# Soundscape of Urban Open Spaces in Hong Kong

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Abstract of the thesis entitled

**Soundscape of Urban Open Spaces in Hong Kong**

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This study aims to investigate the soundscape of urban open spaces in Hong Kong. Open space in densely populated cities has been considered as an important asset for urban inhabitants in that they afford opportunities for leisure, recreation and an active involvement with nature. For quite a long time, visual aesthetic was the dominant consideration in open space design and other senses were given less concern. Continuous stream of attention-demanding sounds from the noisy environment may bombard these open spaces, rendering them no longer able to satisfy the eye alone. Sound and consequently the acoustic environment are receiving increasing attention.

This study used noise mapping technique supplemented by GIS spatial analysis tools to delineate quiet open spaces with traffic noise exposure less than 60 dB (A) $L_{10,\ 1h}$ and conducted field observations to determine their usages. The identified quiet open spaces are either concentrated in hilly and remote areas with low accessibility, or sporadically scattered among tall buildings. Some large urban parks and small sitting-out areas are even located in the center of the city. Larger open spaces serve group visits, such as hiking and sightseeing, while smaller ones are easily accessible to local residents for social and recreational purposes.

The acoustic environment in urban open spaces varies with space and time. To characterize the acoustic quality of soundscapes in the quiet open spaces, sound walk and field recording were undertaken place in 25 selected study sites. Despite the dominance of traffic noise, soundscapes in the urban open spaces are also shaped by natural sounds. Sounds from birds and water are common and prevalent particularly in gardens and playgrounds.

Soundscape approach is a human-centered point of view. How the visitors perceive and evaluate sounds and the acoustic quality has great implication for soundscape design. On-site interview of 1,610 visitors unravels human preference of individual sounds and evaluation of the acoustic quality. Sounds from bird, wind and water are most preferred, while mechanical sounds and road traffic noise are least favored. Human voice is rated in between. Brown's soundscape evaluation framework was substantiated by data collected in this study highlighting the importance of context and presence of wanted and unwanted sounds on subjective evaluation of the acoustic quality. Ordinal Logistic Regression models were developed with significant independent variables, including social-demographic factors, acoustic parameters, visiting habits and presence of wanted and unwanted sounds.

Research findings have great implications for soundscape design of open spaces in compact cities. A properly designed open space offers a comfortable setting for relief, retreat and rejuvenation from the urban life. Endeavors to improve the acoustic quality in the urban open spaces will make cities more livable and sustainable.

# 論文摘要

本論文是針對香港公共開敞空間聲景的研究。公共開敞空間被視爲擁擠都市環境中的寶貴資源，它可以給市民提供休閒、娛樂、親近自然的機會。在過往的研究中，公共開敞空間的規劃和設計多注重視覺的美感，人的其他感官體驗往往被忽略了。由於越來越多的噪音侵入，僅僅靠視覺美感已經不足以滿足要求了。聲音以及聲音環境的質素也開始得到社會的廣泛關注。

是次研究在噪音地圖和地理資訊系統的結合下，描繪出交通噪音低於 60 dB (A) $L_{10,\ 1h}$ 的區域，並且通過實地考察瞭解它們的使用情況。研究結果顯示，受交通噪音影響小的地區有些位於山地和偏遠地區，有些零星地散落在高樓大廈之間的空閒區域，甚至有些就坐落在都市的中心區域。這兩種類型的安靜空間具有不同的社會功能。面積較大的開敞空間供遊人集體活動，遠足或者欣賞景色，而面積較小的則方便當地居民進行休閒和社交活動。

都市開敞空間的聲音環境隨著時間和地點不斷變化。本研究選取了 25 個都市開敞空間，並在此進行了聲學調查和錄音。研究發現，都市交通噪音雖然是主要聲音，但是自然聲音的存在也影響著開敞空間的聲景。鳥聲和水聲是最常聽到的自然聲音，尤其在花園和遊樂場更加顯著。

聲景研究的方法是一個以人爲中心的理念。訪客對聲音以及聲音環境的接受和感知，對於開敞空間的設計有直接的影響。是次研究亦以問卷形式對訪客進行了訪問，揭示他們對城市開敞空間出現的聲音的喜好以及對聲音環境質素的評價。共有一千六百一十個訪客參與了訪問，鳥的聲音，風聲和水聲最受訪客歡迎，機械和交通噪音最不受歡迎。在是次研究所採集數據的基礎上，Brown 教授提出的對聲音環境質素評價的框架得到證明。他的框架強調了情境的重要性，並且提出是否存在訪客喜歡的聲音源決定了聲音環境的質素。此外是次研究還利用有序邏輯回歸模型預測訪客對聲音環境質素的評價，輸入的預測變數

包含社會-人口統計學參數，聲學參數，訪客的參觀習慣以及是否出現訪客喜歡的聲音源等。通過建立的模型分析各個參數對聲音環境質素評價高低的影響。

是次研究的結果爲聲景設計提供了有用的資訊和指導建議。一個設計合理的城市開敞空間可以爲訪客提供良好的休閒、放鬆，遠離城市緊張生活的場所。致力於改善聲音環境質素的實踐，將會推動城市的可持續發展。

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*Sound and space are inextricably connected, interlocked in a dynamic through which each performs the other ...*

------ *Background Noise: Perspectives on Sound Art*, Brandon LeBelle, 2006: 123

# Chapter 1 Introduction

Chapter one provides the background of this study. It begins with an explanation of the research background, followed by an introduction of study objectives and significance, and concludes with an overview of the whole thesis. As an introductory chapter, it attempts to form a conceptual basis for this research as well as to provide a framework for the readers.

## 1.1 Research Background

### 1.1.1 Noise pollution

Environmental noise has gained notoriety for its negative effects on the quality of life, well-being as well as on human health (Berglund *et al.*, 1995). Environmental noise bothers, disturbs or annoys us when we communicate, rest, sleep, read, work or study. It also creates some psychological and physiological health effects. An experiment conducted among international experts in the field of acoustics and noise effects revealed that noise annoyance was the major effect of noise (Guski *et al.*, 1999).

Recognizing the adverse effects of noise, the study of urban acoustic environment has taken a turn in the last decade, shifting its focus gradually from the negative aspects of sound, particularly those from transportation (Lebiedowska, 2005a; Phan *et al.*, 2010), and methods to determine noise exposure level of the urban population (Brown, 1994; Roberts *et al.*, 2003; Coensel *et al.*, 2005) to an appraisal of the total acoustic environment and the positive effects of sound.

There is no dispute that road traffic noise causes annoyance but some studies have challenged the direct relationship between annoyance and noise level (Roberts *et al.*, 2003). Indeed, human perception is determined by multi-sensorial experience. Sound cannot be apprehended in isolation but rather within a global context. A study carried out by Domingo and Isabel (2007) found three relevant dimensions explaining 66% of the total variance of urban acoustic quality: emotional evaluation and strength, activity and clarity (Domingo and Isabel, 2007).

In this sense, physical characteristics of sound in a certain environment may not play an overwhelming role in determining the perception of the total acoustic environment. A young boy who is in favor of rock concerts will probably not feel annoyed when exposed to loud music, while some others may find rock music extremely awful. Therefore personal, emotional, situational and environmental factors, to name a few, also play an important role. These contextual factors together with the acoustical characteristics of sound are all referred to as the soundscape.

### 1.1.2 Soundscape

Sound contributes to an important component of the urban experience. The urban acoustical environment is made up of desirable and undesirable sounds, emanating from various sources, occurring at different times and bestowing special meanings to city dwellers. The murmuring of private conservation, chanting of shop keepers, thundering of passing vehicles and rustling of tree leaves can altogether impart an auditory identity to a city. The sounds in the city, be them human, mechanical or natural, are integral parts of the sonic environment (Raimbault and Dubois, 2005) and are resources that can be used, managed to our benefit (Gunnarsson and Öhrström, 2005) or misused to impair our quality of life (Klæboe, 2007b).

The concept of soundscape was first developed based on an emerging body of knowledge known as "acoustic ecology" (Truax, 1999), which is nurtured by the realization that sound has special meaning in every place and propelled by active discussions in the landscape and acoustics literature (Kihlman and Kropp, 2001b; Kang, 2005) and workshops (e.g. WFAE, Inter-Noise). Soundscape studies are rooted in the belief that landscapes are experienced by humans using all senses.

Early soundscape research focused largely on the aesthetic and geographical dimensions. The former, exemplified by the works of Schafer (Schafer, 1977a) and Hedfors and Berg (2003), highlighted sonic impressions and expressions, whereas the latter focused on spatial differentiation of soundscapes over space (Schafer, 1977b; Porteous and Mastin, 1985). A number of recent works have also probed into the soundscapes of rural areas (Schafer, 1977b), urban neighborhoods (Porteous and Mastin, 1985), urban acoustic refuge (Öhrström *et al.*, 2006b), specific land uses (Finegold and Hiramatsu, 2003), and urban public spaces and parks (Wong *et al.*, 2004; Yang and Kang, 2005a; Nilsson and Berglund, 2006; Payne, 2008). Some other studies indicated that human reactions to environmental noise can be mediated by the neighborhood soundscape, underlining the importance of soundscape studies (Job and Hatifield, 2001; Klæboe, 2007b). The attention given to urban soundscapes is driven by our quest for urban environmental quality and sustainability (Raimbault and Dubois, 2005).

The increasing concern for urban sustainability has prompted many to examine the multi-faceted urban acoustical environment (Yu and Kang, 2005a; Roy and Snader, 2008), highlighting both the positive and negative effects of urban sounds and opening opportunities for the planning and environmental professions to create an ideal acoustic environment (Brown and Muhar, 2004; Guastavino, 2006). Sometimes, it is not desirable to simply create a quiet environment, because some urban areas demand a matching sound, like the sound of bird in a park or the hum of a market place.

In the recent soundscape literature, the quality of soundscape has been highlighted (Brown, 2007a). Issues such as what attributes constitute a "good soundscape" (Brown, 2007b), and how to formulate measures to enhance and protect them, have been unraveled. Besides that, the benefits of having a "good soundscape" for urban inhabitants who are regularly exposed to excessive noise have been emphasized by many researches (Schulte-Fortkamp, 2002; Öhrström *et al.*, 2006b).

### 1.1.3 Open spaces in Hong Kong

Public open spaces within the crowded urban areas have been considered an important asset, because they fulfill many leisure, recreation and social needs of the urban residents (Loukaitou-Sideris, 1995). Many people value the environmental settings, amenities and convenient facilities provided within the open spaces. It is deemed that open spaces have the potential to enhance the positive qualities of urban life: they offer visual and psychological relief in the stressful surroundings of high-paced urban areas and contribute to the quality of life of urban residents and to the overall sense of well-being (Burgess *et al.*, 1988).

The emphasis of urban design for open space is on aesthetics rather than acoustics. Acoustic quality had not been given much consideration until recent years. Indeed, urban open space is one particular environmental soundscape because of its unique features of acoustic environment. Open space introduces nature into our urbanized concrete environment. Large shade trees provide greenery with appeal for bird songs and function as barriers from heavy traffic noises with a reduction of noise exposure level (Wong *et al.*, 2004). The interaction between traffic noise and natural sounds, which for example come from wind and water flow, creates a unique soundscape in the open spaces of Hong Kong.

Soundscapes in the open spaces also vary with space and time. A comprehensive understanding of the variation of soundscapes in different places and how they are perceived and used by local visitors is crucial for soundscape design and urban planning. An appropriately designed soundscape will be beneficial for creating a more livable and enjoyable urban environment.

Confined by the limited amount of developable land available to cope up with the increasing needs of population, open spaces in Hong Kong are located next to main road or surrounded by tall building blocks. In either case, road traffic noise is the main source of annoyance. In spite of the negative aspect of local acoustic environment, Hong Kong, being located in the subtropical region, has diverse landscape features and rich biodiversity. The diversified environment has bestowed on Hong Kong a great variety of soundscapes that are suitable for the investigation of human perception of the sonic environment. Moreover, open space is very popular among urban dwellers in this compact city, which assures a high response in conducting questionnaire surveys with visitors.

## 1.2 Research Objectives

This research aims to investigate the soundscape of urban open spaces in Hong Kong. The specific objectives are:

a. To delineate quiet urban open spaces in Hong Kong and determine their usage;
b. To characterize the acoustic quality of soundscapes in the quiet urban open spaces;
c. To elucidate visitors' perception of and preference for sounds, as well as their evaluations of acoustic quality.

Hong Kong is one of the densest cities in the world with lots of concrete jungles and a busy living style. Hong Kong has an overall population density of 6,160 persons / $km^2$ and the highest density of 116,000 persons / $km^2$ in Mongkok (Gilchriest, 1994). Owing to rapid population growth and limited land resources, dispersed development is unsustainable in Hong Kong, which results in a high-rise and high-density urban form.

Under such a compact urban form, the traffic network is dense. Traffic noise dominates the acoustic experience and sets the background of the sonic environment. In spite of various actions and measures taken by the Government to reduce noise level over the past two to three decades, about 1.1 million people in Hong Kong accounting for 17.4% of the urban population are still being exposed daily at home to high levels of road traffic noise exceeding 70 dB (A) $L_{10,1h}$ (Environmental Protection Department, 2006). The excessive road traffic noise severely deteriorates the quality of life. In this sense, there is probably no other cities in the world that are more in need of a pleasant acoustic environment.

Within Hong Kong's urban boundary, the majority of open space visitors are apparently not bothered by the high noise levels, although the urban open spaces are not free from the assault of noise and air pollution (Lam *et al.*, 2005b). Comprehensive explanation of this paradox is still limited. There is an urgent need to better understand about how people react to various sounds in urban open spaces and how these soundscapes can be preserved and enhanced. This study is deemed critical for the practical acoustic assessment in Asian countries. Findings will enrich the international discussion on soundscape.

## 1.3 Research Significance

Unlike previous studies that focused on soundscapes of urban neighborhoods (Klæboe, 2007a), urban acoustic refuge (Öhrström *et al.*, 2006b), specific land uses (Finegold and Hiramatsu, 2003), urban public spaces and parks (Foth & Van Dyke, 1999; Wong *et al.*, 2004; Yang and Kang, 2005a; Nilsson and Berglund, 2006), this study attempts to characterize soundscapes of different types of urban open spaces and to understand how humans perceive and evaluate the soundscape qualities in these areas.

Urban form and land use planning are significant determinants of soundscape, because they define the location of people and sound sources, the spatial arrangement of open spaces, the traffic patterns and the geometrical void in which sound propagates, diffuses and reverberates. Propelled by continuous growth in economy, population and transport demand over the years, urban fabric and building morphologies have shifted gradually from low to high and from public to private. With the exception of low-rise houses on the fringe, the urban areas are rather high-rise and compact.

Increasing evidence has shown that open public space provides restorative experiences that directly and positively affect people's psychological well-being and health. Living in cramped, small apartments in Hong Kong, local population spends a considerable amount of time outside their residences. Public open spaces play an important role in enhancing urban livability. An understanding of the soundscape in open spaces is as important as ascertaining the noise exposure within the residences.

For quite a long time, the work of environmental authorities has been primarily preoccupied with minimizing exposure to unwanted sounds at the façade of the residential buildings, rather than creating a pleasant acoustic environment for the inhabitants. Especially in the open spaces between buildings and streets, the emphasis of urban design is "landscaping" rather than "soundscaping". This study is expected to contribute to the emerging international research on understanding urban soundscapes and more specifically of the open spaces. As a systematic study of soundscapes in a high-rise city, the findings will contribute to a growing soundscape knowledge base and have implications for the planning and management of acoustic environments to enhance urban livability.

### 1.4 Conceptual Framework

As Truax (1984) defined Soundscape of a place is simply "its acoustic environment with emphasis on the way it is perceived and understood by the individual or by a society". A triangular relationship exists between sound, individual and the environment, with sound being a mediator between individual listener and the environment. The mediating function flow of sound is presented below in Figure 1.1. As the central focus of the anthropocentric term of soundscape, individual listener is the receptor of a soundscape, whose preference and perception largely depends on the holistic environment, personal experience and expectation. In this research, soundscape approach is fully developed by combining these three elements and further displaying their relationship in a three-dimensional framework.

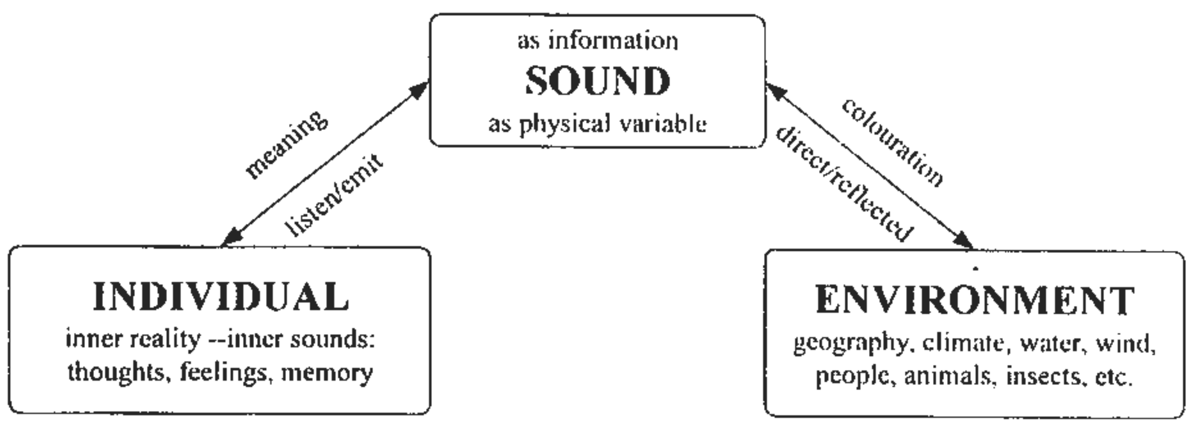



Figure 1.1The mediating relationship of listener to environment through sound (Wrightson, 2000: 12)

This model is adapted from Truax's theory of acoustic communication. In this theory, the mediating function of sound between listener and environment can proceed in both directions. Therefore acoustic communication is modifiable by both the physical environment and listener's perceptual habits. This is quite different from energy or signal based models, in which the notion of context is frequently ignored. In this acoustic communication model, context plays a central role in determining the sonic information (Truax, 1993).

In the assessment of acoustic quality, "quietness" is useful and descriptive. However, it is not so applicable for assessing the holistic acoustic quality. It is obvious that "quiet" is not always the acoustic character that people want in outdoor areas. "High acoustic quality" would be more appropriate to describe a desirable acoustic environment from the human perspective. Brown (2006b) indicated that human preference depends on context and the presence of wanted and unwanted sounds. The criterion should be based on whether sounds that are preferred or wanted in that particular context are heard and whether wanted sounds significantly mask the unwanted ones. He further exemplified his framework by using a two by two dimensional matrix as shown in Figure 1.2.

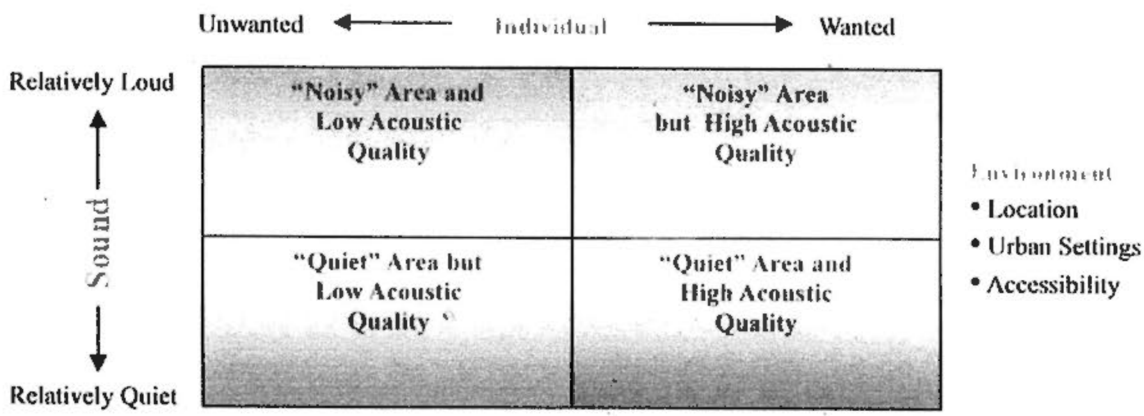



Figure 1.2 Matrix for acoustic quality assessment (Brown, 2006b)

This study employs Brown's framework to evaluate the acoustic quality of selected open spaces in Hong Kong using field measurement results and on-site interview data. The results can be used to test the applicability of such framework in the context of Hong Kong and provide practical evidence.

## 1.5 Overview of the Thesis

This thesis is organized into four sections, which include: 1) the research background and methodological design, 2) characterization of soundscapes in urban open spaces in Hong Kong, 3) examination of the relationship between related factors and evaluation of acoustic quality, and 4) investigation of ways to assess acoustic quality through examining selected samples.

Chapter One provides a snapshot of the whole thesis and explains the rationale and significance of studying soundscape in urban open spaces in Hong Kong. This chapter invites the readers inside and prepares a conceptual basis for embarking into the core of the thesis.

Chapter Two reviews extensively the current literature on topics pertinent to this research. It covers the concept of soundscape and its development from the original concept proposed by R. Murray Schafer to the acoustic communication model and evaluation matrix introduced by Barry Truax and Lex Brown respectively.

Chapter Three introduces systematically the methodological construct of this study and explains its development. It also gives details on the techniques used. The influence of road traffic noise was determined in terms of physical contributions by noise mapping techniques. The sound recordings were made by audio recorders and subjective effects were judged by on-site interviews.

Chapter Four presents how the Geographic Information System (GIS) and spatial analysis techniques were integrated in the process of selection and delineation of soundscapes in open spaces in Hong Kong. It is based on noise mapping results that are designated for calculating sound exposure level coming from road traffic. Findings were displayed in a GIS-based interface.

Chapter Five presents and explains the acoustic characteristics of soundscapes in different types of urban open spaces in Hong Kong. Sound walk and field recordings were performed at different study sites at different times in order to analyze the variation of soundscapes, in terms of sound sources, sound intensity and spatial distribution of sound exposure level.

Chapter Six discusses findings from on-site interviews. It unravels human perception of individual sound sources and subjective evaluation of the acoustic quality. Socio-demographic factors were studied in terms of their influences on subjective evaluation of sound source and acoustic quality. Brown's framework for soundscape evaluation was validated based on the data obtained from the case study in Hong Kong. Ordinal Logistic Regression models were further established for soundscape evaluation of different types of urban open spaces.

Chapter Seven concludes the whole thesis by summarizing the major findings of the study and evaluates the contribution of this study to the theory of high acoustic quality evaluation. Limitations of this study and issues for future research were presented. As an auditory refuge to urban noise, open spaces provide an ideal place with good acoustic environment for urban dwellers. This chapter presents some recommendations from the perspectives of visitors to enhance the acoustic quality in urban open spaces.

## 1.6 Summary

As the introduction of the whole thesis, this chapter provides the background of soundscape study and the significance for study of urban open spaces in Hong Kong. The research objectives and significance of this study have been outlined. Elaboration of the conceptual framework and the structure of the thesis form the basis for the whole research.

*Only a total appreciation of the acoustic environment can give us the resources for improving the orchestration of the world soundscape....*

------ *The Tuning of the World,*
Schafer R.M., 1977: 4

# Chapter 2 Literature Review

This chapter provides a critical review of literature relevant to soundscape studies. Section 2.1 describes the soundscape concept, while Section 2.2 focuses on the usage, management and acoustic design of open spaces. This review helps inform the methodology developed in Chapter Three.

## 2.1 Characterizing Soundscape

Soundscape is similar to the concept of landscape in the sense that both have a human-centered point of view and combine the physical characteristics with mental perception in a particular context. Soundscape approach is not the same as previous methods in dealing with sound. Soundscape approach devoted to the acoustic environment entirely rather than just objectified sounds through qualitative measurement.

