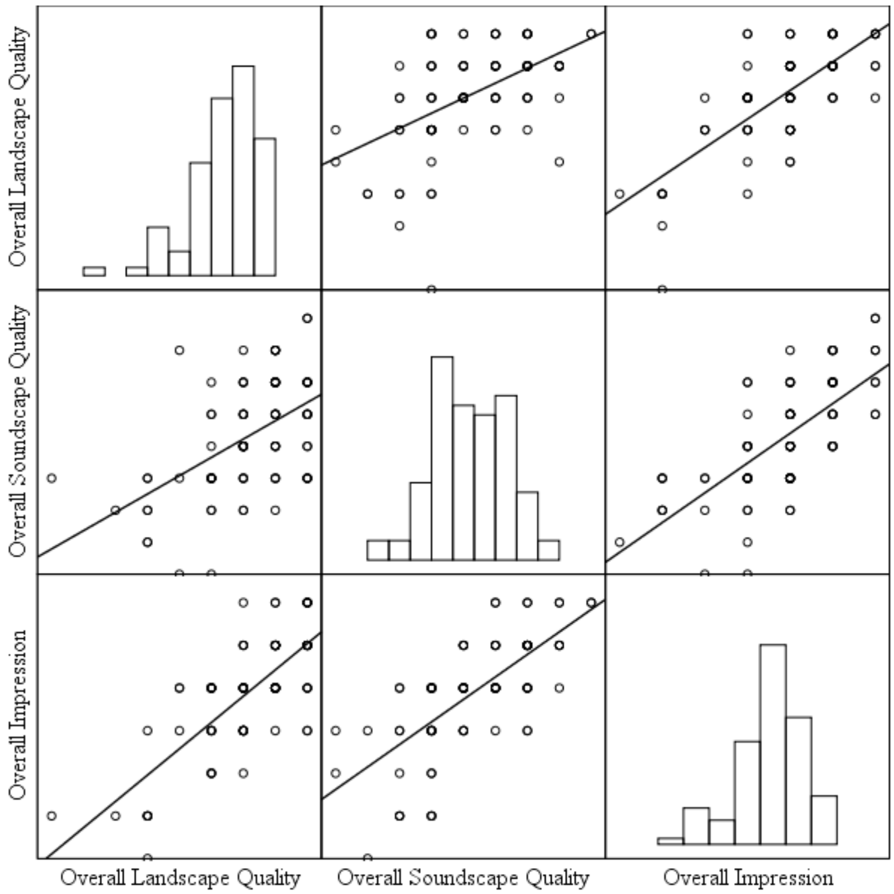


Figure 5.6 Scatterplot matrix of OLQ, OSQ, and OI

5.2.4 Evaluation of Overall Soundscape Quality by Semantic Attributes

In the last part of the third section, participants were asked to evaluate the overall soundscape quality using a 7-point bipolar rating scale. A selection of numbers was provided from -3 to 3, where -3 represents the "most unpleasant", 3 represents the "most pleasant", and 0 is neutral, meaning neither pleasant nor unpleasant. The numbers in between (2 and -2) represent the variation of degree. These sematic attributes were used in this study for the quantitative analysis of people's perception of the acoustical environment. Figure 5.7 demonstrates participants' subjective responses to the overall soundscape through eight pairs of descriptors. The value of each pair was averaged to evaluate participants' overall attitude towards each aspects of the soundscape. All average values fell into the range of 0 to 2, which implies that participants perceived the soundscape as more pleasant, quiet, smooth, varied, calming, directional, natural, and steady than unpleasant, noisy, rough, simple, agitating, everywhere, artificial, and unsteady, respectively. Additionally, it can be summarized from the results that the pleasantness, calming effect, smooth feature as well as the variety of sounds were commonly regarded as significant characteristics of the park soundscape, while the quietness, distribution, category, and stability of sounds were assessed by participants as moderately perceivable. The special events that had significant influence on the soundscape quality such as the trains passing by and the aircrafts flying over might contribute to this result. Overall, the park-users' attitude towards the park soundscape was positive.