Understanding the concepts and theories are of great importance to fully grasp the core concept of soundscape. Before interpreting the associated literature and results of this study, it is necessary to clarify the basic terminology and concept used in soundscape study.

### 2.1.1 Concept of soundscape

The concept of soundscape is not new: Grano first differentiated between sound and noise in 1929 (Turner *et al.*, 2003). The principle then laid comparatively dormant until 1969, when Southworth (1969) tried to establish how participants perceived the sounds of Boston and how this affected the way they saw the city. During the development of soundscape study, some prefer to seek a strict definition whereas others like to use a fuzzy one which is to be further evolved by future work. Schafer and Truax, as part of the World Soundscape Project, attempted to formalize the concept of soundscape. Schafer (1977a) defined "soundscape" as the totality of sounds. Central to the definition of soundscape is the emphasis on the way how the acoustic environment is perceived and understood by individuals or a society (Schafer, 1977a; Truax, 1999; Raimbault and Dubois, 2005; Yang and Kang, 2005b), which thus depends on the relationship between the individual and any such environment (Schafer, 1977a; Truax, 1999).

Soundscape can be described as a triangular relationship constituted and maintained by three components, namely the listener, environment, and mediating sounds (Truax, 1984). Soundscape exists in a physical environment with certain visual and acoustic properties. Sounds within it exhibit certain acoustical characteristics, in terms of sound sources, sound levels, spectrum and temporal pattern. People interact with a particular environment through the sounds within this context. Therefore, to analyze an acoustic environment, the three core components are required to study in integrity.

### 2.1.2 Terminology

A review of literature shows that different terms have been used to describe the entity under study in the soundscape field, including the acoustic environment (Truax, 1984; Porteous and Mastin, 1985), the sonic environment (Schafer, 1977a; Porteous and Mastin, 1985; Truax, 1999), the sound environment (Kihlman and Kropp, 2001a; Finegold and Hiramatsu, 2003; Dubois *et al.*, 2006; Zhang and Kang, 2007), the environment of sound (Truax, 1999), sound variation (Kihlman and Kropp, 2001a; Raimbault and Dubois, 2005), auditory environment (Turner *et al.*, 2003), auditory scenery (Ge and Hokao, 2003), aural space (Schulte-Fortkamp and Lercher, 2003), the natural acoustic environment and environment sounds (Downing and Hobbs, 2005), sound ambient environments (Raimbault and Dubois, 2005), ambient conditions (Raimbault and Dubois, 2005), city soundscape (Lebiedowska, 2005b), the total ambient acoustic environment (Downing and Hobbs, 2005), the total soundscape (Downing and Hobbs, 2005) and the acoustic soundscape (Kihlman and Kropp, 2001a). Their definitions are summarized below in Table 2.1.

Table 2.1 Interpretation for "Soundscape" and "Soundscape Study"

| **Definition** | **Term** |
|---|---|
| "The sonic environment. Technically, any portion of the sonic environment regarded as a field for study." *(Schafer, 1977a)* | Sonic environment |
| "An environment of sound (or sonic environment) with emphasis on the way it is perceived and understood by the individual, or by a society." *(Truax, 1999)* | Environment of sound Sonic environment |
| "Soundscape is defined as the overall sonic environment of an area, from a room to a region." *(Porteous and Mastin, 1985)* | Sonic environment |
| "The soundscape of a place is simply its sonic, or acoustic, environment, with the receiver, or listener, at the centre of the sonic landscape." *(Porteous and Mastin, 1985)* | Acoustic environment (sonic environment) |
| "The term "soundscape" refers to how the individual and society as a whole understand the acoustic environment through listening." *(Truax, 1984)* | Acoustic environment |
| "The term soundscape refers to the total ambient acoustic environment within an area." *(Downing and Hobbs, 2005)* | Ambient acoustic environment |
| "The term "soundscape" can be defined as the auditory environment within which a listener is immersed." *(Turner et al, 2003)* | Auditory environment |
| "Soundscape refers to the auditory scenery, the scenery that can be grasped by ears." (Ge and Hokao, 2003) | Auditory scenery |
| "Soundscape is understood as a socio-cultural event in view of people living in a society in a particular era form relations with their environment through sounds." *(Finegold and Hiramatsu, 2003)* | Sound environment |
| "Soundscape is about relationships between the ear, human beings, sound environments, and society." *(Zhang and Kang, 2007)* | Sound environment |
| The word "soundscape" denotes "an auditory equivalent to (visual) landscape, defined as an environment created by sound." *(Dubois et al., 2006)* | Sound environment |
| "A set of perceived soundscapes delimited geographically and in time, constitutes a sound environment." *(Kihlman and Kropp, 2001a)* | Sound environment |
| The concept explicitly refers to "sound variations experienced in space and time, grounded in the topography of the built-up area and different sounding sources". *(Raimbault and Dubois, 2005)* | Sound variation |
| Define "soundscape as the sound variations in space and time caused by the topography of the built-up city and its different sound sources." *(Kihlman and Kropp, 2001a)* | Sound variation |
| A soundscape is "a sound or combination of sounds that forms or arises from an immersive environment." *(Wikepedia)* | Sounds combination |
| Soundscape means "all of the waveforms faithfully transmitted to our audio cortex by the ear and its mechanisms." *(Pauline, 2005)* | Waveform transmission |

Among these definitions and terms, Brown (2009) suggested an adequate and appropriate term for the entity on which soundscape studies focus, that is "acoustic environment" or less preferable "sonic environment" of any place (Brown, 2009).

### 2.1.3 Attributes of soundscape

Soundscape analysis starts from the discovery of significant features of a soundscape, especially sounds that are important either because of their individuality, their numerousness or their domination. Ultimately some generic classification systems will be devised to categorize the main themes of a soundscape by distinguishing between what are called keynote sounds, signals and sound marks.

#### 2.1.3.1 Keynote sounds

Keynote is originally used to identify the key of a musical composition. In soundscape studies, keynote sounds are those "heard by a particular society continuously or frequently enough to form a background against which other sounds are perceived" (Truax, 1999). In a landscape, factors like geography and climate, as well as water, wind, forests, plains, birds, insects and animals, produce keynote sounds. One characteristic of keynote sounds is that they are not carefully listened to, but are nonetheless recognizable. They are the sounds that one habitually but unconsciously hear (Schafer, 1977a).

#### 2.1.3.2 Sound signals

Sound signal is also named foreground sound. When specific sounds within an environment clearly stand out against the background and are clearly distinguishable from the ambient noise, these sounds are called sound signals (Truax, 1984). The relationship between sound signal and keynote context is much the same as it between figure and background in visual perception. Sound signals can reveal lots of information of the overall acoustic environment. To be interpreted, they are transformed into codes, which allow understanding even of complex messages.

#### 2.1.3.3 Sound marks

One of the key features of soundscape is sound marks, which are parallel to landmarks. Sound marks have qualities that make it unique, possess symbolic power, and catch affectionate attention. They are particularly recognized by a community and its visitors. Sound marks bring uniqueness to a community's acoustic life, and as such, they ought to be preserved.

Among the three, sound signals are the most striking components of the acoustic community. Such sounds are unique and of historical importance; their special status allows them to be regarded as community sound marks. Because of the strong associations attached to sound marks that developed over many years, these sounds are worthy of preservation, like any historical artifact. Sometimes sound marks are also keynote sounds and the subject of background listening, but their special ability to become associated with long-term memories means that they create an extremely important continuity with the past (Truax, 1984).

### 2.1.4 Approaches to Soundscape Study

Soundscape study requires interdisciplinary knowledge from subjects of acoustics, engineering, architecture, environment, psychology, sociology, geography and some other related fields. Consequently research topics are also diversified, including noise control, transportation planning, sound quality evaluation, environmental assessment, urban design and management, etc.

Numerous authors have drawn the analogy of soundscape as the auditory equivalent to landscape (Ge and Hokao, 2003; Raimbault and Dubois, 2005; Dubois *et al.*, 2006). Soundscape can be, as can the landscape, both a physical phenomenon and a perceptual construct (Appleton, 1996; Benson and Roe, 2000).

#### 2.1.4.1 Physical phenomenon

Sound is the transmission of energy in the form of vibrations. Physical parameters are used to describe the acoustic environment and the sound variation with space and time.

- Basic properties of sound

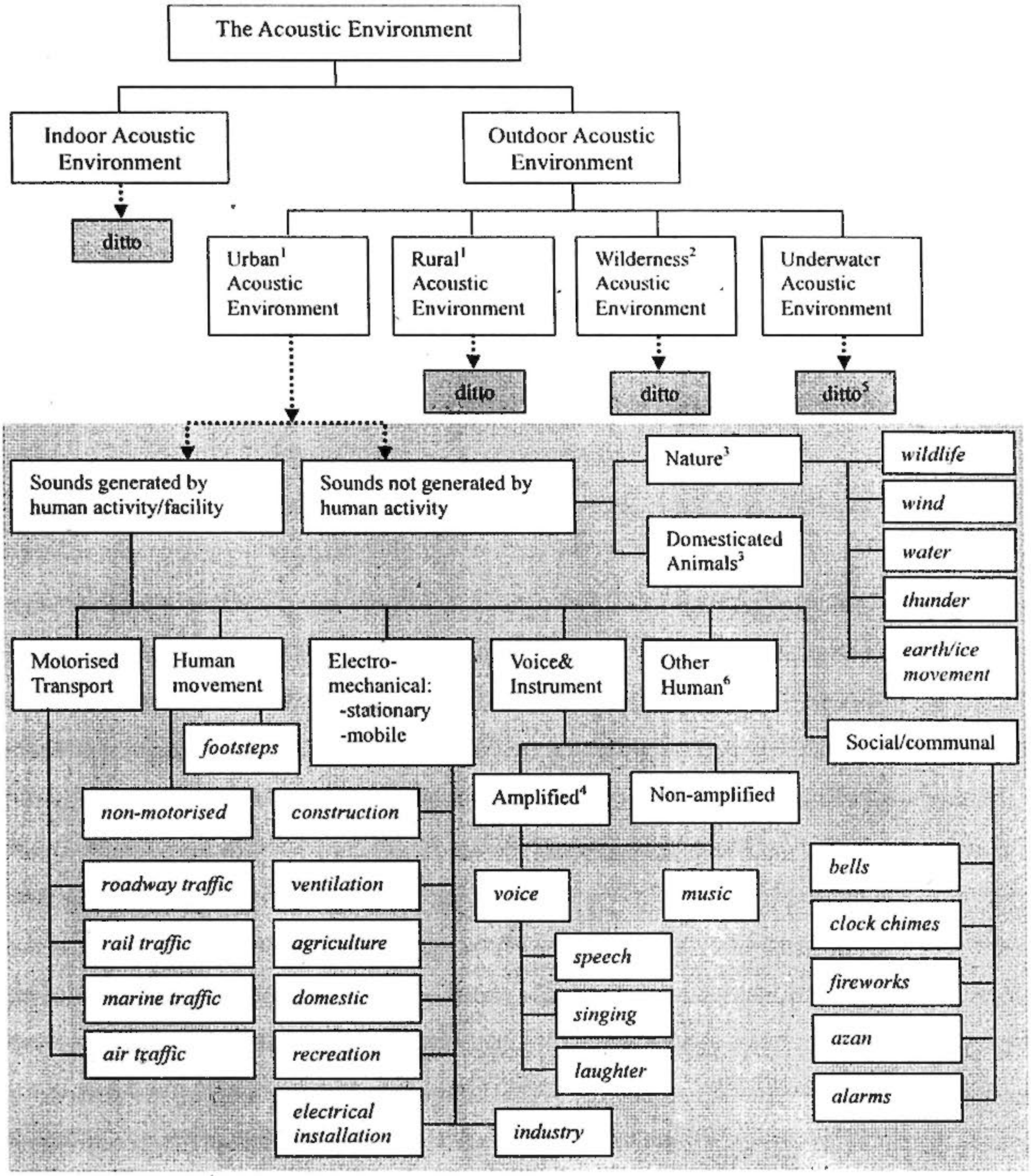
The overall sound level is certainly an important factor for an acoustic environment.

In the past few decades, sound exposure level expressed in terms of the equivalent continuous sound level, $L_{eq}$, has been intensively studied and commonly used. Besides sound level, frequency is another determinant of sound property. Most sounds contain multiple frequencies. A sound can be measured in a series of frequency intervals called frequency bands. Octave and fractional octave bands are often used. A plotted relationship between frequency and sound level is called a sound spectrum (Kang, 2007). Physical indicators provide a good representation of the physical characteristics of an acoustic environment in a particular context and can be easily measured with classical sound level meters.

- Identification of sound sources

People may not always describe the acoustic environment in terms of sound intensity and spectrum. Sound source that composes and produces different sound events is sometimes applied as an indicator that specifies a sonic environment. Sound source identification has been carried out in specific domains of acoustics. The project of Objective Representation of Urban Soundscape carried out by Defréville and Philippe demonstrated the limitation of the energetic indicator and further pointed out that the major influence on inhabitant's feelings was the nature of sound sources (Defréville *et al.*, 2006). Identification and description of sound sources are helpful for interpretation of the perceived soundscapes. Figure 2.1 is a suggested taxonomy of the acoustic environment and sound sources (Brown, 2009).

Sound source, as an important component of a soundscape, is closely related with acoustic quality. Brown (2009) further highlighted the concept of information content within a sound and its relationship with subjective evaluation of acoustic quality. To be specific, the congruence of the sound heard in a particular context, especially the suitability of sound in a particular context, to some extent, determines the acoustic quality (Brown, 2007b).




Footnotes:

[1] The urban/rural distinction will not always be readily defined, but remains useful.

[2] The wilderness category includes national parks, undeveloped natural and coastal zones, large recreation areas etc, and the wilderness/rural divide will not always clear cut.

[3] While "nature" and "domesticated animals" sources are shown as being "not generated by human activity" there are many exceptions—for example the sounds of running water in constructed water features or the sounds of wind on buildings. Domesticated animal sounds will generally be from animals associated with a human activity/facility.

[4] Recording, replay, and amplification may occur for any sounds – as for example in installations playing nature/wildlife sounds.

[5] Because of the different acoustic impedances in air and water, many of the terrestrial sound sources within the shaded area would not be observed under water.

[6] Coughing, for example.

Figure 2.1 A suggested taxonomy of the acoustic environment (Brown 2009)

- Noise control and soundscape

In early studies, noise control dominated the mainstream dealing with sounds. Soundscape approach is fundamentally distinct from conventional noise control methods. Firstly, soundscape approach requires discrimination between different sound sources which are wanted or unwanted in particular contexts; while noise control methods stresses integration of sound energy measurement (Brown, 2007b; Brown, 2007b). Secondly, soundscape approach addresses sounds of preference instead of sounds of discomfort as noise control always does. Soundscape studies primarily examine the acoustic environment where the sounds present produce outcomes that enhance, enable or facilitate human enjoyment, well-being and their special activities (Brown, 2009). Thirdly, soundscape introduces the concept of masking by using wanted sounds to mask those unwanted; but in the field of noise control, to the focus is on reducing the levels of unwanted sounds. Finally, soundscape takes sound as a resource other than a waste as noise control does (Brown, 2006b). To summarize, environmental noise studies only examine one part of the acoustic environment, where the sounds present produce outcomes that have adverse impacts on people; but soundscape takes the acoustic environment as a whole, concerning both the positive and negative perceptions of users regarding various sound sources and contexts.

However, noise control management and soundscape approach have something similar in dealing with sounds, especially in examining the effects of noise in outdoor environments. Researchers in environmental noise management are beginning to investigate the potential role of soundscape approach in the field of environmental noise. In the long run, soundscape will be accepted amongst the mainstream noise activities as a supplement but not a contradiction (Brown, 2007b), since acoustic environment is not just a problem of mitigation, abatement and control. The soundscape concept has the potential to positively use the expertise through the way of soundscape design.

- Acoustic effect

The acoustic effect is another perspective in characterizing the physical soundscape, which attracts significant concern of the public. The issue of noise assessment and control was dealt with more extensively following a meeting of the members of the Expert Task Force of the World Health Organization in London in 1999. In the meeting, the experts enhanced the "*Guidelines for Community Noise*" by giving the guidelines a global coverage and with more details. A group of Swedish scholars led a research program, "Soundscape Support to Health", to develop methods and tools for prediction and improvement of acoustic quality in connection with annoyance, disturbance of sleep, propagation of sound, perception of soundscape as well as planning with respect of impact on health (Kihlman and Kropp, 2001b). The harmful effects of an acoustic environment on mental health of humans have been intensively studied, despite that a cause-and-effect relationship between the two has yet to be firmly determined (Lercher and Widmann, 2001).

Recent epidemiological study from Europe using a stress model demonstrated a linkage between the road traffic noise stressor and its Environmental Burden of Disease (Babisch and Kamp, 2009), through cardiovascular effects. This will enable not only the estimation of public health effects of road traffic noise in a way comparable to that of other environmental agents, but also a reassessment of priorities.

Not confined by noise, the effect of sounds depends on the appropriateness of the sound to that setting (Anderson, 1983). Lubman and Sutherland (2002) studied the influence of soundscapes of classroom and play areas on children's behavior and learning (Lubman and Sutherland, 2002). They found that the sustained high noise levels are averse to behavior, learning and teaching; while low ambient noise allows children to perceive and enjoy quiet sounds. Based on the results obtained, they suggested using natural outdoor soundscape and employing acoustical technology such as sound focusing structures and sound transmission channels to stimulate learning, increase sonic awareness and provide experiential enjoyment of the soundscape.

There is a need of further theoretical development and empirical evidence on the benefits people derive from their experience in areas of high acoustic quality. It is not a fully-developed territory, however, human should have experienced some of these benefits.

### 2.1.4.2 Perceptual construct

As Truax proposed in his book, *Handbook for Acoustic Ecology*, "soundscape emphasizes the way that the acoustic environment is perceived and understood by an individual or a society". Thus soundscape exists through human perception of the acoustic environment (Truax, 1999; Finegold and Hiramatsu, 2003; Raimbault and Dubois, 2005; Yang and Kang, 2005b; Kang, 2007). Understanding how humans perceive sound in an acoustic environment contributes to the knowledge of how sound could influence the individual experience and memories of a place, and how acoustic quality could be enhanced.

Based on previous studies, two parallel lines to study human perception of soundscape have been observed. One line starts from the state of listening and uses psychological indicators. The other line pursues the scientific goal of trying to understand the influence of sound and its interaction within the context of visitors' state of mind. Some others nevertheless propose to combine the best of both worlds in a multi-criteria assessment.

- Process of listening

Both in theory and practice, listening is the crucial interface between the individual perception and the environment (Truax, 1984). It is an active way of receiving auditory information and can be depicted as the psychological attribute which is in action when discerning the sounds heard. Listening is therefore hearing the sounds of the environment and responding to them actively.

The purpose of an individual coming to the space influences how the sound will be perceived. Actually, there are different states of listening awareness that an individual can reach. The most active form of listening is listening-in-search, where the detail of sound signal is the most important, and the person is searching for clues in the sound environment. The ability to focus on one signal in the soundscape is necessary in this form of listening. Listening-in-readiness allows a person to be ready to receive sound information, but the focus of attention is elsewhere. This second type of listening requires a favorable environment where sound signals are not obscured. Listening is not the same as hearing. Hearing is the interception of sound energy, while listening is the processing of that sound energy by brain to useable and potentially meaningful information (Truax, 1984). The state of the environment will also influence what form of listening the user will use.

There are two ways for processing auditory stimuli. One is to understand the sound stimuli as a part of event and the other is to comprehend it analytically or abstractly, if sound source cannot be identified. Dubois et al. (2006) pointed out that as part of an event sounds are processed as effects of the world on the subject. However if human fails to identify sound sources, auditory stimuli will be processed abstractly through physical dimensions (Dubois *et al.*, 2006).

- Perception of sound

A field study in Boston was led by Southworth (1969), involving several subjects, with the purpose of testing human perception of sounds and sights in central Boston. He found two aspects of soundscape that were particularly important in human perception of the soundscape (Southworth, 1969). First, the identity of the sounds, including the uniqueness or singularity of local sounds in relation to those of other urban settings and the extent to which a place's activity and spatial form were communicated by sounds; second, the delightfulness or quality of sounds which caused them to be liked or disliked. The nature of perception could be understood by taking the mobility of people into account. Information picked up as a result of motion was related to the cognitive maps of the nearby environment.

As perception is a very subjective phenomenon, some sounds could be accepted in one setting, while rejected in another setting. Sound source is suggested as an important factor on perception of soundscapes. Traffic noise and sound from people, being the most prevalent sounds, transfer the least information but demand the most attention. On the contrary, informative sounds are usually weaker, less frequent, and hence easier to be masked. Contrast influences people's attention to particular sounds. When a sound stands out from the background, that event means more to the subjects

(Southworth, 1969). In this sense, novel or unexpected sounds inform more than the redundant ones, and subjects pay more attention to them.

- Response to sound

Some investigators attempt to evaluate or predict human perception based on the dose-response relationship, emphasizing on the physical measurement on people's perception. Many have related physical characteristics of sounds to their perceived qualities. The relationship between physically measurable quantities and subjective perception is quite complex, as human sensations involve complicated physiological and psychological mechanisms. The equal-energy hypothesis, on which the physical parameter of $L_{eq}$ is measured, provides a weak and arguable basis for predicting human responses to sound intrusion (Fidell *et al.*, 1996).

Relationship between subjective evaluation and noise exposure has been derived for various noise types (Finegold and Finegold, 2002; WG-HSEA, 2002). Job (1988) reviewed human reactions to traffic noise and showed that noise exposure might only account for 25-40% of the variation in human reaction (Job, 1988). A survey on urban noise annoyance by Zannic et al. (2003) showed that in spite of a reduction in urban noise pollution, there was an increase in the subjective perception of urban noise (Zannin *et al.*, 2003). This disparity indicates that subjective evaluation is not necessarily in line with objective measurement. The influence of individual sensitivity and attitude on perceiving sound sources accounts for more than that given by physical parameters (Job, 1988).

- Sound quality

Subjective evaluations rely on having a statistically significant number of people to compare sound qualities (White, 1975). As attitudes of people relating to sounds vary greatly, obtained results cannot be precise due to the small sample size and large uncertainties during the process. Nevertheless, parameters such as loudness and pitch in relation to physical observables can help make some qualitative statements.

Loudness as one of the psychoacoustic parameters can be loosely defined as the magnitude of the sensation experienced by a listener when sound energy impinges on the ear. However, determining the degree to which sounds may be really annoying is more complex than merely quantifying loudness. Roughness, a modulation-based metric, is often described as grating (Kang, 2007). A rough sound, therefore, is something that is considered unpleasant to a listener. Rough sounds are those whose tones are amplitude-modulated and spaced within a critical band. They may also be characterized by frequency modulation, and a rapidly and repeatedly fluctuating noise. Sharpness measures a sound's spectral balance between low and high frequencies. Signals that are sharper are those that have higher frequencies. Pitch strength is one that distinguishes pure tones amid complex noise. Pitch strength is also referred to as tonality. If contained in a broadband noise, audible pure tones may be annoying. Nonetheless, their contribution to loudness is minimal.

- Perception of soundscape

Psychoacoustic parameters are not sufficient to reflect human perception of the real outdoor acoustic environment. Psychophysical, psychological, experimental and expert approaches have been used to evaluate human perception of the acoustic environment (Tyrväinen *et al.*, 2005). These different research methods produce different types of information for design and management of urban acoustic environment. Among them, psychophysical and expert approaches provide information more easily applicable for practical purposes than other approaches. Psychophysical research tries to analyze and rank the preferences of people in relation to various types of urban environments. The psychological approach provides a framework for preferences and their links to cognitive aspects of the environment.