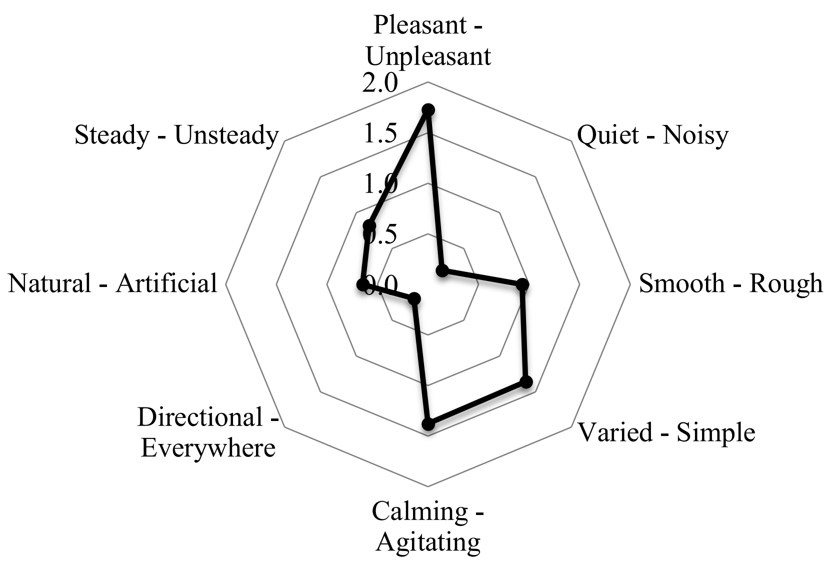


Figure 5.7 The assessment of the overall soundscape quality using eight pairs of sematic attributes

5.2.5 The Awareness of Soundscape in Urban Parks

The last section of the questionnaire is composed of four open-ended questions and a scale bar for participants rating the likelihood of paying more attention to the acoustical environment in the future. The investigation into the change of participants' attitudes toward the acoustical environment after completing the questionnaire can reveal the influence of communicating the concept "soundscape" on people's perception on the overall environment in urban parks and on the adverse impacts of "unwanted sounds." Results are shown in Figure 5.8, with most participants (44.4%) reporting that they would be highly likely to pay more attention to the sounds in urban parks in the future, while a few participants (31.1%) reported that they would be most likely to notice and perceive the soundscape in urban parks because of the questionnaire. One question that was not discussed in this study is the attribute of the influence ("positive" or "negative") on increasing people's awareness of the acoustical environment, which can potentially be explored in future studies.

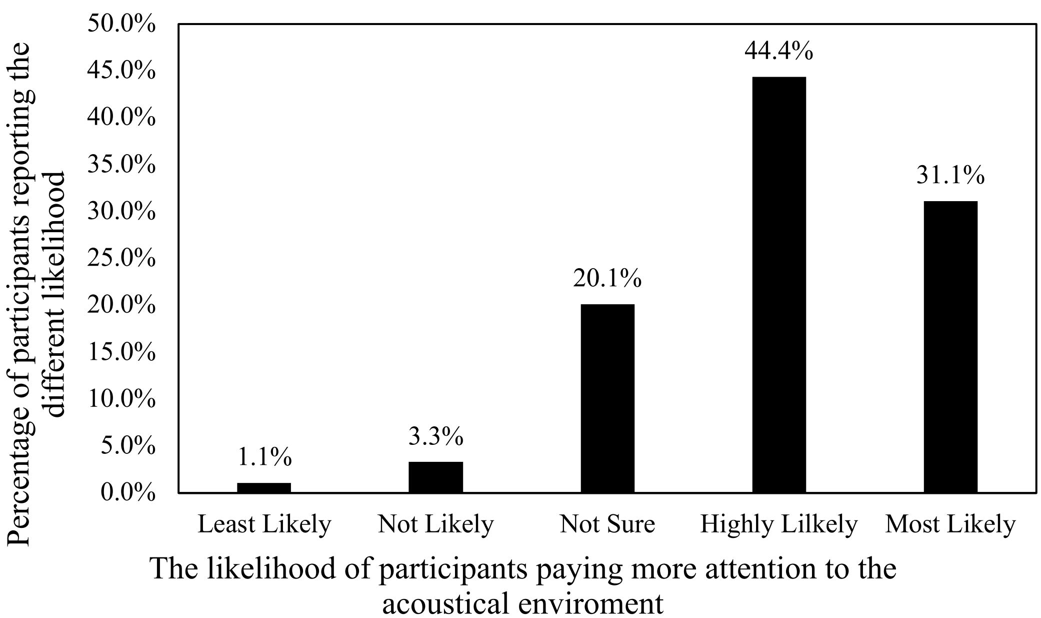


Figure 5.8 The investigation into participants' attitudes toward to the acoustical environment after the questionnaire