There is a consensus in psychology that knowledge of the world surrounding us is classified into objects, which are related to one another by the similarity of their semantics (Rosch and Lloyd, 1978). Like the world outside, an acoustic environment is classified into categories that possess two primary features, one is the level of abstraction and the other is the prototype. Based on loose definition, the level of abstraction is the level of description of the soundscape. The prototype is the member that best represents a category. Through the creation of waiting, selection, and planning effects, the structure of knowledge influences the way the world is perceived. Perception of a soundscape involves a top-down process. Besides one's ability to collect and process auditory information, knowledge about a soundscape is necessary for its perception. Given this backdrop, categorization becomes an congenial experimental way of understanding how knowledge is organized and how information about an acoustic environment is collected through similarities (Tardieu *et al.*, 2008).

- Evaluation of acoustic quality

Subjective evaluation of the acoustic quality is more complicated than evaluation of individual sounds. The particular context, information contained in the sound as well as the individual attitude play an important role in evaluating the environmental acoustic quality (Brown, 2007a). In some soundscape studies, human evaluation is thought to be linked to the evaluation context as well as respondents' characteristics such as education, recreational activities, nature relationship, age and gender (Tyrväinen *et al.*, 2005).

Brown (2006a) suggested a simple but important framework for soundscape evaluation (Brown, 2006a). A two by two matrix was proposed to depict the subjective evaluation of acoustic quality, taking into account the level of sounds experienced on one hand, and whether or not particular sounds heard are wanted or unwanted on the other. This framework underpins the significance of context and the appropriateness of sounds with the environment. However, most of the current noise measurement equipments and assessment procedures simply integrate all sound sources and are not able to distinguish sounds wanted from those unwanted.

Masking is an effective technique that can make the unsuitable sound harder or impossible to hear, for example, the sound of fountains at busy intersections. It is the process through which one sound increases the audibility threshold of another. Sounds with low frequencies create masking effect over higher-frequency sounds. Nonetheless, higher-frequency sounds, to some extent, are also capable of masking sounds with lower frequencies. Masking also occurs for a few milliseconds before and after the desired sounds (Kang, 2007). The most common concepts derived from this knowledge base are being applied in practical planning guidelines.

#### 2.1.4.3 Acoustic ecology

Ecology is the study of the relationship between living organisms and their environment. Acoustic ecology is the study of sounds in relationship to life and society with particular consideration of the effects that the acoustic environment has on the physical responses or behavioral characteristics of creatures living within it (Schafer, 1977a; Truax, 1999). Application of basic ecological concepts and physical principles can inform how sounds will function in an environment.

The model of ecological system where all elements are in balance works well and shows good design features (Truax, 1984). Similarly, there are also balancing forces of physical and biological ecology in the acoustic environment where its sounds and those of the various species create a stable environmental ecology. Constant exchange of information among its elements and interaction by listeners with an environment are requirements for the environment to be well balanced. After all, an environment is viewed as a system of acoustic communication. Therefore, a high degree of redundancy and a lack of information exchange that alienates an individual may cause an environment to become unbalanced (Truax, 1984) .

Acoustic ecology has not emerged before the 1970's when the World Soundscape Project was taken place. Scholars coming from multi-disciplines, including philosophy, sociology and art joined the trip. One of the most influential findings out of the early work was the idea to differentiate "hi-fi" and "lo-fi" acoustic environments. In a "hi-fi" system, a full audio frequency spectrum was produced with a favorable signal-to-noise ratio, while a "lo-fi" system produces not a full frequency spectrum with a poor signal-to-noise ratio. Most natural soundscapes are characterized as "hi-fi" acoustic environments, where all sounds are aesthetically rich, audible without being crowded and pleased to the ears. In other soundscapes dominated by man-made sounds, distortion, broad-band noise and discomfort are frequently found. They would not be favorite soundscapes (Cummings, 2001).

As such ideas spread acoustic ecology is further developed from the revolution consisting of a unification of those disciplines concerned with the science and art of sound. Urban planning is one of the first places that have been concretely influenced. Urban sound ordinances have been developed to limit dangerously loud sounds and shield residential buildings from serious traffic noise, and the value of open space as sonic refuges has become a concern in urban planning.

Since acoustic ecology espouses the value of listening and the quality of soundscape, what needs to be done to improve the soundscape is to implement an education program that will help new generations better appreciate environmental sounds. By this way, sonological competence is raised. In turn, better appreciation of environmental sound and consequent reduction of wasted energy represented by noise lead to the development of a new approach to design (Wrightson, 2000). Acoustic ecology should never become design control, but "rather a matter of the retrieval of a significant aural culture" (Schafer, 1977a).

### 2.1.5 Development of soundscape studies

Soundscape study was carried out initially in the 1960s, by Schafer, at Simon Fraser University. Based on his experience, he said the ability of children to listen was deteriorating. He likewise cited the noteworthy dominance of visual modality in society. The initial focus of soundscape study is the relationship between human, sound and society.

The World Soundscape Project (WSP) was undertaken between the late 1960s and early 1970s. WSP progressed after Schafer, who was concerned of the rough and rapidly changing soundscape in Vancouver, drew attention to the sonic environment through a course in noise pollution. Eventually, a group of students and young composers responded to the call by Schafer. This prompted Schafer to organize in 1975 a European tour for a group he headed. Lectures, workshops, and a research project that conducted thorough investigations of soundscapes in five villages were done in major cities in Europe throughout the tour. The tour ended productive. Through it, a WSP's analogue tape library was established and two articles – a narrative of the trip titled "European Sound Diary" and an in-depth analysis of soundscape called "Five Village Soundscapes" - were published. Moreover, Schafer's "The Tuning of the World," a definitive text on soundscape, was published in 1977. Furthermore, a reference work for acoustic and soundscape terminology, called the "Handbook for Acoustic Ecology" by Barry Truax, was published in 1978.

Subsequent teachings and research on acoustic communication followed up on the initial works on WSP. In 1984, Truax came up with the "Acoustic Communication," which discusses all aspects of sound and the impact of technology, and introduces the works of some composers.

The World Forum for Acoustic Ecology (WFAE), an organization composed of international associations and individuals across a vast range of disciplines as members, was founded in 1993. It served as a venue to share common concerns about the state of soundscape as ecologically balanced. Its members are involved in the study of scientific, social, cultural, and ecological aspects of natural and man-made acoustic environments. The journal "Soundscape: The Journal of Acoustic Ecology" was founded in 2000, coming with news, events, workshops and other activities related to the ecology of sound. A numbet of regional activities are also under proceeding: Australian Forum for Acoustic Ecology (AFAE), Canadian Association for Sound Ecology (CASE), The United Kingdom and Ireland Soundscape Community (UKISC), Finnish Society for Acoustic Ecology (FSAE) and Soundscape Association of Japan (SAJ), to name a few.

Over the last decade, soundscape study has experienced a rapid development. Large-scale noise mapping software packages have been designed and applied in practice worldwide. Correspondingly, various prediction methods for sound propagation in micro- and macro-scale areas have been established and introduced for new noise control measures and design methods. In terms of subjective evaluation, a lot of new evaluation methods have been suggested from a multidisciplinary approach to generalize a holistic perspective of users' opinion on the acoustic environment; general questionnaire survey remains an important and useful method in this aspect. At the same time, the importance of acoustic environment and soundscape design has been gradually recognized, which is a major progress from simply reducing the noise level to a positive design. Therefore, great attention has been paid to noise problems at various levels leading to a series of substantial actions in policies and regulations

(Kang, 2007).

## 2.2 Soundscape of Open Spaces

Pressure for land is becoming extremely high in metropolises; however, government acknowledges the importance of public open space to the mental and physical well-being of both individual and the community. An open space, commonly used as an area for recreation, accommodates sunlight and allows free air movement, thus providing visual relaxation. This trait of an open space is useful for environments with high population densities, such as Hong Kong. In recent years, ways to make open space more attractive for use by the full spectrum of the society have been highlighted worldwide (Thompson, 2002). A number of common themes regarding the protection and enhancement of urban open spaces have been promoted.

### 2.2.1 Function of open spaces

Open space provides a place with open air and recreational facilities for the benefits of the general public (Planning Department of Hong Kong, 2009). Considering the typical high-rise and closely-packed urban development especially residential development in Hong Kong, open space provides a serene and comfortable setting to minimize the unpleasant impacts of high-density developments.

In most urban settlements, public open space, including streets, squares, parks and less well defined "common areas", adds up to more than half the total area of land, leaving the rest occupied by buildings and infrastructure (Rogers, 1999). The network of public open spaces provides a web of connections that offers people a range of choices when deciding the right place for doing their social activities. How to design urban open spaces to better support the demand from the increasingly urbanized society is related to the fulfillment of the major functions that each type of open space might and should perform.

#### 2.2.1.1 Restorative function of open spaces

Restoration is the act of renewing physical, psychological, and social capabilities that have dwindled amid efforts to address adaptive demands of humans. Researchers have been interested over the years to dig into restorative environment given the inspiration provided by the attention restoration and psycho-physiological stress recovery theories. Kaplan's program made great contribution to a theory of restorative environment, in which the reduction of mental fatigue is central to restoration (Kaplan and Kaplan, 1989). The key aspects of restorative settings include fascination, being away, extent and compatibility.

Restorative experiences have shown positive benefits in terms of economics (Kuo, 2001), physical and mental health (Ulrich, 1984). Restorative experiences are important contributors to achieving a good quality of life. Natural environments in general, provide more of a restorative experience than built-up urban environments. The view of nature has shown to provide both health and cognitive benefits in terms of effective functioning and attention. Soundscape perception has also been identified to play a significant role in open space visitors' restorative experience (Payne, 2008). Moreover, the frequency with which visitors use the open space is found to be positively related to their restorative level.

The importance of open spaces and natural surroundings in relieving stress and improving the feelings of well being has been identified in the literature (Hartig *et al.*, 1991; Horoshenkov *et al.*, 2010). Hartig (1991) explored the utility of different theoretical models of restorative experience in a quasi-experimental field study and a true experiment, and obtained evidence of greater restorative effects arising from experiences in the open spaces. This might be attributed to the natural elements in the open spaces, which helps foster inner peace and a renewal of mental energy, so that open spaces are widely recognized as a good place for restoration.

Restorative environments in the open spaces are preferred and chosen as places for recreational activities. According to a research by Simonič on visual landscape preference in Slovenia, urban landscapes containing many natural elements, a good spatial structure, and an organization that allows for both passive and active uses may serve as good restorative environments. Findings of the study backed claims that choice of landscape use and restorative environment scenes are influenced by a particular character, a spatial organization, and the character of present natural elements in the landscape (Simonič, 2006).

There are suggestions on how to design naturalistic open spaces in such a way that elicits landscape experience. A more diverse landscape experience is more likely to achieve restorative role for it. An urban open space would serve the role of a restorative environment if it is designed as a complex, coherent landscape that allows users to visually recognize potentials for a variety of activities involving interaction with nature. An experiential landscape of higher quality may thus ensue. Restorative landscapes, especially those in urban areas, can promote healthier lifestyles, better quality of life, and increased awareness of and interaction with nature.

#### 2.2.1.2 Social network

Open space is conceived of as an outdoor room within a neighborhood, somewhere to relax and enjoy the urban experience. Various activities may be conducted in an open space, such as outdoor eating, street entertainment, sports, civic and political functions, and walking or simply relaxing. Open space is essential given that it serves both the active and passive recreation needs of residents. Active open space is one that allows organized sporting and recreational activities. Examples of an open space are sports fields, ovals, netball and tennis courts, and showground, among others. While on the other hand, passive open space is landscaped as parks, gardens, sitting-out areas, waterfront promenades, paved areas for informal games, children's playgrounds, jogging and fitness circuits, where people can enjoy the surroundings in a leisurely manner (Planning Department of Hong Kong, 2009).

The day-to-day use of open spaces and their relationship with the local community is more important compared to special events that take place in open spaces. Open spaces offer a range of facilities for both young and old and for all sections of a society (Conway, 2000). The open areas of grass could be used for sports, grazing and meetings. Youngsters come to explore and have adventures, adult and adolescents to engage in sports and active activities, extended families or a few friends to drink tea together, and the elderly to sit and enjoy the warm sunshine in a sunny afternoon (Burgess *et al.*, 1988). The design of open space enables some to enjoy quietness and privacy, while others to enjoy group activities, for users are individuals whom bring their own world and needs when visiting.

The desire for social interaction is the major attraction for people coming to the open space. Visitors use such open spaces to promote social integration and enhance the social ties among neighbors. In Hong Kong, home service workers from the Philippines gather in some big open spaces on weekends and enjoy the gatherings which break down racial prejudices and extend similarity. Open space is particularly important for children, as they are given opportunities to adventure, explore, and establish independence. Outdoor experience with natural pleasures is beneficial for children getting socialized and developing their personalities.

Burgess et al. (1988) presented the result from the Greenwich Open Space Project based on qualitative research with four in-depth discussion groups that people preferred open spaces when they could accommodate a rich mixture of social and physical activities (Burgess *et al.*, 1988). Highly qualified open spaces improve the urban life by providing a variety of physical settings, culture, and social activities. Well-designed and maintained public spaces should meet the requirement of high diversity for public interaction and social integration.

**2.2.1.3 Refuge and Reconnecting nature**

Open spaces serve as a buffer between developments and between communities. They provide a green break in a densely populated community and vary the urban skyline by interrupting blocks of buildings with trees and open spaces. Open spaces provide opportunities to escape routine, and serves as areas where an individual may contemplate and interact with nature (Burgess *et al.*, 1988: Chiesura, 2004). A city will have a very different character with scattered open spaces than it would have without them (Kelly and Becker, 2000).

Through a questionnaire survey, Chiesura (2004) found a strong demand of people to relax and step away from the hectic rhythm of the city (Chiesura, 2004). Open space constitutes a sort of "oasis", offering not only the possibility to escape from the worries and the routine of everyday life, the traffic, the noise and the pollution of the city, but also from the physical contours of the city. An outdoor experience may have its benefits. With it, stress may be reduced, opportunities for contemplation may increase, and moments of peace and tranquility may be attained. Experiencing nature elicits a positive feeling resulting from relaxation and rejuvenation. People need to feel a sense of spirituality, which elevates their states of mind to a higher level of tranquility and away from the stressful thoughts of daily activities, and which make them feel being part and in harmony with a bigger entity.

Benefits related to mental health and reduction of stress are proved by contemporary research on the use of urban open spaces (Hartig *et al.*, 1991; Conway, 2000). According to Schroeder (1991), a relaxed condition results from natural environments characterized by vegetation and water (Schroeder, 1991). Natural elements, which serve as natural tranquillizers, thus benefit residents of urban areas, which are commonly stressful. Kuo et al. (1998) examined the potential for providing basic landscaping in making the city a better place to live. Their findings verified the benefits of open space in helping people to relax and renew, reducing aggression from crowding (Kuo *et al.*, 1998).

Trees, grasses, flowers and animals are not isolated features or specimens but parts of a living whole in which both people and nature live in close companionship. Urban residents enjoy the changing seasons, e.g., the autumn leaves, chestnuts, summer and winter walks; feel the sun, the wind or the rain, and walk, run or just sit down and appreciate the view. The intrinsic qualities of the natural environment contribute to the pleasurable experiences as well as the desire to touch, smell, see and hear elements of the natural world (Harrison *et al.*, 1987).

An integrative approach to open space planning and management that provides opportunities for leisure and interaction with nature is ideal for residents of local communities (Burgess *et al.*, 1988). A discrepancy sometimes occurs between what residents and conservationists perceive as an ideal environment. Therefore, planners should know how to balance the two perceptions.

#### 2.2.1.4 Pursuit for Sustainability

The 1992 Rio de Janeiro conference on environment and development was a sign of renewed awareness of the contribution open spaces make to the quality of life through recreation and the environment (Woudstra, 2000). The conference discussed the recommendations on sustainability stated under The Brundtland Report (1987). The report said sustainability is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." While there is a clear definition for sustainability, there has yet to be a generally accepted definition for a sustainable city. Nonetheless, there have been various criteria and indicators suggested to determine what a sustainable city is. Criteria related to the environment, people's satisfaction, experiences, and perception of the quality of life have been taken into account in coming up with definitions for a sustainable city. Factors like amount of public open spaces per inhabitant, presence of public parks, and presence of recreation areas are often considered vital in making a city an ideal place for residents. A pleased citizenry in turn is required to achieve sustainable development (Chiesura, 2004).

Presence of urban open spaces in urban contexts improves the quality of life and the sustainability of the city. Vegetation in open spaces cleans the air by absorbing pollutants, moderates the city climate and encourages airflow, thus providing physical benefits. It also has psychological advantages and a calming effect. According to previous studies, people consider feelings and emotions evoked in an open space as valuable for their well being (IUCN, 1991). Lots of direct benefits have been identified through emotion release in an open space. Psychophysical equilibrium can be regenerated with a breakdown from routine and spiritual reconnection with nature. These benefits are crucial for maintenance of a good-quality human life, which in turn is necessary to achieve sustainable development (Chiesura, 2004). These emotional and psychological benefits are fully exploited in cities where open space forms an important part of the civic infrastructure (Woudstra, 2000).

Urban open space is an important element of a high quality sensorial world. It is the foundation for public interaction and social integration and provides the sense of place essential to engender civic pride. It is an environment that facilitates sharing of values and experiences among families and friends, and allows favorable interaction among ethnic groups and tolerance of each other (Burgess *et al.*, 1988).

So far, there has been much focus on the delivery of quantity and little on the benefits of quality. The benefits of design are underrated although professional designers are involved in a regeneration project. For a public open space to be ideal, it must possess a balance of recreational facilities, and plenty of social settings. An ideal public open space is not merely one that is a mixture of single-function zones. Urban integration requires building an urban open space that is not isolated but an essential part of an urban landscape that has its own functions (Rogers, 1999). Designers, planners, and leisure managers are responsible for making sure open spaces are accessible and allow a range of pleasurable experiences (Burgess *et al.*, 1988). An urban community becomes more able to articulate shared values if residents are more actively involved in its affairs and if their needs are assessed. Local planners are more able to plot strategies for sustainability if said values are articulated (Chiesura, 2004).

### 2.2.2 Acoustic design of open spaces

The acoustic environment in the open spaces is now bombarded by a continuous stream of attention-demanding sounds from the noisy outside world. It is no longer sufficient to design the open spaces that satisfy the eye alone. To design and provide a good outdoor environment, sound as a component of the biological and social environment should be taken into account (Hedfors, 2003a).

Schafer says acoustic design involves discovery of principles and development of techniques by which the social, psychological, and aesthetic qualities of an acoustic environment may be enhanced (Truax, 1999). Certain sounds may thus be eliminated through noise abatement, while other sounds that give character may be preserved under said principles. Moreover, said principles likewise allow imaginative placement of sounds to create attractive and simulating environments (Brown and Muhar, 2004). Pascal Amphoux's work on sonic identity described three methods as defensive, offensive and creative, which respectively means to preserve the sonic environment against noise pollution, to strengthen the acoustic environment and to build the sonic landscape (Hellström, 2002).

#### 2.2.2.1 Interaction of visual and aural aspects

For quite a long time, urban planning and design tend to focus on the visual aspects of a space and give the other senses less concern. In fact individual uses all senses when experiencing an environment and the impacts of the environment on these senses alter the experience of the users. Therefore, the acoustic perception of open spaces should be treated in the same way as visual dimensions, which have been promoted over the past decades, are.

A number of previous studies have suggested that aural and visual aspects are closely related, both contributing to the identification and interpretation of the surrounding spaces. A place which seems pleasing must do much more than appeal to the eye. Yu and Kang (2008) compared the differences in sound level evaluation between people who were watching and not watching and found that the effects of watching behavior were much more related to the sound level evaluation, again indicating visual and aural interactions (Yu and Kang, 2008). Auditory perception improves when accompanied by related visual displays and similarly, sounds can direct attention to related visual elements (Broadbent, 1987). Carles et al. (1999) studied the influence of interaction between visual and acoustic stimuli on perception of the environment and concluded that the congruence or coherence between sound and image influenced preferences (Carles *et al.*, 1999).

Depending on their level of compatibility, sound and sight may interact and support, or interfere with each another (Southworth, 1969). When sound and sight are paired, receivers either gain or lose depending on the amount of correlation between the two. Visual-auditory settings that were evaluated by the subjects as more pleasing were more informative, unique, and demanded less attention.

#### 2.2.2.2 Differences between soundscape design and noise control

Noise control practice is active in the protection of people who are indoors, particularly in the residential buildings or workplace. It is implemented in three levels: reduce sound level from the source, manage the transmission path between the source and receiver, and protect the receiver. In contrast to the focus on the influence of outdoor sound on people staying indoors, soundscape design is more suitable for dealing with sound heard in open spaces, since it approaches sound as a resource and an element of design to be utilized for improving the acoustic quality and consequently the general environmental quality. For example by locating music installations close to noisy streets, the road traffic noise in an urban area can be masked by music.

The adverse effects on communication or sleep are measured using the noise criteria, which may be applied to a limited extent to acoustic design in open space. Considering the extreme situation that is the absence of sound, quiet or tranquil is not always considered as better characteristics of an acoustic environment. Some sounds could convey a city's identity and others may form parts of a society's culture. Soundscape approach for acoustic design is not about quieting places but enhancing human enjoyment.

Soundscape approach could be considered as an extension of traditional noise control. Before new preferred sounds are added, several existing noise should be reduced by effective methods applied in noise management. These include careful location of noisy activities, introduction of new types of highway and street design, invention of special vehicle design and masking of existing noise by added sounds (Southworth, 1969). The last is related to the concept of soundscape. There are cases where an acoustic disturbance results in decrease of environmental quality. Nonetheless, natural sounds may help to enhance the quality of environment. Since it is not reasonable to expect low levels of traffic noise in current urban areas, the opportunity for alternative acoustic experience relies on innovative soundscape approaches.

#### 2.2.2.3 Sonic identity

The work on sonic identity is based on diagnosing the good, to make inquires about the situations of well-being and also to promote the favorable conditions of an actual and specific sonic quality. Open space is a special type of urban environment that any acoustic design should highlight the significance of quality in the sense that each open space has a certain characteristic sonic identity within its diversity. However, in most open spaces, the acoustic environment is not unique and informative, which results in the misinterpretation or confusion of settings. A successful acoustic design should enhance the particular characteristics that significantly contrast with other settings. This depends on a clear statement of the proposed acoustic objective of one setting, taking into account the diversity of activity, needs and interests.

Sound source is the basic element that constitutes an acoustic environment. Masking one sound by another is a method to create an identifiable acoustic environment (White, 1975). Most of the prevalent sounds in the city, like traffic noise, communicate the least valuable information but mask informative sounds which are usually weaker and less frequent. It is a loss in sensitivity to a stimulus during exposure to another stimulus. Low-frequency tones, in general, are more effective in masking high-frequency ones and vice versa.

Another way is by contrast, as contrast can direct the attention to particular sounds and consequently determine an event's significance. When a sound stands out from the background, it means more to the subjects. Incongruous sounds are apparently less annoying when they can be identified and localized, compared with the situation that they continue to mystify (Broadbent, 1987). Based on a study of the relations of prominent sounds in a background, Hedfors and Berg (2003) presented a figure showing the relationship between perceived intensity of the background and perceived intensity of sonic figures (Hedfors and Berg, 2003b). Four quality extremes along the two dimensions are shown in Figure 2.2.

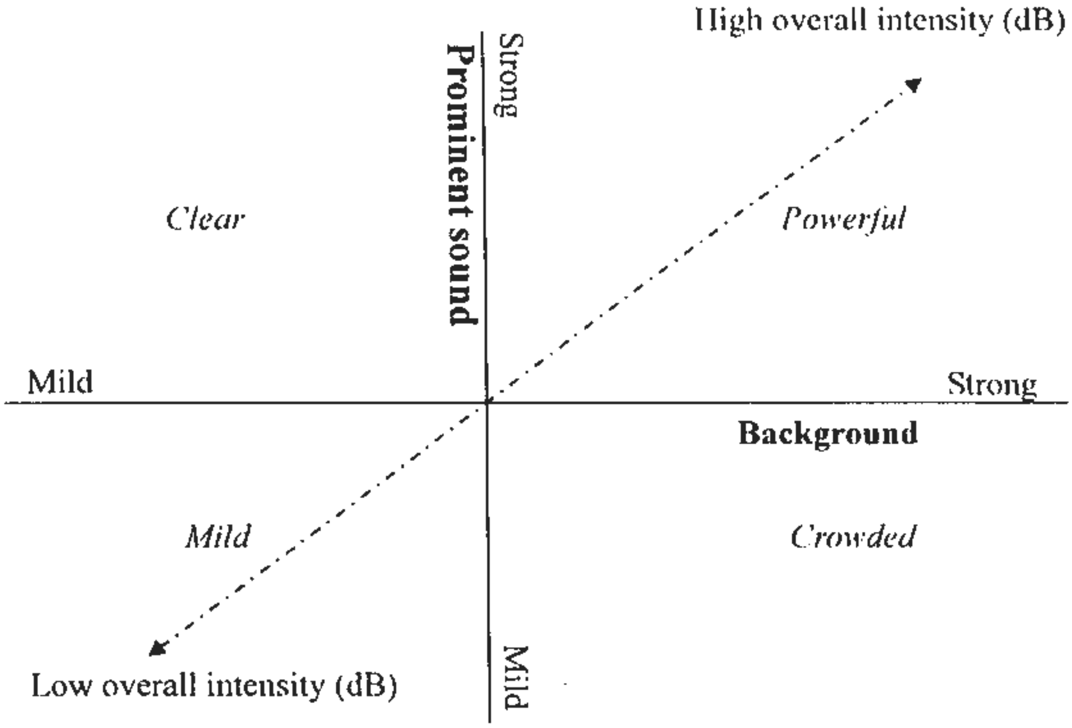



Figure 2.2 Dimensions of intensity and clarity resulting in four acoustic qualities (Hedfors, 2003)

Hellström (2002) adopted Pascal Amphoux's work on the sonic identity of European cities, which provided a detailed set of guidelines leading to the description of the sonic identity of a city as it was heard and experienced from the inhabitant-listeners' perspectives (Hellström, 2002). There are three main steps under his methodology. The first step uses sonic mind maps to select representative locations expressing each of the type of relationship to the environment, including known, lived and sensed. Then the second step serves as a logical continuation on the technique and a reprise on the methodology. A sequential analysis presented by a chart is used to synthesize results obtained from the extended interviews. The synthesis provides significant components of inquires needed for the final interpretation. The third and last step is to interpret characteristics of a sonic identity. The features result in the production of "sonic identity chart" for each sequence presenting information on the sequence, comments of listeners, the application of corresponding qualitative criteria, and expressions or suggestive quotes obtained during the description or identification process (Paquette, 2004).

Pleasantness of sounds appears to depend on much more than the physical qualities of sounds. If the sounds are found informative, responsive and culturally meaningful, they will be perceived as being more pleasant. Natural sounds are often rated positively, mechanical sounds are rated negatively, while human and animal sounds are rated intermediate to the others (Anderson *et al.*, 1983). People like quiet but informative places and prefer sound settings that inform one of the spatial and activity character and have constantly varying novel sounds (Southworth, 1969). Less pleasing sound settings are more attention-demanding and less informative, such as the roar of a busy street. Annoyance with this type of sound becomes greater if it continues. The most identifiable acoustic sites also contain visible exterior activity and often have unique spatial characteristics. Ambiguous form would confuse visitors who would judge them differently. Similarly, vague foreground sounds may disguise important information.

**2.2.2.4 Micro zoning and macro acoustic design**

Apart from reducing the noise exposure level, increasing the soundscape identity, adding delightful sounds and enhancing the relationship between sound and the visible forms, acoustic design in larger open spaces should also consider the wide range of activities in which case zoning of the site into different activities will be appropriate.

Appropriate zoning inside a large open space is of basic value for accommodating the diverse interests of a small community or a major city, while maintaining a reasonably acceptable environmental quality. For different situations and places, there will be particular requirements of acoustic environments to increase human enjoyment and quality of experience, similar to visual preference that has been incorporated into design. For example, the proposed acoustic environment for a playground inside a public park may be to hear the sounds made by people, such that only the sounds of voices and footsteps but not amplified music and traffic noise may be wanted. The design of such place then has to ensure the former not to be masked by the latter.

Soundscape system is complex and the subjective opinions are conflicting and contradictory, but general guidance should still exist in terms of specification of acoustic objectives. To date research results are not providing enough guidance for setting acoustic objectives for different types of open spaces, however, their recommendations are to deviate from the nature of most acoustic criteria that are based on overall sound level and adhere to methods based on the information content of sounds. Brown and Muhar (2004) provided a list of acoustic objectives for different outdoor spaces, with most of which relating to natural sounds, particularly the sounds generated by wind, by moving water, or by animals, or ensuring human sounds predominate over mechanical or amplified sounds (Brown and Muhar, 2004). The suggested objectives for each type and zone of open space need to be referred to in the design or management process as the proposed acoustic environment for particular sites and sub-sites under different contexts.

From a macro scale, open space intend to function like large green lungs within the built-up areas in the comprehensive planning for a city. Considering different function, nature, form and intensity of development for open spaces and recreation facilities, the Hong Kong Government has recommended a hierarchy of open spaces. Local open spaces in highly developed urban areas must be close to residential homes and must allow passive recreational activities for residents. District open spaces should allow active and passive recreational activities for a bigger population. Regional open spaces should have a location strategic enough to benefit residents and tourists (Planning Department of Hong Kong, 2009).

Sounds produced by activities should be located to minimize the potential disturbance to nearby residents. Noisy traffic interchanges, streets or airplane takeoff and landing routes should not interfere with concentrations of interacting people or residential and open space areas where repose is desired. Careful acoustic design would not only enhance city life by helping to overcome the stress and dominance of visual sight, but also be an approach for developing the sensory awareness of city residents and provide an environment that is more responsive to human needs and expectation.

## 2.3 Summary

Soundscape study has experienced a fast growing period over the past two decades, with significant development in both theory and application. Based on related literature in soundscape study in the open spaces, the evolvement of the concept, research methodologies as well as contributions to the improvement of acoustic quality have been summarized. In this section. issues that are still under hot debate together with knowledge gaps in this field are revealed.

### 2.3.1 Issues under discussion

Soundscape is an interdisciplinary field involving researchers and practitioners coming from a wide variety of fields. Up to now, it appears that a legitimate interdisciplinary cooperation has not yet been achieved and traditional barriers between subjects of humanity, natural and social studies still exist. There is a necessity to have more open dialogue between the advanced artists and scientific communities. To develop a comprehensive soundscape lexicon, clarifying concepts that can be used in the analysis and future design of the sonic environments might be more appropriate.

The available conceptual models have so far been used at particular time and place. depending on political acceptability, timeliness and the ability to produce interesting results (Jäviluoma and Wagstaff, 2002). So the concept of soundscape and acoustic ecology is questioned by some scholars, who argue it not advanced with the times. It is true that there is a need for further self-reflection within the field of acoustic ecology, but it does promote the study of not only acoustics per se but also the qualitative properties of sound. the associated social and cultural values, and ways to intelligently organize sonic life within different places.

The majority of studies on sound have tended to focus on acoustics and noise, ignoring the ways in which sounds can function positively in the environment. From the view of noise control which is based on sound intensity, previous studies have attempted to characterize the spatial and temporal variations in sound levels, investigate the effects of interactions among biological, geographical and human factors, as well as focus on the relationship between sound exposure level and human response, and on the sound effects. The effectiveness of noise control method is challenged by many scholars who advocate the soundscape approach. However, no fundamental agreement has been achieved among acousticians and administrative authorities.

### 2.3.2 Knowledge gaps

Previous studies of open spaces have sought to demonstrate different characteristics from the perspectives of recreation, aesthetics, and sustainability of a city rather than the soundscape in open spaces. Also, most of them are more concerned either with large, bio-diverse or relatively untouched ecosystems, with less scientific attention being paid to the type of nature where people live and work, the small-scale green areas in cities, and their benefits to urban dwellers. An understanding of how to incorporate the acoustic consideration into the design of open spaces that connect closely with people's daily life is of necessity and great value.

Physical parameters have been demonstrated to have limited application in judging the acoustic quality of an area. In subjective evaluation of the acoustic environment, there is as yet no commonly accepted view on how people perceive the acoustic world and what constitutes an area of high acoustic quality. In this proposed study, a number of factors are considered and statistical prediction models are applied to understand the subjective evaluation of acoustic quality.

Despite the growing interest in soundscapes, there has been lack of implementation of visions related to those. It is highly necessary to move this conceptual field forward by providing some applicable recommendations for planners, landscape architects, engineers, acousticians and others involved in the planning and design of the acoustic environment.

Hong Kong, as a compact city with open spaces intermingled in the dense transportation network, provides a good platform for studying human perception of, preference for and interaction with sounds. Open spaces as the most frequently accessed recreation sites are closely related with people's urban life. With a wide range of sounds present in the open space, sound event, sound tonality, frequency spectrum as well as sound exposure level all vary with time and location. It is an appropriate place to further unravel the subjective evaluation in acoustic quality and provide applicable recommendations for acoustic design in urban areas.

*Acoustic experiences create, influence and shape the habitual relationships we have with any environment.....*

------ *Acoustic Communication*,
Barry Truax, 2001: 13

# Chapter 3 Methodology

The methodology developed to answer the research questions involves firstly identifying appropriate study sites, secondly collecting data in the field, and lastly processing and interpreting those data. Based on literature review, this chapter brings out a holistic conceptual framework of the study and introduces the methods and techniques applied for achieving the research objectives.

## 3.1 Methodological Framework

In describing the soundscape's capacity to convey information, sound is considered as the mediator between the listener and the environment. Sound refers to the acoustic characteristics of sound, including sound component, intensity and spectrum. The "acoustic environment" refers to the physical characteristics of sound and its variations over time and space in a particular context. As the final receptor of a soundscape, the listener perceives the sound and the acoustic environment with regard to one's personal experience, expectation and comprehension. It is a process of communication between listener and sound in a particular environment. Listeners' perception of sound is not capable of being separated from the context. Sound is a subconscious symbol and a reminder of a sense of place (Truax, 2001). The triangular relationship between sound, listener and environment forms the conceptual background of this study.

Hong Kong is a typical Asian dense metropolis where the open spaces are often sited right next to major roads. However, previous studies showed that while most park visitors are aware of traffic noise, they nonetheless regard the overall environment as of good quality and do not consider road traffic noise as a major concern (Wong *et al.*, 2004). This cannot be explained directly by referring to conventional acoustic parameters. In order to unravel how the park users evaluate the acoustic environment, a multi-pronged approach has been employed in this study to characterize it, relate it to a particular context and to understand the acoustic quality from the perspectives of visitors.

To select study sites for in-depth analysis, this study commenced with the identification of quiet areas in the city using the noise mapping technique supplemented by GIS spatial analysis tools and on-site reconnaissance. To obtain data on the physical characteristics of sound, as well as its spatial and temporal variations, both sound recording and field observations were conducted. To unravel how open space users evaluate the acoustic quality, on-site interview was undertaken at the same time of sound recording. After field work, statistical analysis tools were used to interpret data for useful information of soundscape evaluation. To facilitate a better understanding of this study, the conceptual framework is presented in Figure 3.1.

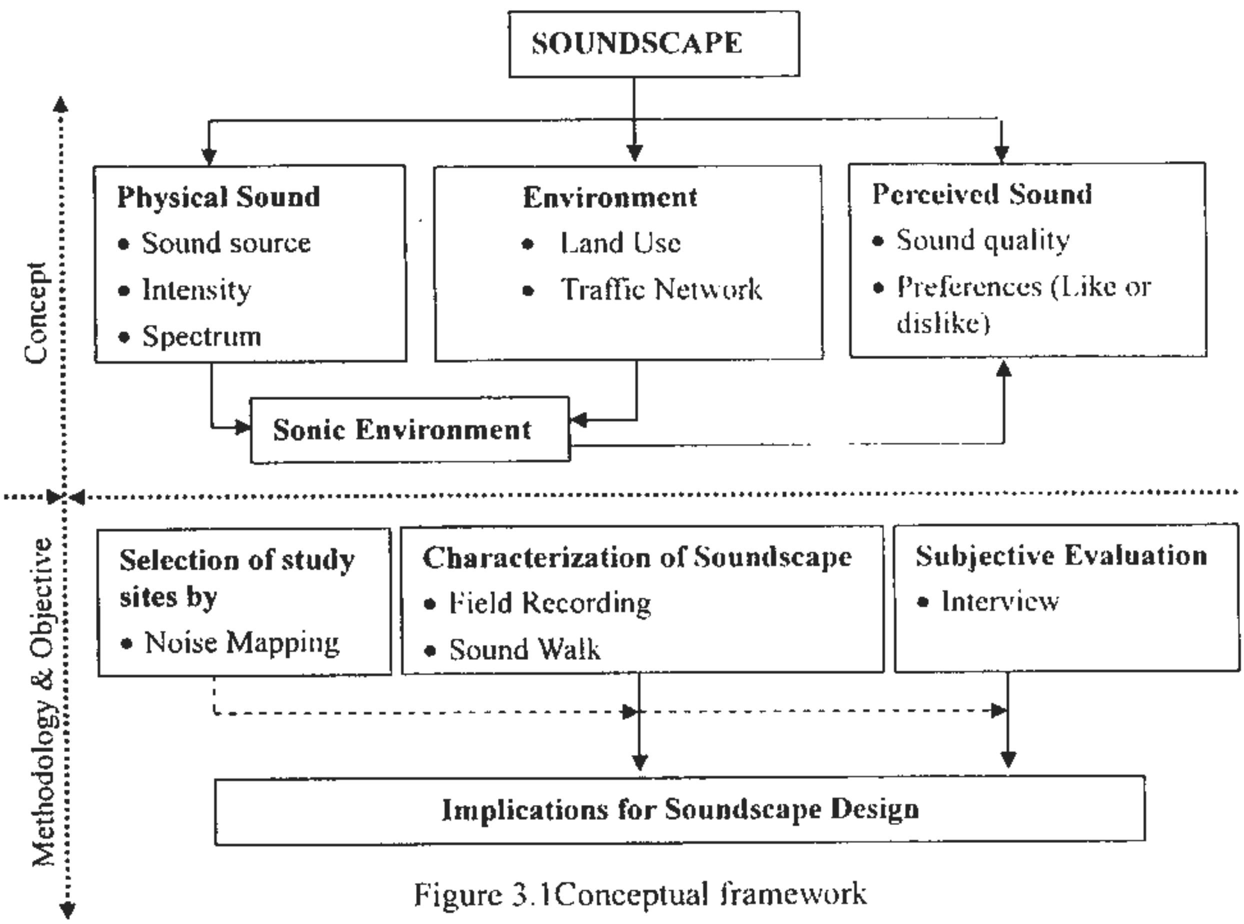



Figure 3.1Conceptual framework

### 3.2 Research Design

Many studies have argued that the notion of soundscape cannot be expressed only by words, numbers, or other measurable parameters no matter how sophisticated they are. The soundscape approach adopted in this study combines field recording and understanding of user's perception through interview to give a comprehensive picture of human-soundscapes interaction in the urban open spaces of Hong Kong. As presented in section 1.2 of Chapter One, this study has three closely linked objectives, namely (1) delineation of quiet urban open spaces and determination of their usage; (2) characterization of the acoustic quality of soundscapes in the quiet open spaces; and (3) elucidation of visitors' perception of and preference for sounds, and their evaluation of the acoustic quality. The methodological design is shown in Figure 3.2.

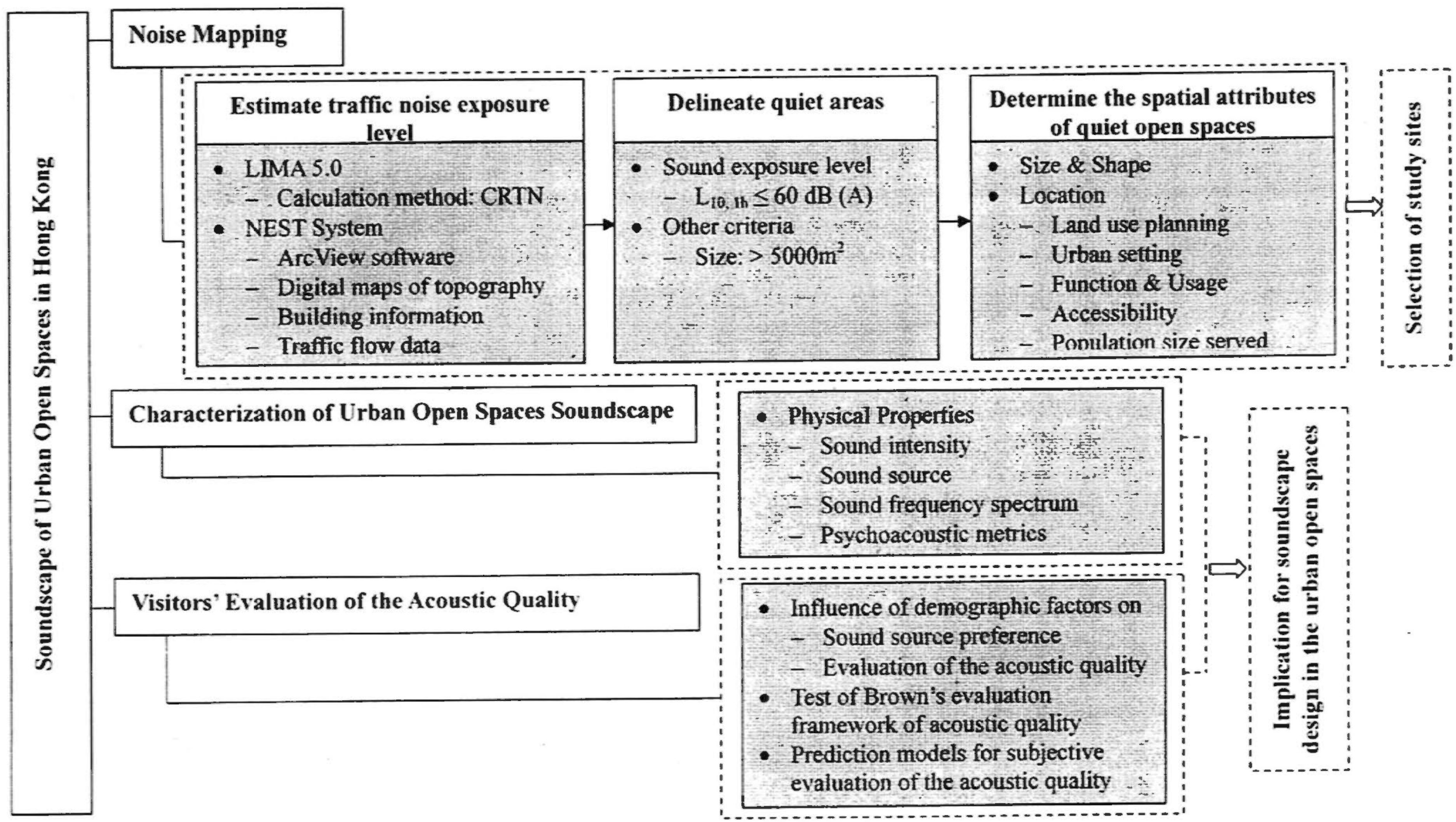



Figure 3.2 Framework of research design

To achieve these objectives, quiet urban open spaces in the city had to be selected. This study adopted the following criteria: (1) they should be open places with diversified biological and physical characteristics, which may yield varied sound elements and distinctive temporal and spatial attributes; and (2) they should also be places where traffic noise is not so dominant that the natural and man-made sound sources are masked.

To select the above mentioned quiet urban open spaces, the study commenced with the noise mapping of traffic noise. Recognizing that noise mapping in large cities requires huge manpower input and can be a study of its own; this study did not attempt to map the whole area of Hong Kong. Instead, only six out of a total of eighteen administrative districts were mapped. While the selection of these six districts was not random, the final list represented different land use types, development history and population density. The next step was to delineate "quiet areas" in these selected districts, defined arbitrarily as areas exposed to road traffic noise less than 60 dB (A) $L_{10,\,1h}$. Quiet areas so delineated were further overlain with land use maps to locate "quiet open spaces" which formed the pool of candidates for in-depth investigation. These "quiet open spaces" were further classified according to their respective types (park, garden, plaza, sitting-out area, playground and sports ground). For each type, four to five individual open spaces were chosen considering the variety of sound elements, accessibility as well as popularity. At the end, a total of twenty-five open spaces were selected for intensive field work. It was at each of these 25 locations, known as "study sites" in the rest of this thesis, that field sound recordings were made and users were interviewed. Field work was conducted at different times to minimize the temporal and environmental effects on the results. The procedures of each step in the research are shown in Figure 3.3 and will be explained in detail in the following sections.