Chapter 6 Discussion

The main findings from the data shown above can be summarized to answer seven research questions put forward in Chapter 1:

1. **Is there any pattern for the distribution of the average sound pressure level (SPL) in Penn Park? Which part of the park is acoustically the "quietest" and which part is the "loudest"?**

   The average sound pressure level of Penn Park in all measured days falls within the range of 50-74 dBA. There are significant differences in soundscape at different locations of Penn Park: Sampled position #6 and #4 are the two quietest locations in the park (56.3 dBA and 57.5 dBA, respectively), while sampled position #1 is concluded to be the loudest location (62.5 dBA), followed by #7 (62.3 dBA) and #10 (61.1dBA). The area surrounded by sampled position #7, #8, #9, and #10 has the highest average sound pressure level (61.1 dBA) and the area surrounded by sampled position #4, #5, and #6 has the lowest average sound pressure level (57.5 dBA). Some special events including the passing of high-speed trains, CSX freight train, and motorcycles can dramatically increase the sound pressure level at specific locations.

2. **Is there any significant difference between the sound environment of the park in weekday and that in weekend?**

   The comparison of the area with low LAeq in Penn Park between weekday sound map and weekend sound map for three months demonstrates that the average sound pressure level of the park in the weekend day is relatively lower than that in weekday.

3. **How many types of sound in Penn Park are reported by interviewees, what are they, and how pleasant are they?**

There are 13 types of sound identified by participants: birds, traffic, train, sports, wind, people talking/yelling, construction, mowing, aircraft, footsteps, kids playing, bikes, and insects. The sound of birds was the most frequently reported type of sound (23.0% participants), followed by the sound of traffic from the street (18.5% participants) and the sound of train (13.7% participants). In terms of the pleasantness, it is found that three types of natural sounds (birds, insects, and wind) have the highest average value for pleasantness. Mechanical sounds (traffic, train, construction, mowing, etc.) are reported as the least pleasant sounds.

4. **Is there any reported subjectively dominant sound and what is it?**

Approximately 40% of the participants reported that there was no identified subjectively dominant sound in the surroundings. 25.9% of participants reported the sound of traffic as a subjectively dominant sound, while 11.1% participants mentioned the sound of the train, and 9.9% of participants mentioned the sound of birds was the subjectively dominant sound.

5. **Is there a correlation between every two of the three selected indicators – Overall Landscape Quality (OLQ), Overall Soundscape Quality (OSQ), and Overall Impression (OI)?**

All three indicators are significantly positively correlated to each other. The improvement of the overall landscape quality and of the overall soundscape quality can significantly increase the park-users' overall impression on the park. And the change of overall landscape quality can have stronger impacts on the overall impression than the change of overall soundscape quality, which is in accordance with the fact that people's perception of an urban park is primarily influenced by the visual aspects of the park. Nevertheless, the sonic environment can additionally strengthen the interaction between human and the surroundings, which has indirect impacts on park-users' experience of the park.

6. **What are the characteristics of the soundscape in Penn Park that perceived by the interviewees?**

The Overall Soundscape Quality (OSQ) was evaluated by questionnaire participants with eight pairs of semantic attributes. Participants' responses to the eight semantic attributes of soundscape reflected that the overall soundscape in Penn Park is more pleasant, quiet, smooth, varied, calming, directional, natural, and steady than unpleasant, noisy, rough, simple, agitating, everywhere, artificial, and unsteady, respectively. The pleasantness, calming effect, smooth feature and the variety of sounds are remarkable characteristics of the park soundscape that can be perceived by park-users.