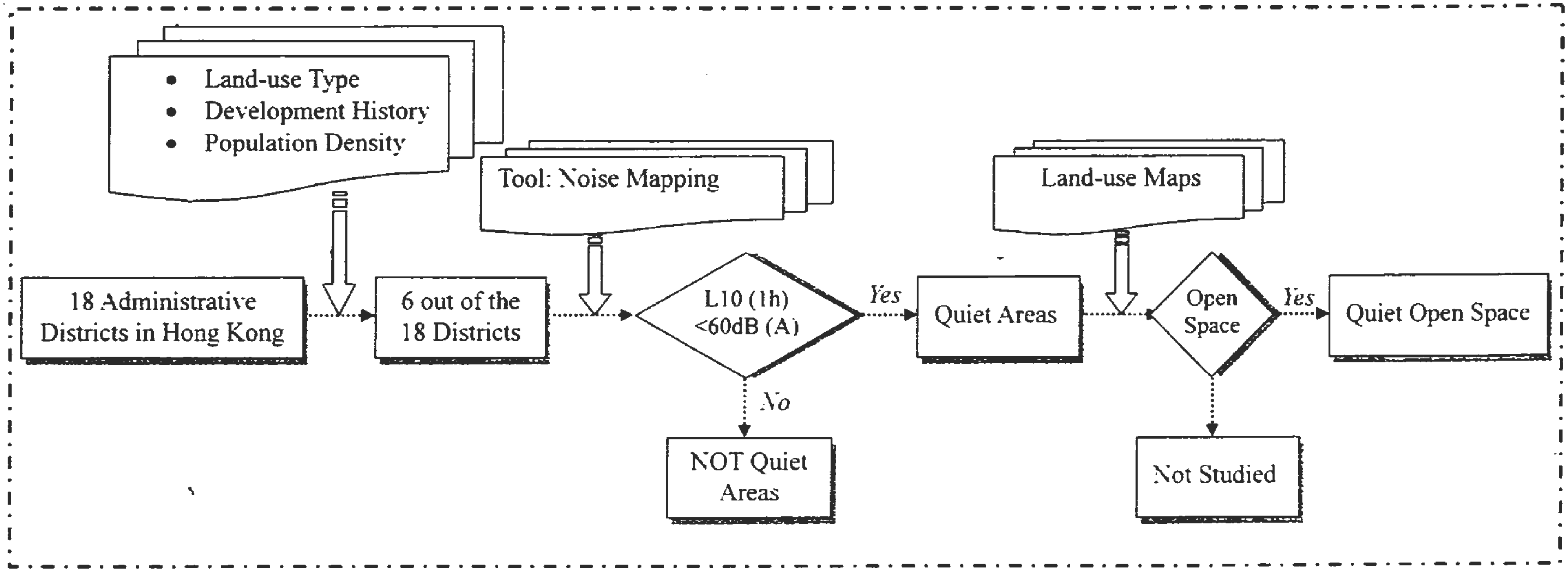



Figure 3.3 Research steps and procedures

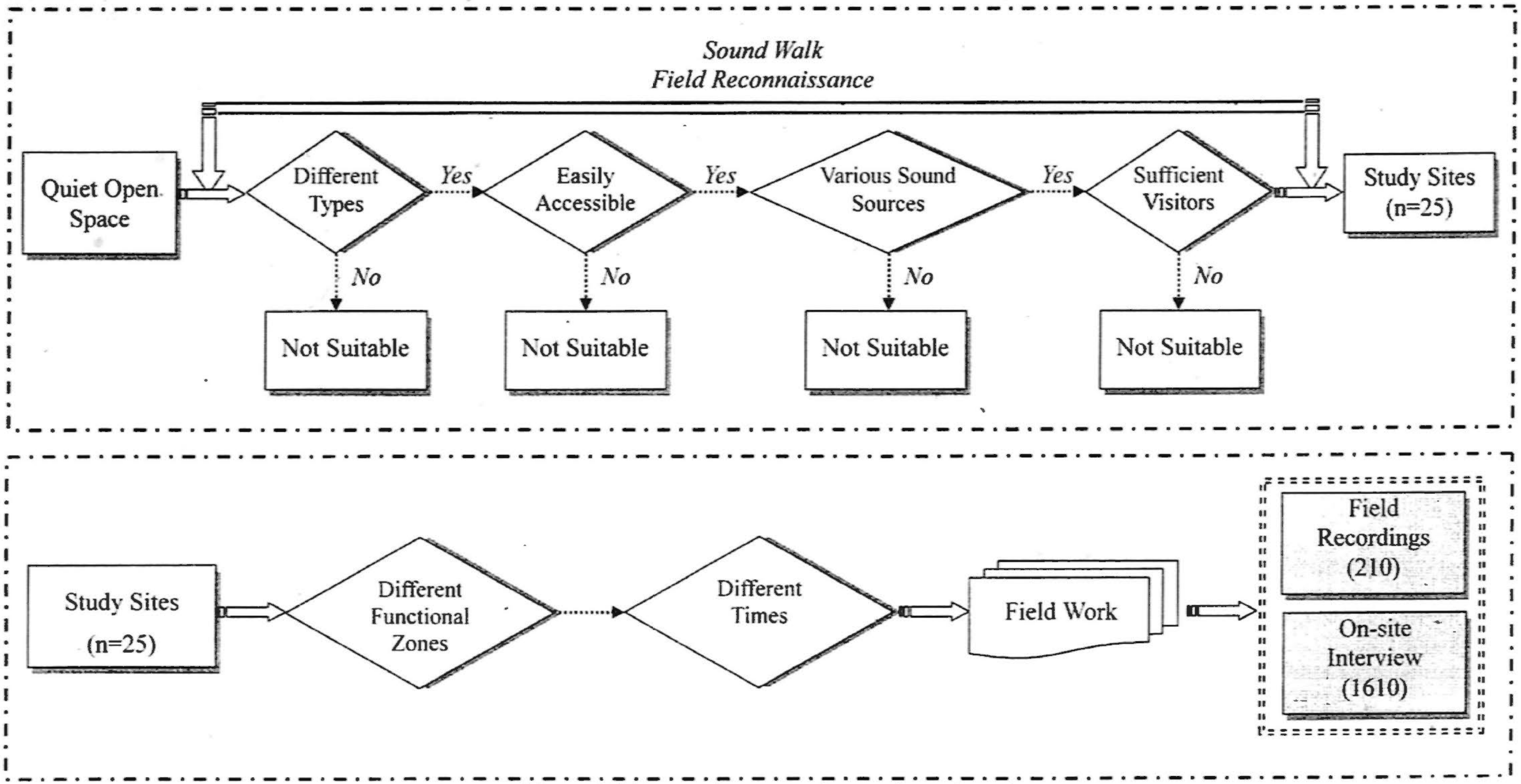



Figure 3.3 Research steps and procedures (*cont.*)

### 3.3 Identification of Study Sites

Methods and tools used to select suitable study sites are described in detail in the following sections.

#### 3.3.1 Noise mapping and GIS technique

Noise modeling is a widely used method to determine noise exposure and facilitate noise planning in built-up areas. Noise maps are generated for projects ranging from small scale developments with a single noise source to large agglomerations with many noise sources. In the European Directive on the Assessment and Management of Environmental Noise (END), member states are required to apply strategic noise mapping to urban agglomerations with population in excess of 100,000 persons to provide a representation of the noise levels within that area (The European Parliament and the Council of the European Union, 2002). Noise mapping for road traffic noise and rail noise is carried out throughout the world, both for large scale and community level acoustic simulation in order to investigate noise impact from transport infrastructure. The spatial distribution of sound could be presented in two or three dimensions to suit the urban morphology.

There are three types of noise prediction models, namely the optical model, acoustical model and mathematical model. Optical and acoustical models are scale models using hardware miniature to replicate the real world. Optical models are simple but they can only yield approximate results. Acoustical models are more reliable but are expensive to set up and run. Mathematical models are based on physical laws and empirical data. One of the popular prediction models is CRTN (Calculation of Road Traffic Noise) model (Department of Transport Welsh Office, 1988) which was originally developed by the UK Department of Transport and has become popularized worldwide. This model is being used extensively in Hong Kong for noise prediction and planning (Environmental Protection Department, 2000).

Data used for modeling the traffic noise exposure in the city are 3-dimensional data, such as buildings, earth profiles, and road schemes. To resolve problems related with 3D data manipulation, GIS based software, such as ArcGIS, was integrated with traffic noise prediction model to enhance the visual capability. Consequently, noise mapping software, such as LIMA, CadNaA, Raynoise and Mithras, have been developed with the capability of direct data exchange to and from a GIS environment. LIMA, for example, can combine with GIS to describe space entities, including terrain, noise barrier and their effects, so as to accurately simulate refraction, reflection, diffraction and absorption in the process of propagation. After calculation, data was exported from LIMA into GIS for creation of noise contour maps. In this process, noise modeling is one function of the GIS system. Calculation flow within this system is demonstrated in Figure 3.4.

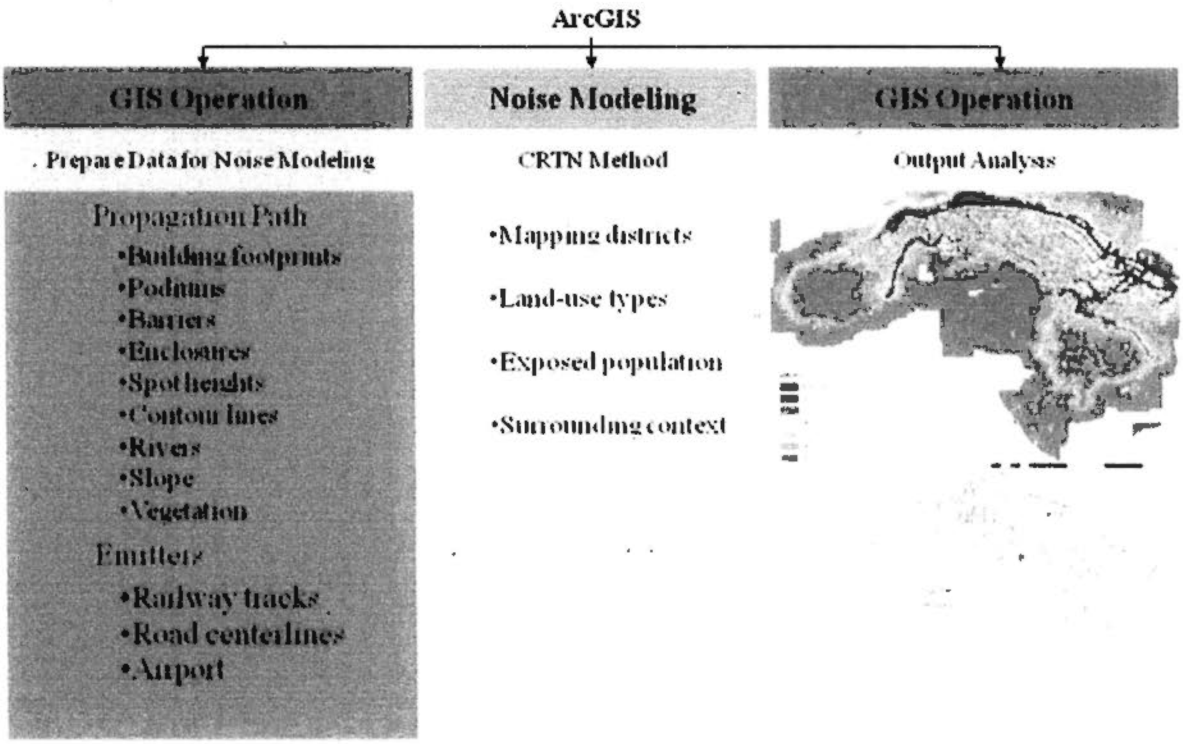



Figure 3.4 Calculation flow

### 3.3.2 NEST system

The system integrating the noise mapping software LIMA, the GIS software ArcGIS and various sources of data in Hong Kong is known as the Noise Exposure System Tool (NEST) (Fig. 3.5). In this system, GIS software ArcGIS enables data input, data editing and presents the results in attractive 3D or 2D portrays. LIMA Environmental Noise Calculation & Mapping Software (Version 5.0) is used to model road traffic noise. The prediction module used is UK's national road traffic noise calculation standard, the Calculation of Road Traffic Noise 1988 (CRTN). In this study, assessment was made for points located at 1m by 1m noise grids in all six selected districts, and vertically at 1.5 meters above the local ground simulating the height of ear of a normal person. After calculation, a 2D noise map, displayed through GIS interface, gave noise levels together with nearby buildings and roadways.

The input data for NEST included digital topographic map, building layout, height and podium, roads segments and type, surface texture, screening structure as well as traffic flow data in terms of speed, volume and percentage of heavy vehicles. The digital maps and road traffic flow data were obtained from the Land Department and the Transport Department respectively. Air photos were used to check ground conditions and road configuration. Digital terrain models with roads, railways, buildings and traffic parameters were established using these data. Other data of road segments, buildings, barriers, and terrain were inputted to form a 3D model.

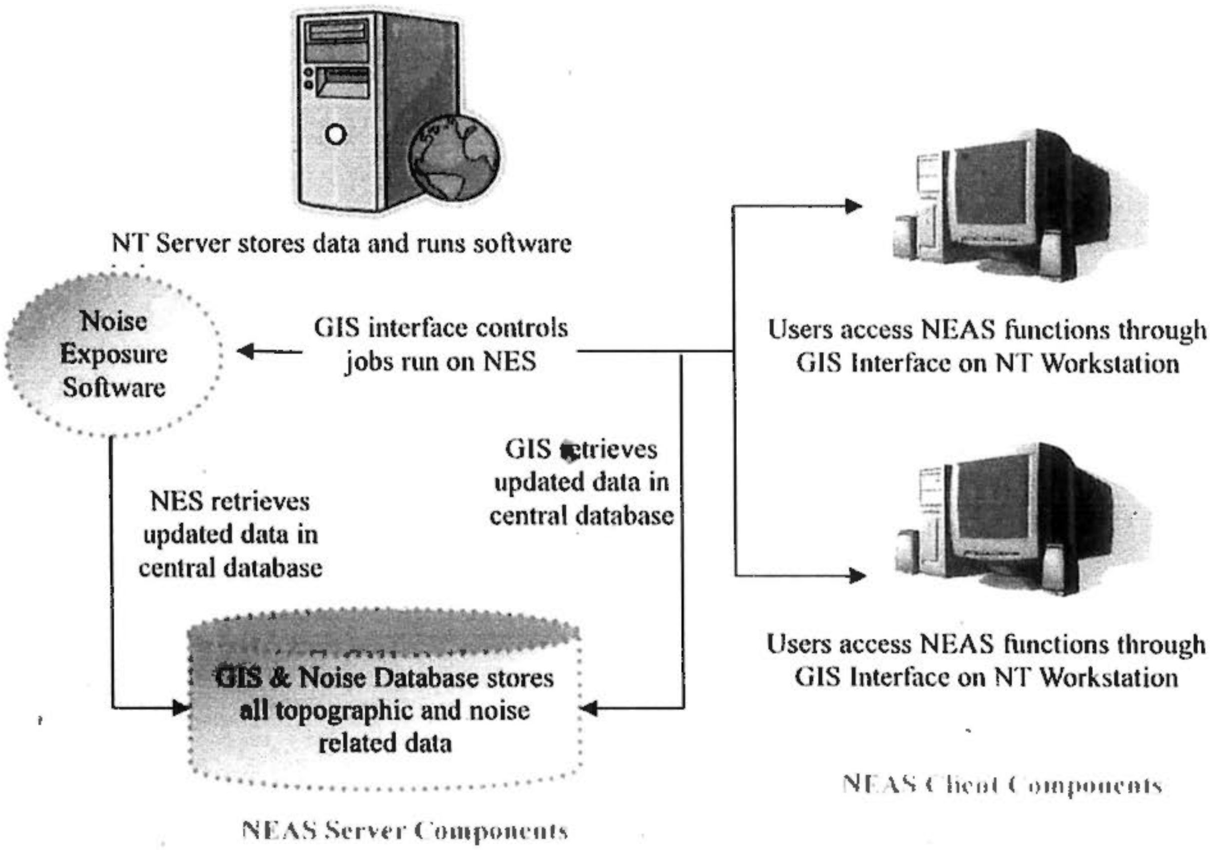



Figure 3.5 Noise Exposure System Tool (NEST)

As earlier indicated, it was not possible, for a project of this nature and duration, to model the whole of Hong Kong. The six administrative districts mapped included, Central and Western, Yau Tsim Mong, Wan Chai, Sha Tin, Tai Po and Sham Shui Po. The calculated noise levels were displayed in different colors according to different categories of noise levels. Through this model, areas exposed to road traffic noise with $L_{Aeq}$ less than 60 dB (A) $L_{10}$ (1h) were delineated for subsequent identification of quiet open spaces. The choice of 60 dB (A) rather than 55 dB (A) was made because of the compact urban setting of Hong Kong and the resultant high level of road traffic noise.

### 3.3.3 Determination of spatial attributes of quiet open spaces

The noise contour map is a graphical representation of noise levels in the city. The spatial characteristics of quiet open spaces were determined by overlaying the noise map on land use maps and population distribution. An output map gives a clear picture of noise distribution and illustrates how the road traffic noise affects the nearby residents.

Defined as areas with road traffic noise levels below 60 dB (A) $L_{10,\ 1h}$, quiet areas were delineated and presented in color for further processing. Land-use map was overlain with noise contour map, and hence the quiet open spaces were identified. These identified quiet open spaces were subsequently analyzed, in GIS, in terms of accessibility and size. Only those that were accessible and larger than 5000 $m^2$ were selected as candidates for further selection by relating to the type of open space. The estimation for the proportion of population exposed to traffic noise beyond 70 dB (A) $L_{10,\ 1h}$ was derived by overlaying the noise maps on an urban GIS-based dataset of buildings, dwellings and population in the buildings.

## 3.4 Characterizing the Soundscape

While some previous studies used laboratory simulation (Lam *et al.*, 2004a; Ma and Yano, 2004) to study human evaluation of outdoor soundscape, such an approach has limitations (Lam *et al.*, 2009a). Recognizing the limitations of laboratory simulation, this study adopted the approach of sound monitoring and interview with park users in the field. The work was carried out in the summer and autumn of 2008 at 25 study sites in Hong Kong. Table 3.1 gives the background information of these sites. Among the 25 selected sites, there is significant variation in physical conditions, urban morphology, and demographic and behavioral attributes of the visitors. At each study site, different functional zones were identified. Sound recordings and on-site interviews were performed at different functional zones of the study sites and at different times, which yielded a total of 210 sets of 15-minute field recordings with concurrent field observation, as well as 1610 successful interviews. Appendix C shows the number of successful interviews in different time of the day and at different functional zones.

Table 3.1 Basic information of the study sites

| Study sites | District | Main functions | Development history |
|---|---|---|---|
| Status Square<br>Monument<br>Charter Garden<br>Hong Kong Park<br>Harcourt Garden | Central and Western | Mixed commercial and residential area: the central Business District of Hong Kong with the oldest residential zone in the west | One of the first developed areas in Hong Kong, old buildings with less than 20-stories are common in Western but modern high-rise skyscrapers in Central |
| Cultural Center<br>Avenue of Stars<br>Clock Tower<br>Kowloon Park<br>Macpherson Playground<br>Sai Yee Street Garden<br>Mong Kok Road Playground | Yau Tsim Mong | Mixed commercial and residential area, building blocks and roads are interconnecting with each other in a grid form | Old urban areas |
| Victoria Park<br>TLW Garden<br>Wan Chai Park | Wan Chai | Mixed commercial and residential area | Old urban area |
| Sha Tin Park | Sha Tin | New residential area | New town developed since the 1980s |
| Tai Po Waterfront Park<br>Wan Tau Kok Playground<br>Wan Tau Kok sitting-out area<br>Tai Po Central Town Square<br>Tai Po Tau Playground | Tai Po | Newly developed residential areas with an industrial estate in the east: proclaimed a new town with numerous tall buildings erected in an orderly manner and the third lowest population density | Used to be a simple rural town, which has been gradually transformed into a thriving modern town over the years |
| Shek Kip Mei Estate<br>Shek Kip Mei Sports Ground<br>Sham Shui Po Park (1)<br>Sham Shui Po Park (2)<br>Shek Kip Mei Park | Sham Shui Po | Old residential area: building blocks and roads are interconnecting with each other in a grid form | Second oldest residents |

### 3.4.1 Sound walk

In order to unravel the sonic factors that characterize a place, sound walk was undertaken. This was conducted at different functional zones in each selected study site. The listeners at each location identified the sound sources, evaluated the acoustic quality and highlighted particular sound events during the walk. The time for one walk lasted for a maximum of half an hour, corresponding to the distance people could cover on foot in an average city by keeping certain homogeneity. These sound walks were done by student helpers with normal hearing ability. They also noted the profile of the main group of visitors and the activities undertaken.

### 3.4.2 Field recording

To capture the acoustic characteristics, field recording was conducted simultaneously with sound walks. The recordings were made with a Brüel&Kjær 4101 Binaural Microphone in conjunction with a SONY PC204AxDAT Recorder (Figure 3.6). The binaural recording technique was used instead of the single channel technique because one-channel measurements were unable to represent the environmental sound quality and the human response in a complex environmental sound situation was constituted by several spatially distributed sound sources.

The sound recordings were performed at the height of the walker, so that obtained signals could better simulate the natural binaural listening behavior of pedestrians. Each recording lasted for 15 minutes. In order to avoid any sound caused by the interaction between ear and microphone during the period of measurement, the recording was set to pause while the listener was walking. Sound recordings were saved in Sony DDS-1 4GB/Premium 90P 2GB DAT tapes. The sampling sound clips' time and its corresponding recording time are marked down as reference for latter analysis.


Figure 3.6 B&K 4101 Binaural Microphones (left) and Sony PC204AxDAT Recorder (right)

### 3.4.3 Acoustic analysis of the audio recording

All the sound clips were played back in the laboratory where the dual channel audio signals were combined and transferred to Brüel & Kjær type 2250 Investigator in conjunction with Application Software Evaluator Type 7820 for the determination of commonly used metrics such as $L_{Aeq}$ and one third octave frequency spectrums in one-second intervals. The AC input sensitivity for the transmission of data to the Brüel & Kjær type 2250 investigator was adjusted before downloading data. The sound recordings were also analyzed to obtain some psychoacoustic measures using Brüel & Kjær PULSE Sound Quality software. Graphs and tables for the obtained numerical data were presented in standard forms, which were then exported to Microsoft Excel or SPSS format for calculation and analysis. Such data were also used to prepare spectrograms which showed the variation of sound intensity and spectral characteristics over time.

The post-processing of sound recordings began with conventional acoustical analysis in terms of spectrum, keeping tracks of the A-equivalent sound level and other measuring parameters, which are listed in Table 3.2. The acoustical and psychoacoustic variables represent objective physical indicators of the sonic environment experienced by the respondents. Frequency spectrum can also be used to identify sound sources and make comparison with sound walk notes. By integrating the quantitative and qualitative data, soundscape characteristics will be fully understood.

Table 3.2 Psychoacoustic metrics and acoustical matrics

| | | | | | |
|---|---|---|---|---|---|
| Psychoacoustic Variables | Stationary Loudness [sones] | Roughness [asper] | Fluctuation Strength [vacil] | Tone-To-Noise Ratio [dB] | Prominence Ratio [dB] |
| | Statistical Loudness Max [sones] | Statistical Inst. Loudness[sones ] | Zwicker Sharpness [acum] | Aures Sharpness [acum] | |
| Acoustical Variables | $L_{Aeq}$ [dB] | $L_{Ceq}$ [dB] | $L_{Zeq}$ 12.5Hz ~20kHz[dB] | $L_{10}$ [dB(A)] | $L_{50}$ [dB(A)] |
| | $L_{90}$ [dB(A)] | $L_{Cpeak}$ [dB] | $L_{AE}$ [dB] | $L_{AFTeq}$ [dB] | |

### 3.5 On-site Interview

At the locations where interviews with the visitors were undertaken, 15-minute sound recordings were made within an hour of the interview. The park users were interviewed using a structured questionnaire (Appendix A).

#### 3.5.1 Questionnaire design

The questionnaire was initially developed in Chinese, translated into English and translated back to Chinese to ensure that the meaning of the questions was clear. Some questions were expressed on a Likert-type scale from one to five; for example 1, very bad; 2, bad; 3, moderate; 4, good; 5, very good. Others were open questions. Recognizing that most people may find it difficult to talk about issues concerning the sonic environment as some sounds are hard to verbalize, the questionnaire was designed not to elicit desired answers by presenting only questions with fixed answers. A combination of structured and open-ended questions allowed probing into issues pertaining to soundscape evaluation.

Semantic differential method was used for perceptual and cognitive questions because it could elucidate the relationship between the environment and an individual. In this study semantic differential scales were applied to determine important factors that described soundscapes in the urban open spaces. People were asked to evaluate the acoustic quality with the help of a list of opposing adjectives, such as noisy-quiet, artificial-natural and joyful-depressing. The polar oppositions can serve as a catalyst capable of evoking emotions and memories, which are hard to verbalize, when connected to the sounds of a site. The adjectives were presented across a numerical range of five points in order to find out how well these adjectives described the soundscape portrayed and the sound preference could thus be studied systematically with polar oppositions. This method enables awareness of the connotations and emotional meanings which are attached to the sounds in a certain place.

The questionnaire was constructed in a progressive way, starting with general questions about the visitors' visiting habits, place of residence, transportation method, visiting frequency, visiting time as well as main activities. In order not to influence the judgment or attract the attention of participants into predefined questions for soundscape evaluation, questions in the second part were couched as an evaluation of the total environmental quality. This was then followed by questions on visitors' degree of liking of the acoustic environment. Perceptual variables in terms of quietness, naturalness and joyfulness were used to evaluate the influence of affective attributes that visitors ascribed to the sonic environment. In the third part, visitors were asked to nominate the sounds they heard on site and to identify the degree of preference of individual sound sources. Finally, visitors' personal information, including age, gender, and occupation status as well as education background was collected. The whole questionnaire was ended by an evaluation of the performance of the interviewees.

### 3.5.2 Conduct of the interview

Interviews were conducted by three well-trained student helpers, who had fully understood the objectives of the study, the execution procedures, and most importantly, were familiar with the way to ask questions listed in the questionnaire. To obtain a representative sample of subjective perception of the acoustic environment, visitors to the study sites were sampled for the interview. Despite the respondents were, strictly speaking, not selected randomly, extra care was exercised to ensure that visitors of different ages, sex and undertaking activities were sampled.

The interview based on the questionnaire took about ten to fifteen minutes to complete. In total, over 1630 visitors responded, out of whom 1610 successfully completed the interview. The interview took place at all the 25 selected study sites.