7. **What is the change of people's awareness of the soundscape in this urban park after the questionnaire? How likely will people pay more attention to the sound environment in urban parks in the future?**

Most participants (44.4%) reported that they would be highly likely to pay more attention to the sounds in urban parks in the future, while a few participants (31.1%) reported that they would be most likely to notice and perceive the soundscape in urban parks because of the questionnaire. Therefore, it can be concluded that communicating the concept and characteristic of soundscape with park-users can significantly change their awareness of the sonic environment in urban parks. The experience of parks in the future can be more positive and more interactive as a result of increasing interests in soundscape.

In addition to the findings summarized above, there are some other patterns and relationships can be analyzed from the data. The results of the questionnaires suggest that mechanical sounds were the most frequently reported sound category followed by natural sounds and human-made sounds, in spite of which, the sound of birds (natural sound) was the most frequently identified individual sound and was rated the most pleasant sound in Penn Park. Moreover, even though the results indicate that the sound of insects was the least frequently identified type of sound, it was evaluated as the second most pleasant sound in the park. Therefore, in terms of an individual sound, the frequency of being reported does not necessarily represent a high reported frequency of the corresponding sound category or a high average value for pleasantness. Additionally, the evaluated high pleasantness value of natural sounds and low pleasantness value of mechanical sounds confirm a previous theory that natural sounds are positively associated with the pleasantness in urban soundscape while the mechanical sounds are more associated with the unpleasantness (Ö. Axelsson, M. Nilsson, & B. Berglund, 2010). It is also interesting to find that almost half of the questionnaire participants reported that there was no identified subjectively dominant sound in surroundings. In a soundscape study of Pérez-Martínez G. et al. (2018), only around 6% of questionnaire participants did not choose any sound as subjectively dominant in a given place. The percentage of participants reporting no subjectively dominant sound may be related to the specific composition of the acoustic environment and the social and cultural background of participants, which could be studied in the future research. The analysis on the interrelationship between OLQ, OSQ, and OI illustrates that the improvement of either landscape quality or soundscape quality can effectively enhance park-visitors' overall impression on the park, but the change of landscape quality has more significant impacts on the overall impression than the increase of soundscape quality, which reveals that compared to acoustic quality, the aesthetic value of urban parks still plays a dominant role in enhancing the satisfaction from visiting experience. Nevertheless, the design and planning of soundscape could be taken as an important part of landscape design to assist with strengthening the connection between park visitors and their environment. As it is shown in case studies, incorporating acoustic factors to the park design not only minimized the harmful impacts of urban noise but also increased the human-nature interaction. The soundscape can be regarded as a complementary approach to contribute to the overall park design. Results of the optional questions in the questionnaire indicate that participation in the soundscape study encouraged park-users to pay more attention to the acoustic environment in urban parks in the future. The communication about the concept of soundscape with park visitors is suggested to be integrated into the soundscape design of urban parks to promote the public understanding of soundscape and maintain the aesthetic, natural, and cultural qualities of urban parks (J. Kang et al., 2016).

Chapter 7 Conclusions and Outlook

Urban parks are one of the important green space in enhancing the quality of urban environment and providing multiple services for urban dwellers. Park-users' perception of the physical built environment in urban parks has significant impacts on the use of the space. This study investigated park-users' attitudes toward the quality of urban parks from a perceptive of soundscape assessment and selected a specific urban park – Penn Park as the case study. Both acoustical and psychological approaches were adopted to conduct a comprehensive evaluation of the soundscape quality in Penn Park. In addition to the investigation on the spatial distribution of sound pressure level, this study also examined the pleasantness of identified sounds, subjectively dominant sound, the relationship between overall landscape quality, overall soundscape quality, and overall impression, and the park-users' perception of eight pairs of semantic attributes in soundscape quality.

However, this study has several limitations. First, the research only investigated the soundscape of Penn Park in three months, so the results reflected the soundscape characteristics of spring and summer but did not reveal a seasonal pattern over a year. The data collected are not representative enough to inform the soundscape of Penn Park in other seasons. Besides, this study focused on a specific urban park. Given that the features and services of urban parks are various, the improvement approaches for the soundscape quality in Penn Park may not be applicable to other different types of urban parks. Moreover, this study did not analyze the participants' subjective evaluation of the soundscape corresponding to the sound pressure level of ten sampled positions. Future research could focus the analysis on the relationship between sound pressure level and people's corresponding responses to the sonic environment. Lastly, although the awareness of soundscape has been increased after the questionnaire, the impacts of increasing awareness were not studied.

There are several implications and recommendations for the future urban park soundscape study and soundscape design. One of the practical implications lies in the improvement of the soundscape in Penn Park and other similar urban parks. The soundscape quality can be improved by creating more areas in the park as sound buffers, where the unwanted sounds are minimized by physical built structures (such as noise reduction barriers and trees). Physical noise reduction methods, however, has been studied to not necessarily improve people' experience of the parks (W. Yang & J. Kang, 2005). It is essential to investigate park-users' subjective psychological responses to the physical environment of parks. Previous research revealed that the soundscape dominated by natural sounds was perceived to be more pleasant than the environment dominated by mechanical sounds or human-made sounds (Ö. Axelsson et al., 2010; G. Pérez-Martínez et al., 2018). As it is indicated by the results, Penn Park visitors reported natural sounds, particularly the sound of birds, as the most pleasant type of sound. Therefore, the soundscape quality of Penn Park can be improved by increasing natural sounds (birds, insects, wind) and enhancing the pleasantness from visiting this park. Water sound is another sound that most participants suggested to be introduced to the park in the optional section of the questionnaire. From the case studies, it can be found that landscape practitioners leveraged the sound of water to mask the street noise. The sound of water, as both an acoustical as well as an aesthetic element in park design, should be taken account in the process of improving the overall impression of urban parks. In the future research of urban park soundscape, it is suggested that both the positive and negative effects from encouraging park-users to pay more attention to the acoustic environment in urban parks should be studied and design techniques for maximizing the positive effects and minimizing the negative effects should be explored. Moreover, it is necessary to conduct further research on the interaction and interrelationship between soundscape characteristics and landscape features and their potential collective effects on more positive visiting experience.

Overall, urban parks are important green space to connect urban dwellers and natural environment and create a sense of community. The involvement of soundscape in the park design can build a healthier and more satisfying urban open public space for urban residents, improve the urban life quality, and contribute to the development of sustainability in urban planning and design.

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Appendix Questionnaire about Soundscape Quality

All collected information will be confidential and only used to this project

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Please select or write down the information that best describes you:

- Gender ☐ Male ☐ Female ☐ Other ________ ☐ Prefer not to answer
- Age
  ☐ 16-20 years old ☐ 21-25 years old ☐ 26-30 years old ☐ 31-40 years old ☐ 41-50 years old
  ☐ 51-60 years old ☐ 60-70 years old ☐ 70 years or older ☐ Prefer not to answer
- Ethnic origin (please check all applicable)
  ☐ White ☐ Hispanic or Latino ☐ Black or African American ☐ Native American or American Indian
  ☐ Asian/Pacific Islander ☐ Other
- Education (please check all applicable)
  ☐ No schooling completed ☐ Some high school ☐ High school ☐ Some college ☐ Bachelor's degree
  ☐ Master's degree ☐ Professional degree ☐ Doctorate degree ☐ Other
- Occupation _______________ (please indicate your occupation types here, if you are a student, please fill it with "student")
- Association with UPenn (please check all applicable)
  ☐ I'm currently studying at Penn
  ☐ I'm currently employed at Penn
  ☐ I'm currently studying or employed at other universities in Philadelphia (Drexel, Temple, etc.)