People had been approached while they were inside a particular functional zone of the study sites. To avoid inducing responses, the interviewers were instructed not to mention that the research was to study the soundscape or acoustic quality. Instead, they were told that the interview was about the general environmental quality which was a more general aspect. During the process of interview, necessary explanation was given in face of any difficulties in understanding the questions.

### 3.6 Data Analysis

Data analysis involves three major steps, done roughly in the order of organizing the data for analysis, describing the data and then testing hypotheses and models for inferential results. A good preparation of data links to better interpretation that is specifically related to research questions raised at the beginning of the study. Field work results in terms of the physical recording, observation and interview feedbacks were all coded into Statistical Package of Social Science (SPSS).

In this study, a large number of people have been interviewed which yielded lots of data. Descriptive statistics and graphic representation of the data provided quantitative information of the sample and measurements. Descriptive statistics simplified the large amount of data in a sensible way. Correlation is one of the most common and useful statistics describing the degree of relationship between two variables. Correlation coefficient indicates whether the relationship is caused by chance or statistically significant.

Inferential statistical methods were also employed to reach conclusions from the immediate data. In this study, general opinions of the whole population were inferred from the sample by using inferential statistics. A majority of inferential statistics come from a general statistical model known as General Linear Model, such as T-test, Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA), Regression Analysis as well as other multivariate methods like Discriminant Function Analysis. These methods were applied in different sections of this study. Preferences of visitors for sound sources and the acoustic quality were analyzed and compared among different types of urban open spaces using Analysis Of Variance (ANOVA). T-test was used to compare the average performance between two groups or categories of sample. Discriminant Analysis and Logistic Regression Models were used to divide the soundscapes into meaningful groups based on their similarity.

## 3.7 Summary

This chapter provides the methodological framework of the whole study. To characterize the soundscape and understand the acoustic quality, this study was carried out by combining the subjective and objective evaluations of the acoustic environment. The physical acoustic environment was characterized by field recording and sound walk observation, while the perceptual acoustic quality was evaluated by conducting on-site interviews. In total, 25 open spaces located in six administrative districts with different characteristics were selected for field recording and on-site interview. All data obtained were analyzed by using SPSS software. Descriptive and inferential statistic methods were employed at different stages of the study. Results will be presented in the following chapters.

*"Sounds good" mustn't necessarily be quiet…it is rather a space where the sonic ambience seems to be adequate……*

------ *The Sonic Identity of European Cities*,
Pascal Amphoux, 1993: 7

# Chapter 4

# Quiet Open Spaces in the City: Spatial and User Characteristics

Chapter 4 attempts to identify quiet open spaces in urban Hong Kong, examine their spatial distribution, and determine their main users. Noise mapping technique was used to locate quiet open spaces, and interviews were conducted to determine the socio-demographic characteristics of their users. The spatial and user characteristics of these spaces lead to a better understanding of soundscape evaluation in Hong Kong.

## 4.1 Road Traffic Noise in the Urban Region of Hong Kong

The first task of this study aimed at identifying quiet open spaces in urban Hong Kong. In Europe noise mapping is commonly adopted to identify quiet areas. As stated in the European Directive on the Assessment and Management of Environmental Noise (END), EU Member States need to clarify definitions of quiet areas. Although there is no common definition, the criterion in terms of noise limit value fall in the range 45-55 dB (A) for quiet areas in urban agglomerations, and40-45 dB (A) for open country. Noise mapping has been used in this study, but a different criterion is adopted in defining the quiet areas in Hong Kong.

With its high-rise buildings forming a concrete jungle, Hong Kong is one of the most densely populated cities in the world. In such a compact urban setting, the transportation network is dense and roadways are often situated next to residential buildings (Lam *et al.*, 2009a). The resulting high levels of traffic noise undermine the quality of urban living. The importance of a pleasant urban acoustic environment has prompted many sectors, including the government, to search for appropriate approaches to urban noise control. The adoption and evaluation of noise control strategies require data on the noise exposure of urban inhabitants. In quantifying the urban acoustic environment, the first step is to obtain the noise levels of the city area and provide estimates on the noise exposure of the urban population (Brown and Lam, 1987). Toward this end, noise mapping may be utilized. By mapping those areas of the city where traffic noise levels are high, quiet areas can be delineated and they are where sound sources other than traffic may dominate, including those that are currently used as urban open spaces.

Traditional noise prediction methods are not applicable to large urban regions and areas with complicated urban morphology and building and road configurations. Even if they are, noise prediction would be a formidable and time-consuming task, particularly for compact and densely populated cities. Noise mapping has taken advantage of recent advances in noise prediction methods, geographical information systems (GIS), and micro-computing technology to develop cost-effective and relatively reliable tools for estimating the acoustic environment of cities, as well as the noise exposure of inhabitants.

This study focuses on road traffic noise only because previous studies (Lam *et al.*, 2009a; Lam, 2009) suggest that road traffic noise is the dominant noise source in the city. Quiet areas so identified form a set of candidates for further in-depth investigation. Using the methods described in Chapter 3, we delineated the quiet urban areas. Subsequently, we estimated the percentage of areas exposed to traffic noise lower than 60 dB (A) $L_{10,\ 1h}$ (Table 4.1). For particular application in Hong Kong, road traffic noise is represented by dB (A) $L_{10,\ 1h}$[1], for the hour having the peak of traffic flow. Table 4.1 shows the percentage of population exposed to high levels of traffic noise over 70 dB (A) $L_{10,\ 1h}$ based on EPD estimates.

[1] $L_{10,\ 1h}$ is the noise level exceeded for 10% of the 1 hour period. It is generally used to describe traffic noise during the hour of peak traffic flow.

Table 4.1 Characteristics of traffic noise exposure

| District# | Area ($km^2$) | Population* | >70 dB (A) * (% of population) | < 60 dB (A) (% of area) |
|---|---|---|---|---|
| CW | 12.4 | 259,400 | 15.7 | 66.5 |
| SSP | 9.4 | 345,900 | 26.1 | 24.4 |
| ST | 68.7 | 621,000 | 15.5 | 20.4 |
| YTM | 7.0 | 276,800 | 37.1 | 22.3 |
| TP | 136.2 | 308,500 | 17.4 | 44.6 |
| WC | 9.8 | 164,500 | 24.9 | 57.1 |

#: CW – Central & Western; SSP – Sham Shui Po; ST – Sha Tin; YTM - Yau Tsim Mong; TP – Tai Po; WC – Wan Chai.
*Source from: http://www.epd.gov.hk

As shown in Table 4.1, despite the actions and measures taken by the government to reduce road traffic noise, a significant proportion of people are still exposed to road traffic noise exceeding 70 dB (A) $L_{10,\ 1h}$, which is the planning criterion in Hong Kong. This reflects urban density and the proximity of dwellings to roads, which are caused by a combination of factors, including the scarcity of habitable land, high population density, and a dense transportation network. The percentage of areas exposed to traffic noise less than 60 dB (A) $L_{10,\ 1h}$ varies across different administrative districts. Central and Western District and Wan Chai District have relatively higher percentages of areas exposed to traffic noise less than 60 dB (A) $L_{10,\ 1h}$. Of the six selected districts, two commercial and business districts have relatively more areas exposed to traffic noise less than 60 dB (A) $L_{10,\ 1h}$. The explanation can be found by overlaying the noise contour maps (Figure 4.1–4.6) with other land use and transport infrastructure maps.

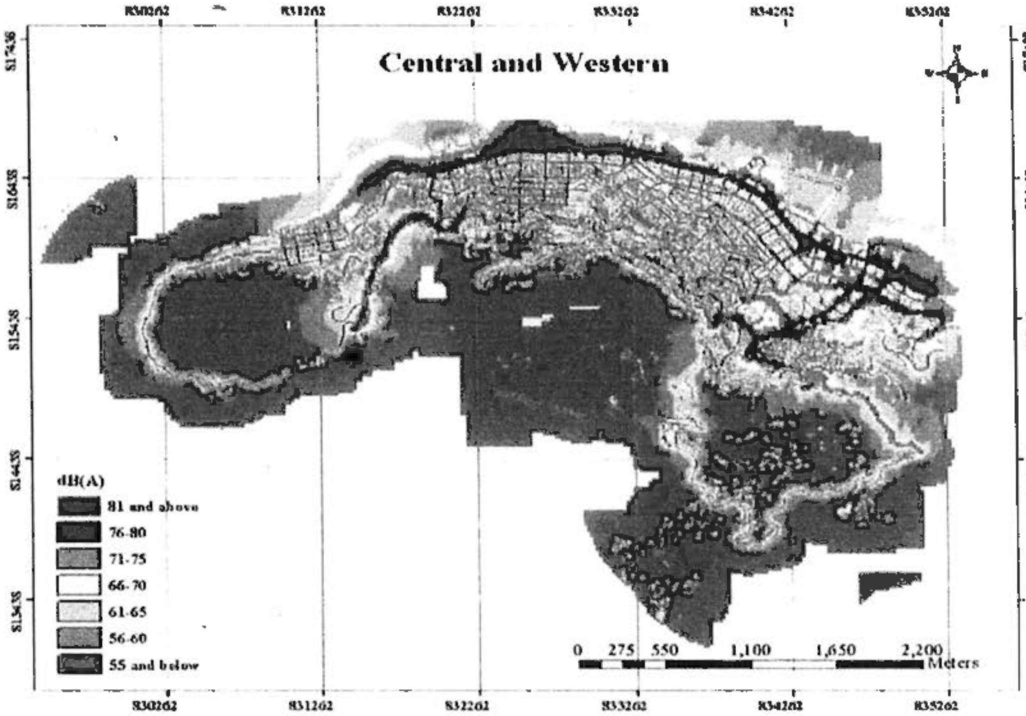



Figure 4.1 Traffic noise exposure level in Central and Western District

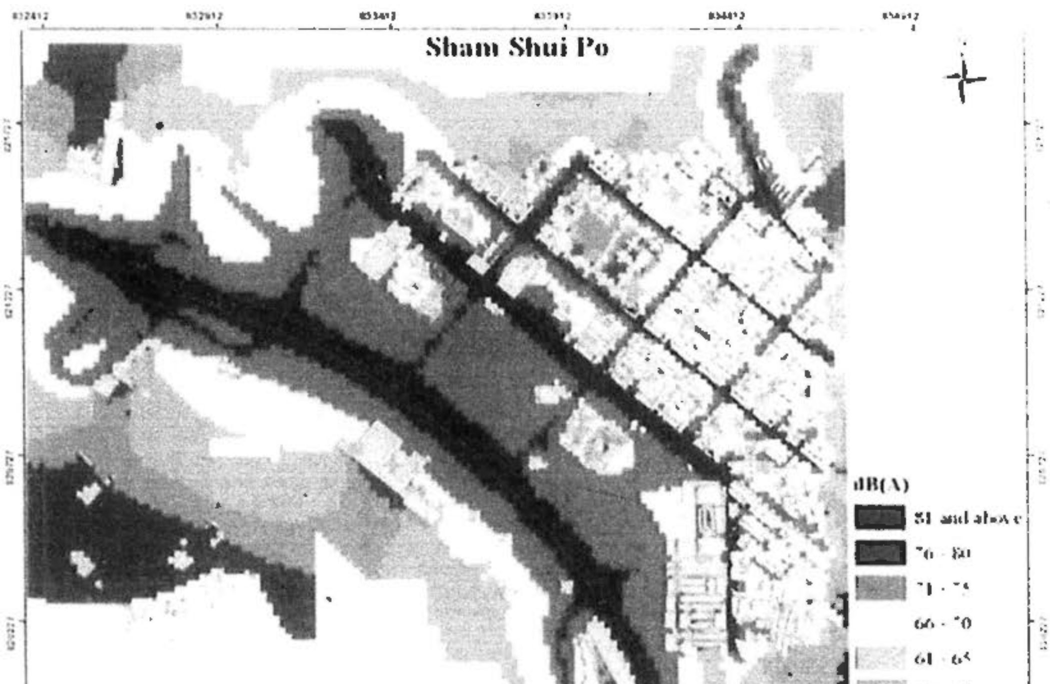



Figure 4.2 Traffic noise exposure level in Sham Shui Po District

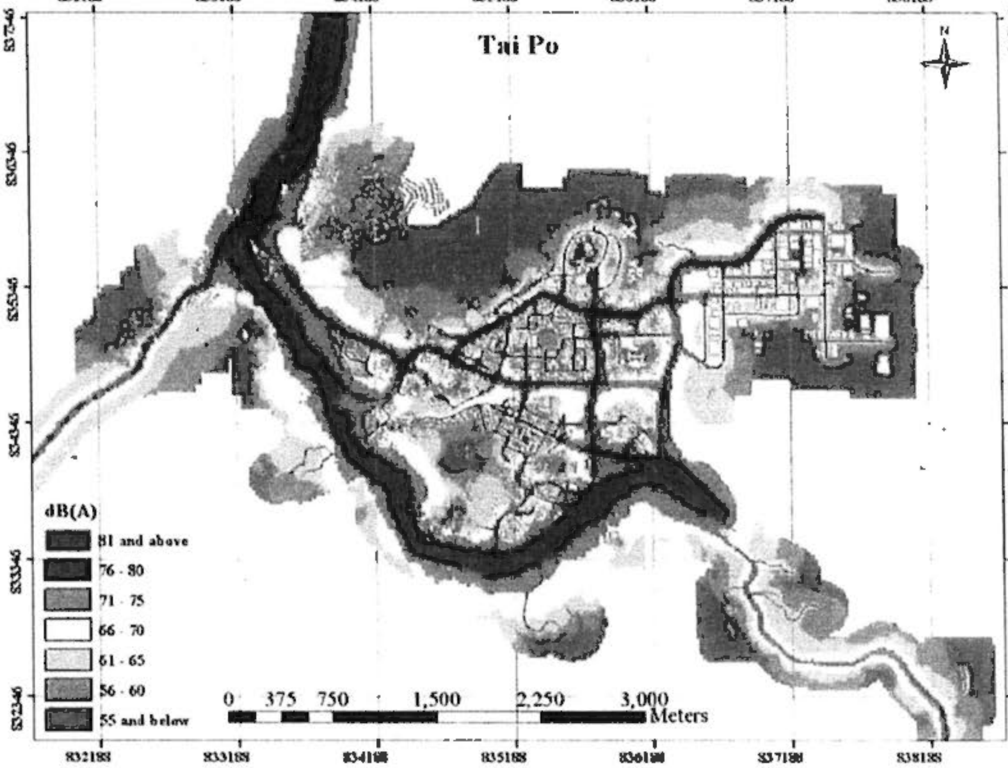



Figure 4.3 Traffic noise exposure level in Tai Po District

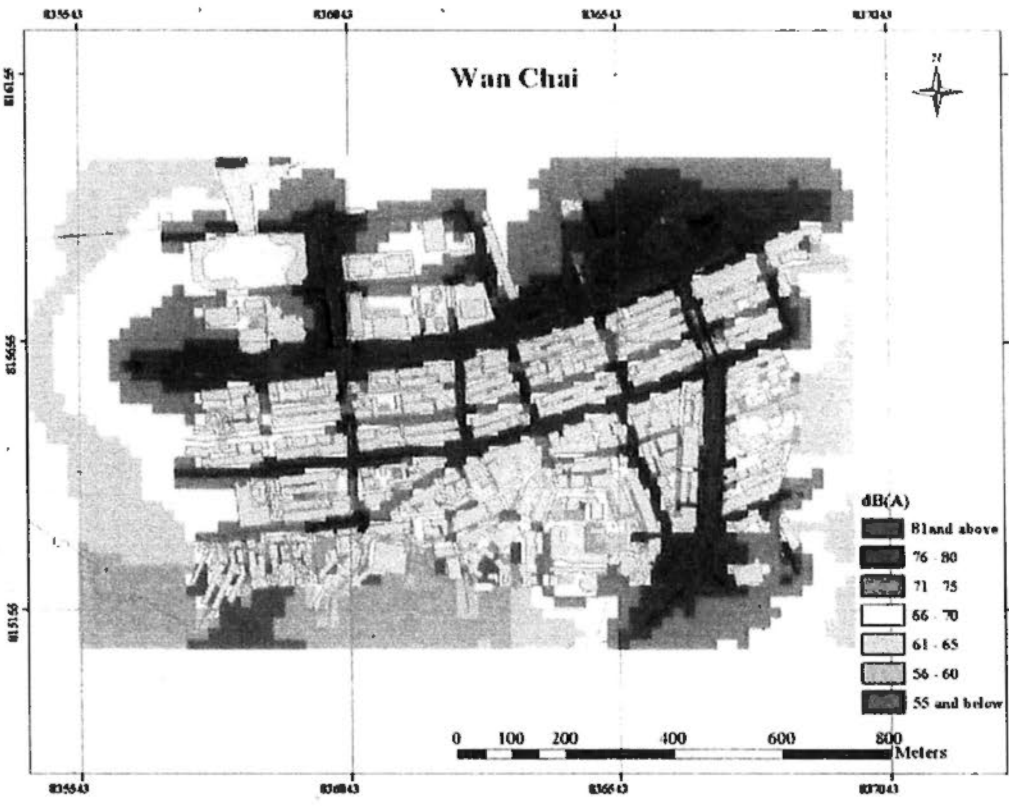



Figure 4.4 Traffic noise exposure level in Wan Chai District

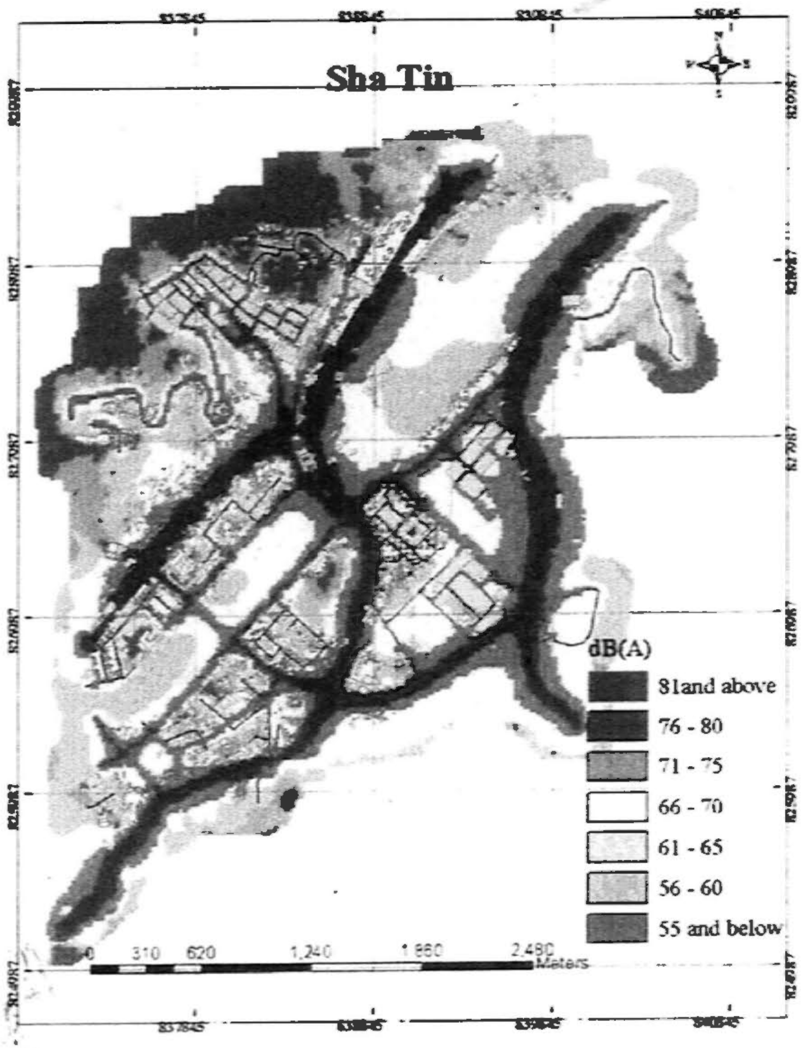



Figure 4.5 Traffic noise exposure level in Sha Tin District


Figure 4.6 Traffic noise exposure level in Yau Tsim Mong District

## 4.2 Location of Quiet Areas in the Urban Region

Quiet areas feature quietness inside urban agglomerations; hence, they can be regarded as a special type of soundscape where people can temporarily recover from urban stress and restore their health and well-being (Brambilla and Maffei, 2006). Such areas are sometimes known as areas of high acoustic quality (Brown, 2006a). Clearly, these areas do not necessarily involve the absence of sound. While it would be erroneous to assume that places exposed to high levels of traffic noise cannot be places of high acoustic quality, quiet places in the city are more likely to qualify for such places. Hence, this study begins with a search for quiet areas in the city through noise mapping.

Quiet areas are particularly important in Hong Kong, a unique, dense, and compact city where high-rise buildings abound. With a population of 6.8 million concentrated in an urban area of slightly over 200 km$^2$, the city's population density is one of the highest in the world (Lam *et al.*, 2004b). The total area of Hong Kong is much larger than its urban area; urban development has been confined to Hong Kong Island and Kowloon Peninsula around Victoria Harbor and a number of new towns in the New Territories. Outside the urban boundary, much of the lands are either designated as country parks and water gathering grounds or are impossible and costly to develop because of their steep and rugged terrains. This results in a dense traffic network with consequent high levels of traffic noise. Under such circumstances, it is necessary to reduce noise levels in high exposure areas and protect soundscapes in quiet areas to provide urban dwellers with sonic refuge, which is important in maintaining their quality of life.

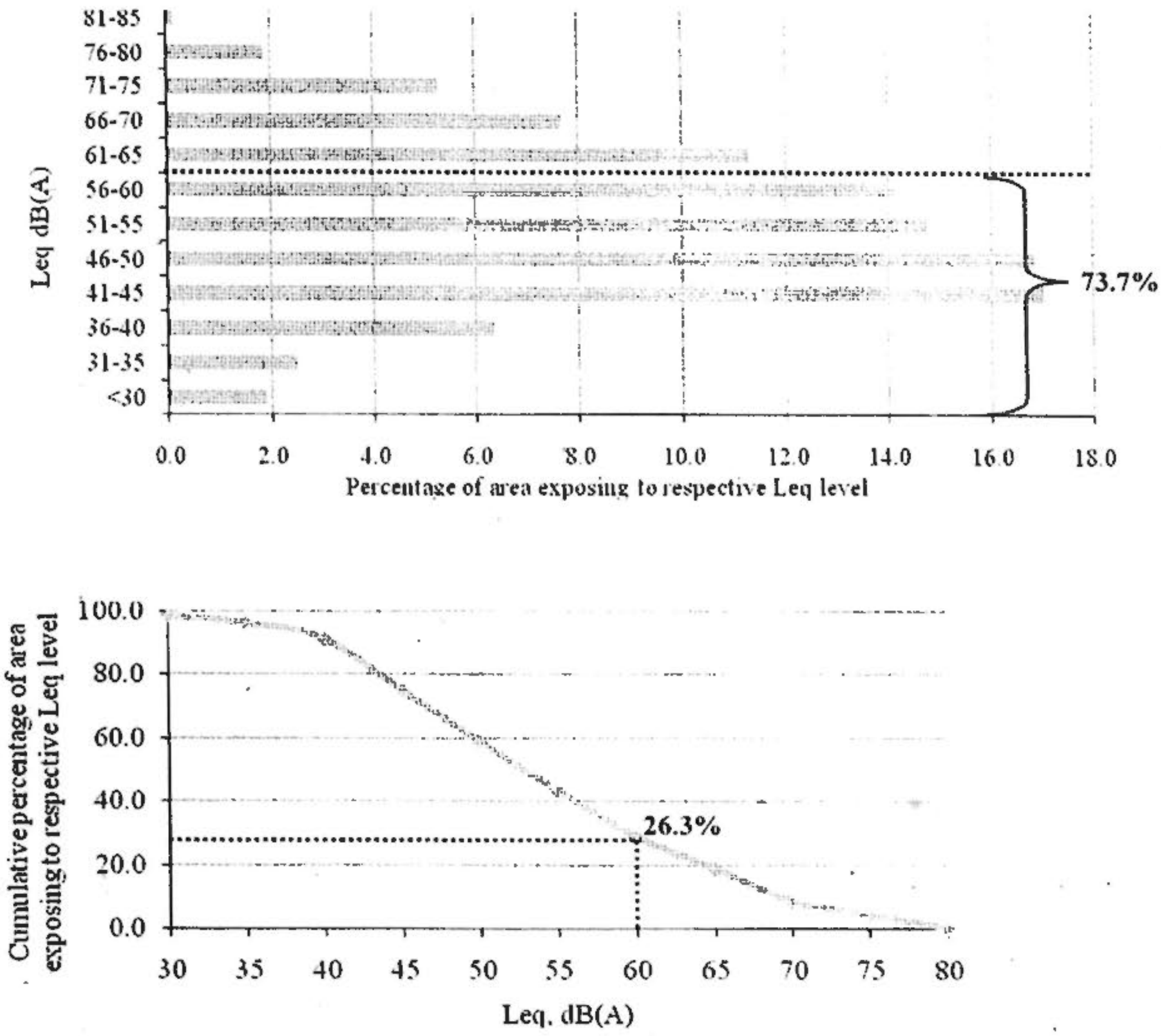
In this study, quiet areas are arbitrarily defined as areas exposed to road traffic noise less than 60 dB (A) expressed in terms of $L_{10,\ 1h}$. This is based on the assumption that traffic noise is the dominant noise in Hong Kong (Lam *et al.*, 2009b). While it is recognized that the criterion used in this study, 60 dB (A) $L_{10,\ 1h}$ [58.1 dB $L_{Aeq}$], is higher than that recommended by WHO (i.e., 55 dB $L_{Aeq}$), it is deemed more appropriate to use a less stringent criterion in Hong Kong because of its compact urban setting and the prevailing high noise levels.