☐ None of the above

The following questions are about how you use Penn Park:

- How far do you live from Penn Park (3000 Walnut St)? (a rough estimate)
  ☐ 0 – 2 blocks ☐ 2 – 4 blocks ☐ 4 – 7 blocks ☐ 7 – 10 blocks ☐ 10 blocks and more

- How often do you visit the park in a **month (**or how many times have you visited Penn Park in the past month)? If this is your first time visiting the park, please circle "once a month."
  ☐ 1-5 times ☐ 6-10 times ☐ 11-15 times ☐ 16-20 times ☐ greater than 20 times (almost every day)

- How do you generally use the park? (check all boxes that are applicable)
  ☐ Commute: school-related ☐ Commute: occupation-related ☐ Eating
  ☐ Relaxation ☐ Studying, reading, writing ☐ To be in a "natural" setting
  ☐ Recreation (running, biking, walking, dancing, listening to music, etc)
  ☐ Other, please note ___________________

- Which time period during the day do you generally visit the park? (check all boxes that are applicable). If this is your first time visiting the park, please indicate the time period you are filling out this survey.
  ☐ 6 am – 8 am ☐ 8 am – 10 am ☐ 10 am – 12 pm ☐ 12 pm – 2 pm
  ☐ 2 pm – 4 pm ☐ 4 pm – 6 pm ☐ 6 pm – 8 pm ☐ 8 pm – 12 am

- How long do you usually stay in the park?
  ☐ 0 – 2 min (s) ☐ 2 – 5 mins ☐ 5 – 10 mins ☐ 10 – 30 mins
  ☐ 30 mins – 1 hour ☐ 1 – 2 hours ☐ 2 hours and more

The following questions are about the acoustic environment on site:

1. Please report **three** types of sound you have noticed at this spot in the park (such as bird song, speech, footsteps, grass mowing, street traffic, wind blowing, water flowing, aircraft noise) and circle a number in the following scale which best describes each sound you have identified:

Three Types of Sound	Most unpleasant	Unpleasant	Neither unpleasant nor pleasant	Pleasant	Most pleasant
①	1	2	3	4	5
②	1	2	3	4	5
③	1	2	3	4	5

2. Do you notice a dominant sound in surroundings? If so, please report the your **subjectively dominant sound** in Penn Park (note: please choose **the most significant sound** from your answers to the first question); If not, please answer "**No**"

3. Please rate the following three indicators on site using the following scale from 1 to 10, where 1 is the lowest mark (☹) and 10 (😆) is the highest mark:
   (a) Overall *Landscape* Quality (can be rated by how acceptable and enjoyable the landscape is)
   (b) Overall *Soundscape* Quality (can be rated based on the features of sounds, your feelings about perceived sounds and how acceptable and enjoyable the sounds are)
   (c) Overall Impression (can be rated based on your answers to **Overall *Landscape* Quality**, **Overall *Soundscape* Quality,** and any other factors that you consider important)

Types of Indicator	Low	☹			Middle	😑				High	😆
(a)	1	2	3	4	5	6	7	8	9	10	
(b)	1	2	3	4	5	6	7	8	9	10	
(c)	1	2	3	4	5	6	7	8	9	10	

4. Please evaluate the **(b) Overall *Soundscape* Quality** of surroundings using the following matrix. **Circle** the number that applies:

	Very	Fairly	Little	Neutral	Little	Fairly	Very	
Pleasant	3	2	1	0	-1	-2	-3	**Unpleasant**
Quiet	3	2	1	0	-1	-2	-3	**Noisy**
Smooth	3	2	1	0	-1	-2	-3	**Rough**
Varied	3	2	1	0	-1	-2	-3	**Simple**
Calming	3	2	1	0	-1	-2	-3	**Agitating**
Directional	3	2	1	0	-1	-2	-3	**Everywhere**
Natural	3	2	1	0	-1	-2	-3	**Artificial**
Steady	3	2	1	0	-1	-2	-3	**Unsteady**

The following questions are open-ended questions and optional:

1. How likely do you think you will pay more attention to the sounds in Penn Park in the future because of this questionnaire? Please answer this question using the following scale. Circle a number on the scale, where **-4** represents the least likely and **4** represents the most likely:

-4	-3	-2	-1	0	1	2	3	4
Least Likely		Not Likely		Not Sure		Highly Likely		Most Likely

2. What types of sound in Penn Park do you think should be increased or added to the park design?

3. What types of sound in Penn Park do you think should be decreased or mitigated in the park design?

4. Please provide any suggestions for park-designers to ameliorate the soundscape in urban parks. If you have no suggestions, please leave blank here.

Thank you so much for sharing your precious time and thoughts!
A pair of earplugs are provided here as a reward for your participation