To be consistent with the noise criterion used in noise planning in Hong Kong, which is expressed in terms of $L_{10,1h}$, this study adopts the following equation to convert $L_{10,1h}$ into $L_{Aeq}$ (Lam *et al.*, 2005a; Lam, 2009):

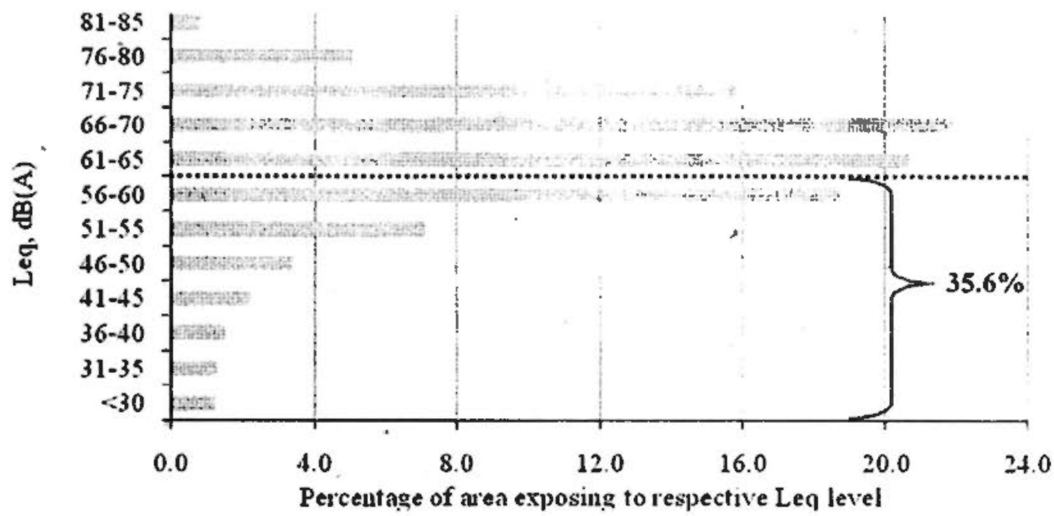
$$L_{Aeq} = 0.94\,(L_{10,1h}) + 1.7$$

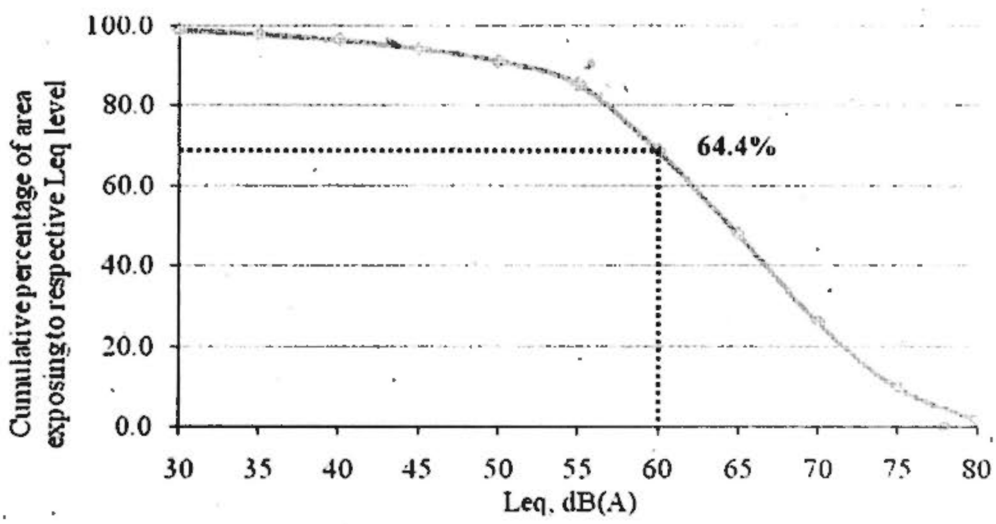
Figure 4.7 shows the noise exposure levels and cumulative frequency curves in the six selected districts. In general, the calculated traffic noise exposure levels range from 40 to 85 dB $L_{Aeq}$, and the distribution of traffic noise levels varies across the six districts.

(a) Central and Western District

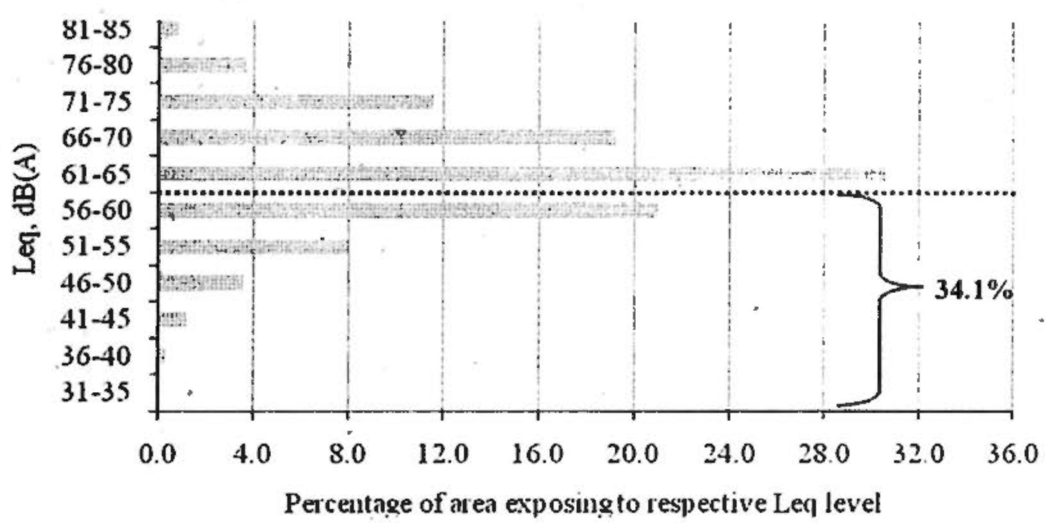


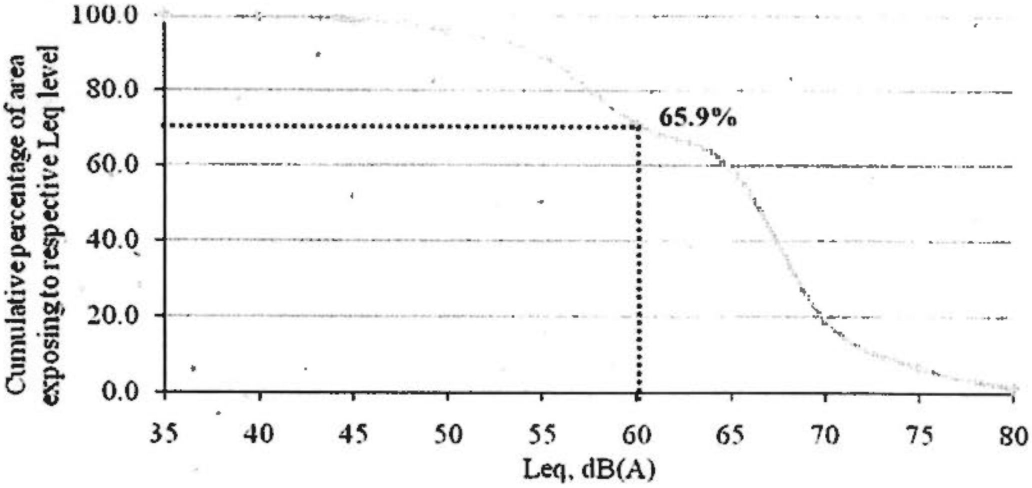
(b) Sham Shui Po District



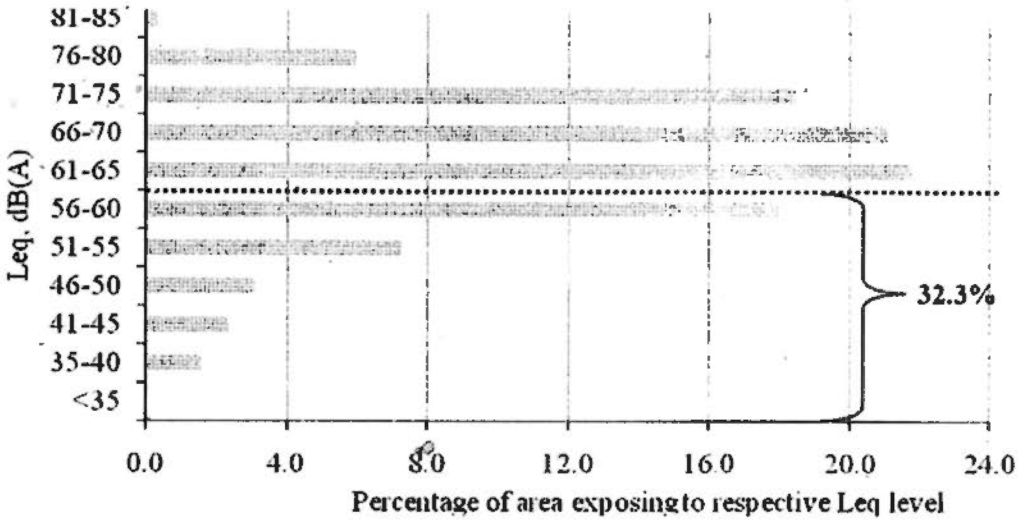



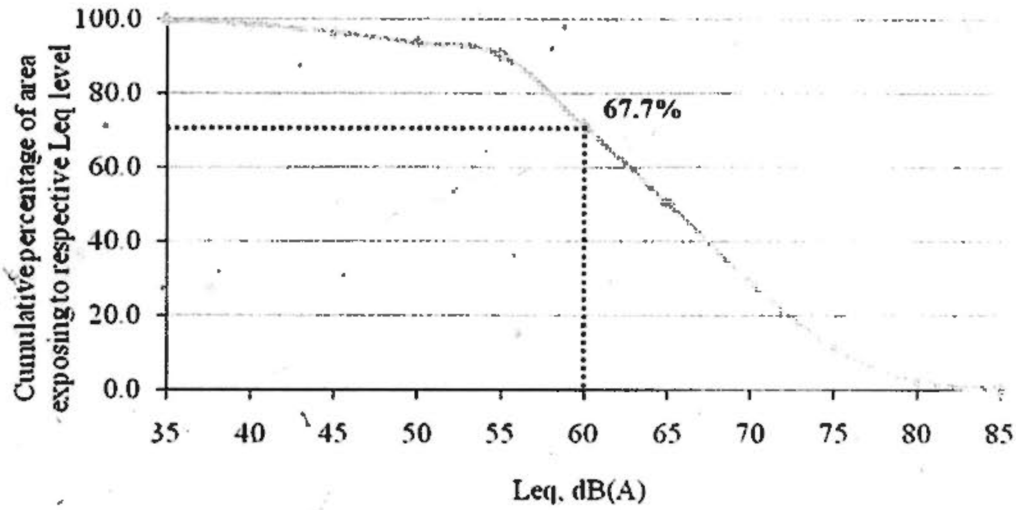

(c) Sha Tin District



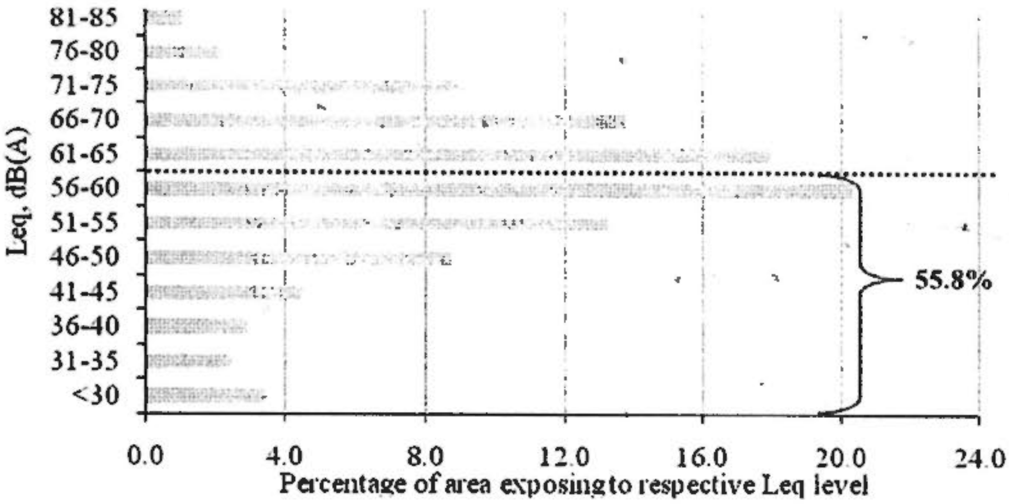


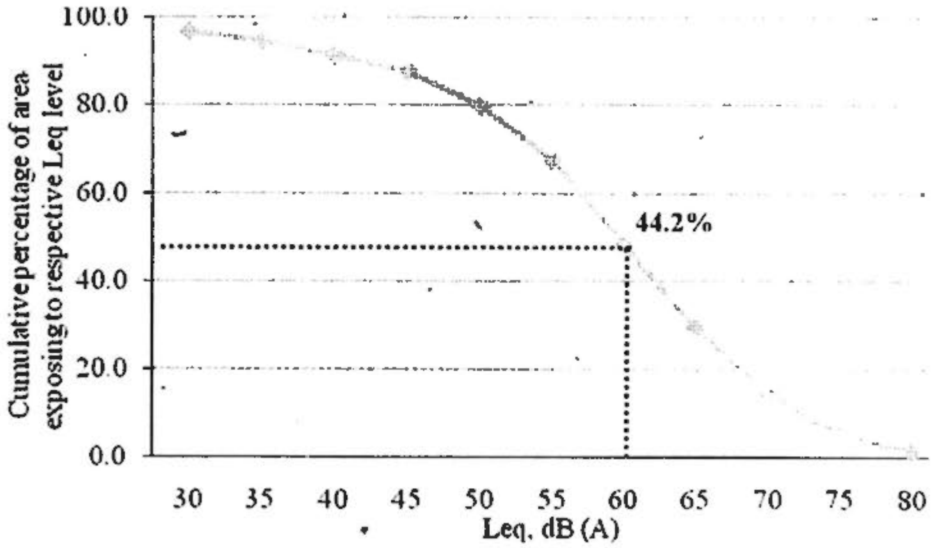

(d) Yau Tsim Mong District



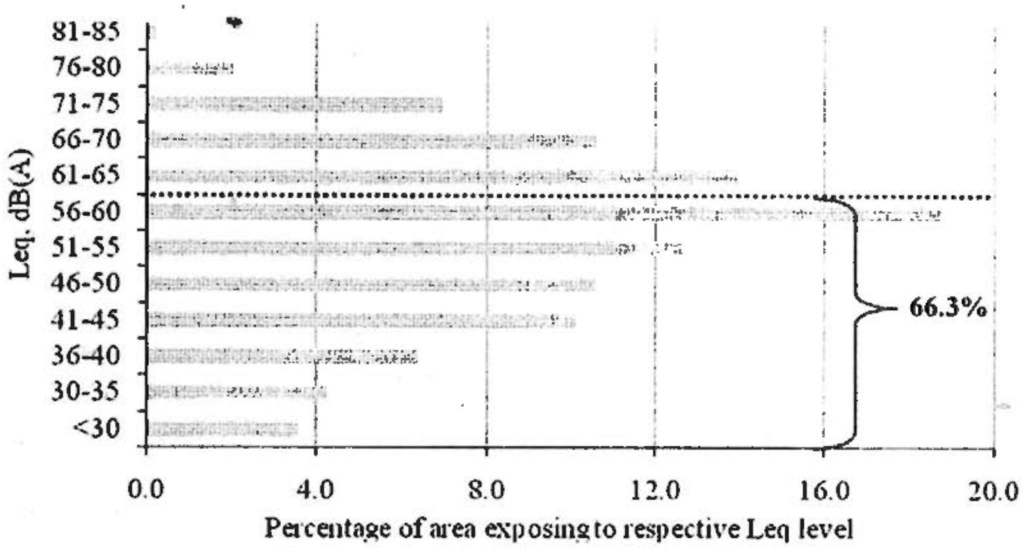



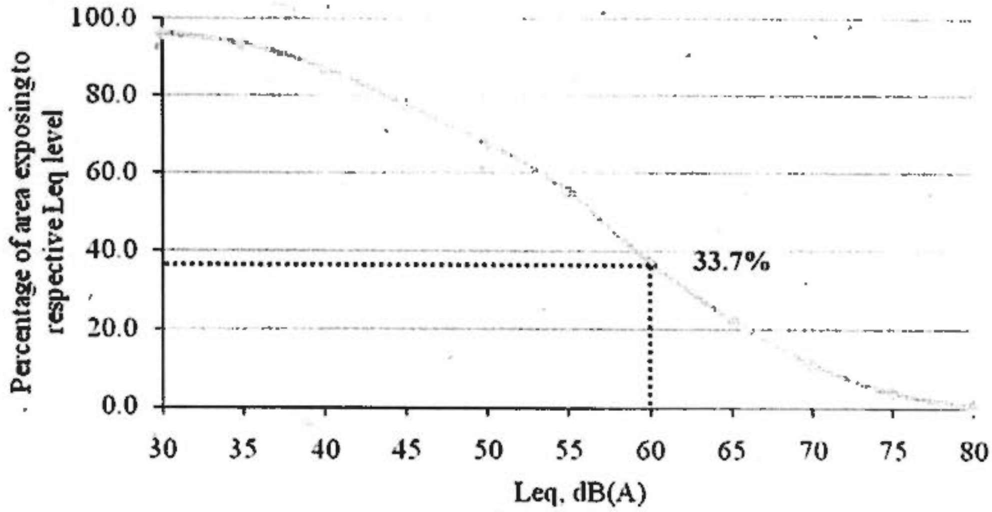
(e) Tai Po District




(f) Wan Chai District






*Note: the red dotted line highlights the criterion for quiet area, 60 dB $L_{Aeq}$

Figure 4.7 Percentage of areas exposed to respective $L_{Aeq}$ level and the cumulative curves for percentage of areas exposing to respective $L_{Aeq}$ level

For example, in the Central and Western District, there is a special reason why about two- third of the area is exposed to noise level below 60 dB $L_{Aeq}$. Urban development is concentrated in the northern coastal area, and a relatively large area in the southern part of the district is hilly and undeveloped. In fact, it is designated as a green area for conservation purposes by the planning authority (Figure 4.8). This green area is administratively within the boundary of the district; hence, the area exposed to noise levels less than 60 dB $L_{Aeq}$ is accordingly higher. Vehicular road access in the green area is very limited, resulting in relatively lower noise levels. Hence, caution must be exercised when interpreting data on low noise level exposure.

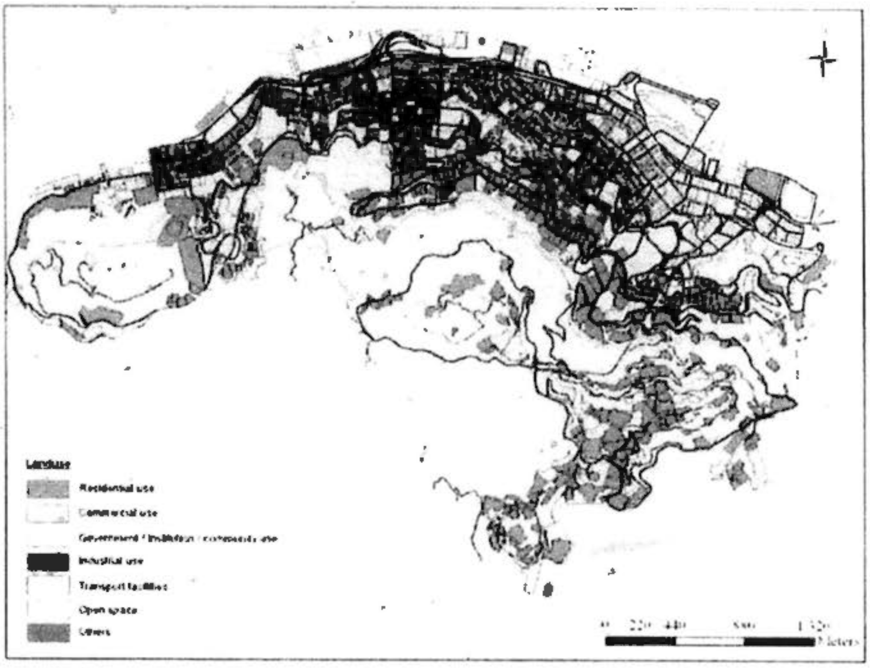


Figure 4.8 Land-use of the Central and Western District

Nearly half of Tai Po District and Wan Chai District is exposed to traffic noise less than 60 dB $L_{Aeq}$. Wan Chai is a mixed commercial and residential district, whereas Tai Po is a newly developed residential area with industrial factories in the east. Their respective land use types are shown in Figures 4.9 and 4.10. Despite different land use types in these districts, the impact of traffic noise is quite similar, with about half of the area exposed to traffic noise levels between 56 and 70 dB $L_{Aeq}$. The distributions of traffic noise exposure in both districts approximately obey the law of normal distribution (Figure 4.7), with their average noise levels being 56 and 60 dB $L_{Aeq}$, respectively.

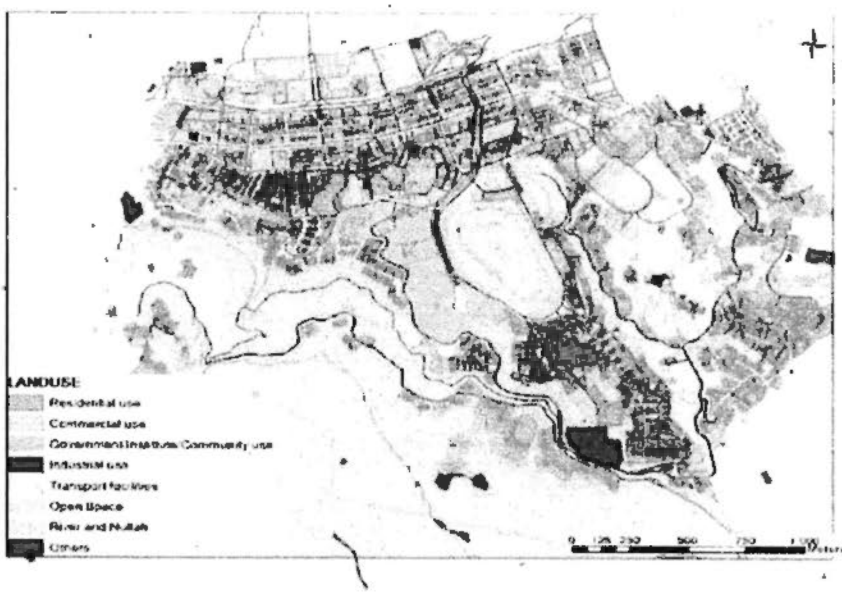


Figure 4.9 Land-use of the Wan Chai District

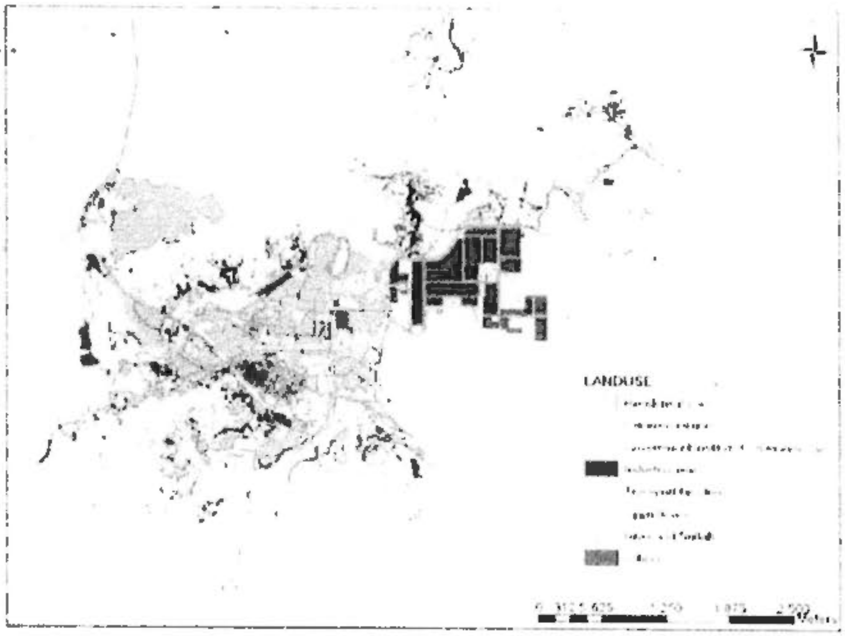



Figure 4.10 Land-use of the Tai Po District

Compared with the above two districts, noise levels in the other three districts (i.e., Sha Tin, Sham Shui Po, and Yau Tsim Mong) are much higher, with over than 60% of the area exposed to traffic noise exceeding 60 dB $L_{Aeq}$. This is attributed to the intensive network of roads penetrating the whole area, forming street canyons. Noise emanating from nearby roads reverberates between buildings, and such is difficult to reduce. Figures 4.11 and 4.12 provide spatial pictures of the land use schemes of the local districts. These pictures make it possible to analyze the direct causes of high noise levels and to determine suitable methods to control and manage noise intrusions.

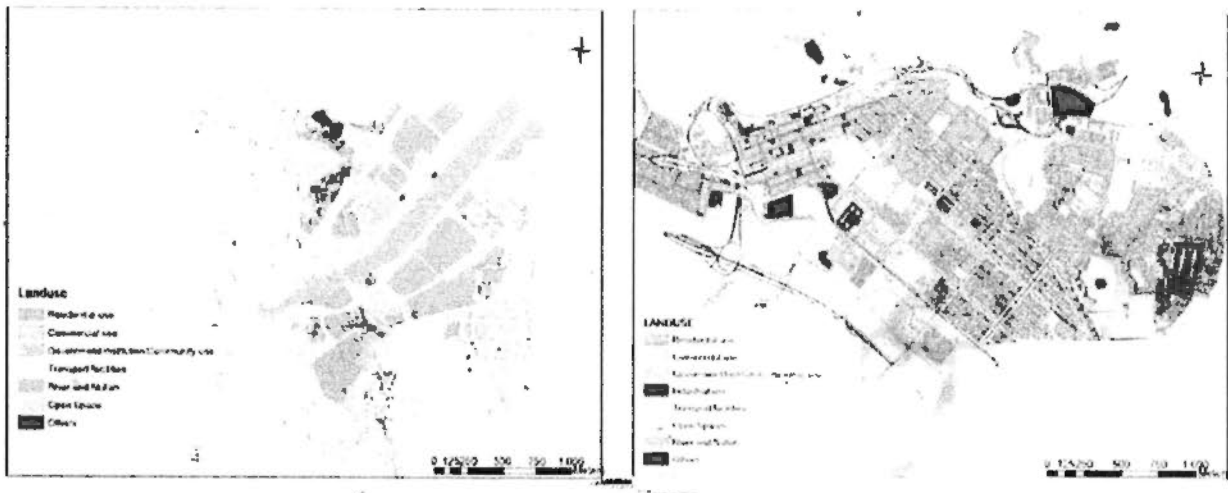



Figure 4.11 Land-use of Sham Shui Po (left) and Sha Tin (right) District

Figure 4.12 Land-use of the Yau Tsim Mong District

In summary, quiet areas in the six districts exposed to road traffic noise less than 60 dB $L_{Aeq}$ were delineated by noise mapping. The spatial components were integrated in the GIS database, and a number of layers were combined, including those on the location of residential buildings, roadways, land use types, and noise contours. In an earlier study, Lam (2009) examined the relationship between noise exposure and urban form in a compact and dense city like Hong Kong, and noted how hard it is to achieve significant noise reduction due to lack of space and multiple reflections from tall buildings in a street canyon environment (Lam, 2009). In tackling noise problems, it is increasingly being realized that there is a need to protect areas with high acoustic quality, take proactive steps to locate such areas, understand their acoustic and soundscape attributes, and prevent their further deterioration.

### 4.3 Spatial Distribution of Quiet Open Spaces

As elaborated in Chapter 3, the identified quiet areas were further overlain with land use maps to locate quiet open spaces that form a set of candidates for in-depth study. The candidate sites include urban parks, open spaces, and undisturbed outdoor areas at the fringe of the city, which are all recognized as open spaces according to planning guidelines.

Figure 4.13 shows the location of quiet open spaces as revealed by noise maps of the six districts, with the yellow color representing open spaces exposed to traffic noise less than 60 dB (A) $L_{10, 1h}$. Quiet open spaces vary in size and shape. Two types can be identified: one is smaller in size, surrounded by tall buildings, and the other is larger in size, usually located farther away from residential buildings. Spaces of the latter type are commonly large urban parks or even more remote country parks.

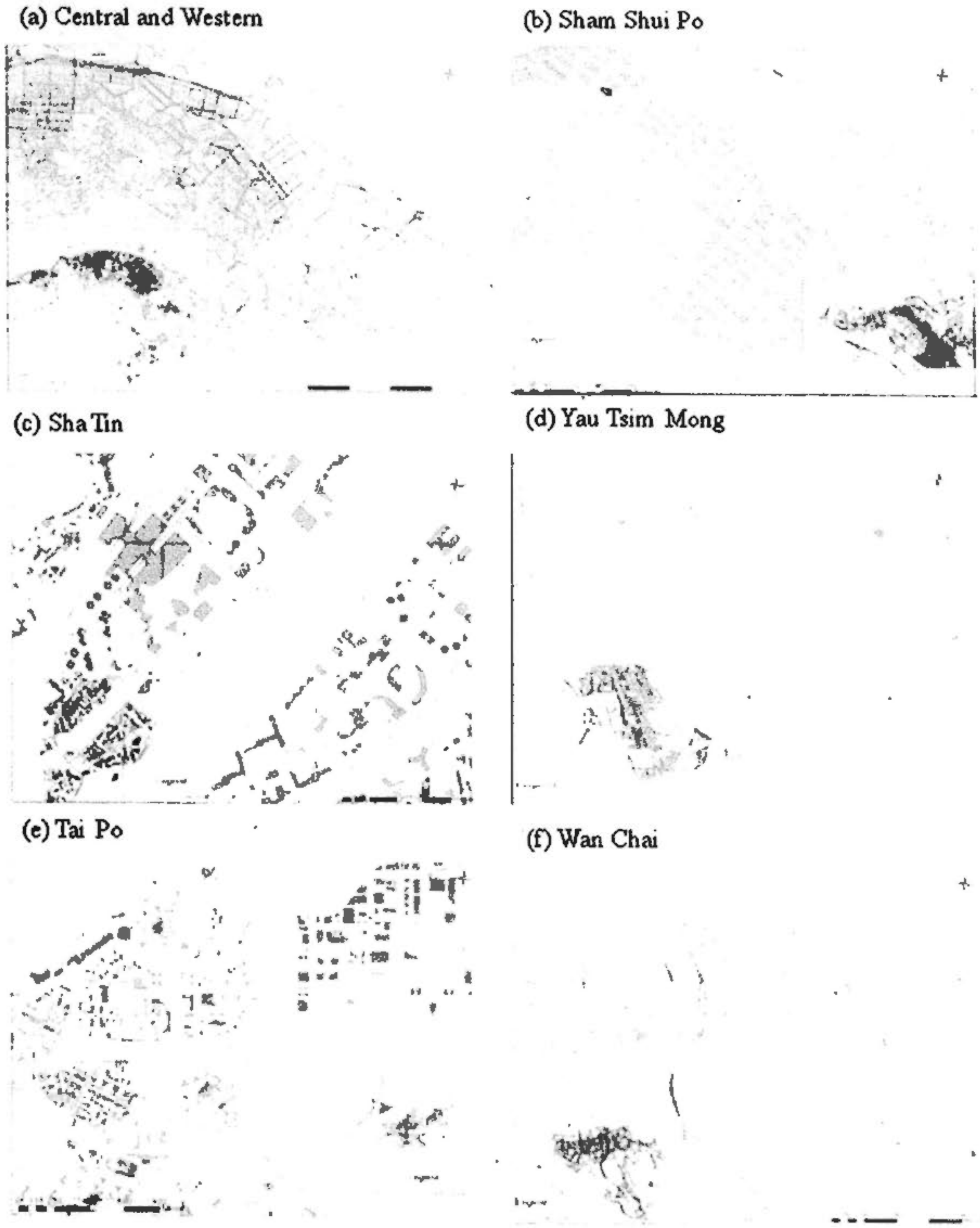



Figure 4.13 Spatial distribution of quiet open spaces denoted in yellow

These two types of open spaces serve different purposes. Large open spaces attract visitors in groups and provide various facilities in the form of functional zones, each of which attracts different population segments. On the other hand, small open spaces are more scattered but more accessible. In the Central and Western District, most of the quiet areas are located in the southern hilly areas, which are farther away from residential buildings concentrated along the northern coastal area. Hence, only a small proportion of the residents can access, benefit from, and enjoy these quiet open spaces. In contrast, the lower housing density of Sha Tin District makes it possible for a relatively larger percentage of the population to live adjacent to quiet open spaces, including small sitting-out areas located between housing blocks. Table 4.2 summarizes the locational characteristics of quiet open spaces in the six districts.

Table 4.2 Spatial characteristics of quiet areas

| District | Spatial characteristics of quiet areas |
|---|---|
| Central and Western | small in size, mainly founded in small open spaces with tall building blocks at the edge or at the central part of large parks |
| Sham Shui Po | a large part is dispersed into the remote undeveloped areas; with some minor spots immersed within the dense residential buildings |
| Sha Tin | some are amongst public housing estates and the other smaller in size are inside urban parks or open spaces |
| Yau Tsim Mong | small in size, mainly in sitting-out areas distant from major roads or in areas bounded by building blocks |
| Tai Po | largely located in the industrial estates where the traffic flow are not busy; accompanied by those in public housing estates |
| Wan Chai | several scattered through the areas within the grids of land; several spread into the outskirts |

The spatial distribution of quiet open spaces can be explained in terms of the influence of traffic noise. Large open spaces are more likely to be quiet because the sufficient space allows for sound propagation. Appropriate distance from peripheries makes the inner part of open spaces much quieter. For smaller open spaces, the surrounding densely packed building blocks function as noise barriers, insulating them from outside noise.

Identifying the location of the two types of quiet open spaces is closely related to the selection of study sites for sound recording and on-site interviews. The identified quiet open spaces are further categorized based on the classification schema in the planning guidelines of Hong Kong. Study sites are identified from a pool of candidates, representing each type of open space.

### 4.4 Usage of Quiet Open Spaces

Urban open spaces come in different sizes and shapes, and they serve different kinds of visitors with different expectations. Any sound recording and social survey program has to recognize these differences and obtain adequate samples for different open spaces, acoustic environments, and kinds of visitors.

### 4.4.1 Types of open spaces

Open space as a kind of land use zone is essential to the mental and physical well-being of individuals and the community (Planning Department of Hong Kong, 2009). It is used principally for both active and passive recreational activities. Generally, active open spaces provide outdoor recreational facilities, including game facilities, paved areas for informal games, jogging and fitness circuits, and children's playgrounds. On the other hand, passive open spaces are landscaped as parks, gardens, sitting-out areas, and waterfront promenades, where people can enjoy the peaceful environment in a leisurely manner. Open spaces are classified based on several essential elements, such as type of use, size, and population served. The National Recreation and Park Association in America has published a guideline for parks and recreational places entitled *Park, Recreation, Open Space, and Greenway Guidelines*, which is widely applied or modified in different countries (Mertes and Hall, 1995). A summary of this classification schema is shown in Table 4.3.

Table 4.3 Park and Open Space Classification

National Recreation and Park Association Guideline

| Classification | General description | Location criteria | Size criteria |
|---|---|---|---|
| Mini-Park | Address limited, isolated or unique recreational needs | Less than ¼ mile distance in residential setting. | Between 2500 sq.ft. and one acre in size. |
| Neighborhood Park | Basic unit of the park system serving as the recreational and social. focus of the neighborhood. Focus is on informal active and passive recreation. | ¼ to ½ mile distance and uninterrupted by non-residential roads and other physical barriers. | 5 acres is considered minimum size. 5 to 10 acres is optimal. |
| School-Park | Depending on circumstances, combining parks with school sites can fulfill the space requirements for other classes of parks, such as neighborhood, community, sports complex and special use. | Determined by location of school district property. | Variable-depends on function. |
| Community Park | Serves broader purpose than neighborhood park. Focus is on meeting community-based recreation needs, as well as preserving unique landscapes and open spaces. | Determined by the quality and suitability of the site. Usually serves two or more neighborhoods and ½ to 3 mile distance. | As needed to accommodate desired uses. Usually between 30 and 50 acres. |
| Large Urban Park | Large urban parks serve a broader purpose than community parks and are used when community and neighborhood parks are not adequate to serve the needs of the community. Focus is on meeting community-based recreational needs, as well as preserving unique landscapes and open spaces. | Determined by the quality and suitability of the site. Usually serves the entire community. | As needed to accommodate desired uses. Usually a minimum of 50 acres, with 75 or more acres being optimal. |

| | | | |
|---|---|---|---|
| Natural Resource Areas | Lands set aside for preservation of significant natural resources, remnant landscapes, open spaces, and visual aesthetics/buffering. | Resource availability and opportunity. | Variable. |
| Greenways | Effectively tie park system components together to form a continuous park environment. | Resource availability and opportunity. | Variable. |
| Sports Complex | Consolidates heavily programmed athletic fields and associated facilities to larger and fewer sites strategically located throughout the community. | Strategically located community-wide facilities. | Determined by projected demand. Usually a minimum of 25 acres, with 40 to 80 acres being optional. |
| Special Use | Covers a broad range of parks and recreation facilities oriented toward single-purpose use. | Variable-dependent on specific use. | Variable. |
| Private Park/Recreation Facility | Parks and recreation facilities that are privately owned yet contribute to the public park and recreation system. | Variable-dependent on specific use. | Variable. |

Adapted from:
Mertes, J.D. and J.R. Hall. *Park, Recreation, Open Spaces and Greenway Guidelines*. Washington, DC: National Recreation and Park Association, 1995.

In Hong Kong, there is no specific classification schema for open spaces. Hence, this study refers to the guideline proposed in the research entitled *Environmental Quality and Visitor Behavior in Parks and Open Spaces in Hong Kong* (Lam *et al.*, 2004b), in which—based on Hong Kong's local environment—open spaces are classified as urban parks, gardens, sports grounds, playgrounds, sitting-out areas, and plazas. A brief description of this classification schema is presented in Table 4.4.

Table 4.4 Classification of urban open spaces in Hong Kong

| Type | Size ($1000m^2$) | Description | Visitor |
|---|---|---|---|
| Urban park | >20 | Integrated park consisting of playgrounds, sit-out areas and/or public sports grounds | Everybody in the city |
| Garden | 5-30 | Consisted of sitting-out areas and/or mini sports grounds | Nearby residents or passers-by |
| Sit-out area | <10 | Resting place with seats and/or pavilion | Nearby residents |
| Playground | <10 | Small area with playing facilities | Children living nearby |
| Sports ground | 10-50 | Large sized sports ground possession as least one standard soccer field | Everybody in the city |
| Plaza | <10 | Historical artifacts, information and educational markers, landmarks and artwork express the unique features | Everybody in the city |

Adapted from:
Lam, etc., *Parks, People and the Environment: A study of the Environmental Quality and Visitor Behavior in Parks and Open Spaces in Hong Kong*, 2004

To develop an effective plan for site selection, which can provide confidence that the results obtained are valid and indicative of the present situation of open spaces, all the candidate sites representing different types of open spaces were sifted through by field reconnaissance. Special attention was given to function, nature, form, intensity of development, popularity, and accessibility. A hierarchy of open spaces was selected based on a full consideration of their particular characteristics. In total, 25 open spaces exhibiting diversified properties were identified, including 9 urban parks, 4 gardens, 2 sports grounds, 3 playgrounds, 3 sitting-out areas, and 4 plazas. Examples are illustrated in Figure 4.14.

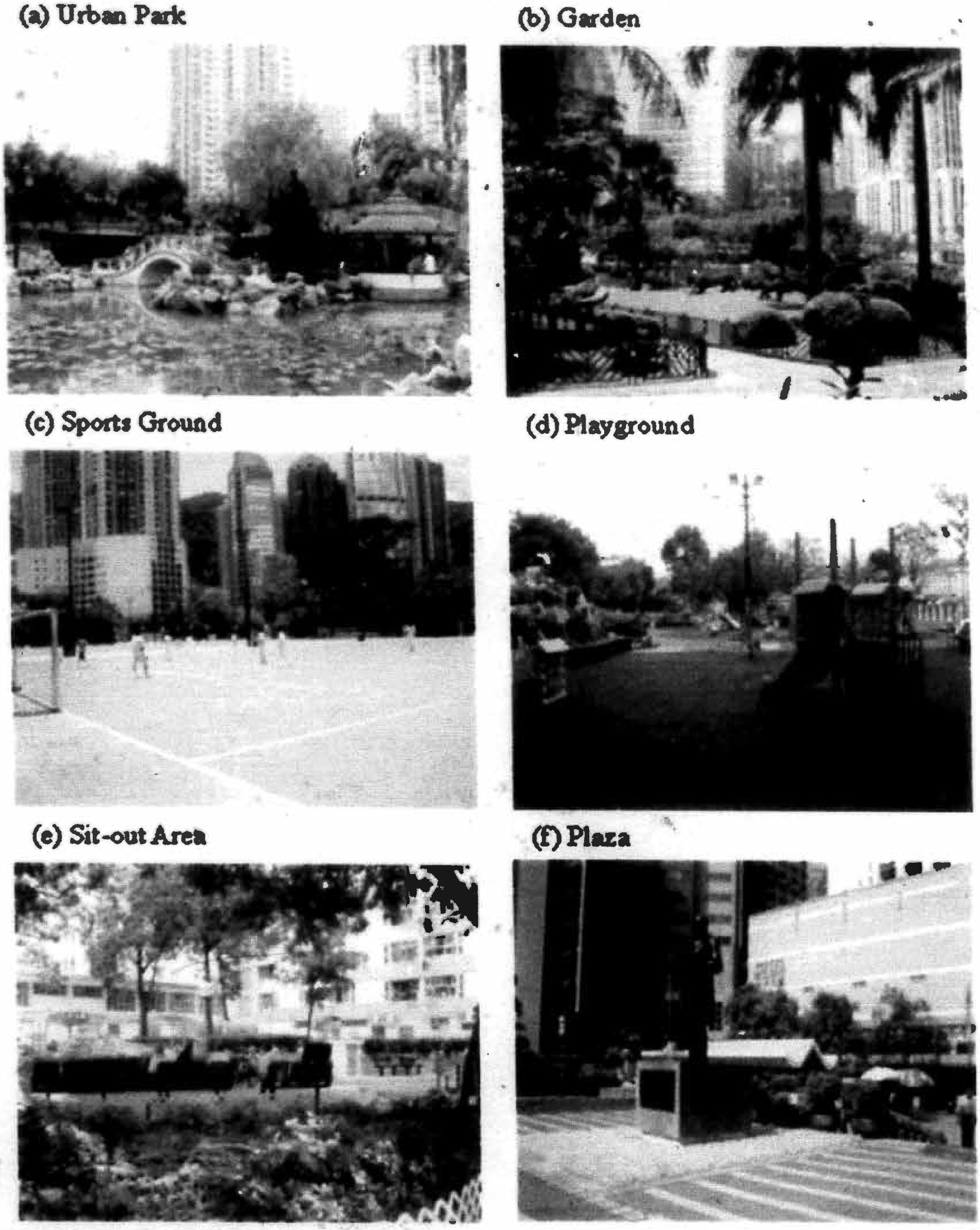



Figure 4.14 Examples of different types of open spaces in Hong Kong

All the six types of open spaces are easily found in the city areas. They are suitable places for soundscape study because aside from traffic noise, many positive sound elements are observed in these areas.

### 4.4.2 Visitors in open spaces

For on-site interviews, it is important to choose appropriate samples to represent the whole population. Demographic factors and activities are carefully considered in selecting visitors for interviews.

#### 4.4.2.1 Demographic profiles of visitors

The six types of open spaces suggest various visitor profiles. Logic and experience suggest that different people visit different urban open spaces at different times and with different purposes (Boyd and Butler, 1996; Chiesura, 2004; Lam *et al.*, 2004b). The recreation opportunity spectrum (Boyd and Butler, 1996; Joyce and Sutton, 2009) is a framework for recreation management that defines the types of opportunities available in a given location. Visitors have a recreational opportunity when they can undertake an activity within a setting and gain experience. In the framework, the settings, activities, and opportunities for gaining experiences are arranged along a continuum or spectrum.

Visitors to Hong Kong's open spaces exhibit a wide age range (below 18 to over 60 years) and have various educational backgrounds and occupations (Table 4.5). In general, those aged between 41 and 60 years make up almost one third of the respondents. They spend much time in open spaces. Table 4.6 shows a roughly equal percentage of male and female visitors. In terms of occupation, retirees, housewives, and students represent a large proportion of the visiting population (Table 4.7). Moreover, nearly half of the visitors have secondary school education (Table 4.8). These demographic patterns do not cover visitors in sitting-out areas due to their limited number, especially in summer. The sample size for sitting-out areas has not reached the requirement for statistical analysis; hence, interview data from sitting-out areas were not included in the analysis.

Table 4.5 Number of interviewees in various age groups

| Age | Garden | | Park | | Playground | | Plaza | | Sports ground | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage |
| <18 | 5 | 2.8% | 56 | 5.8% | 5 | 17.2% | 31 | 8.0% | 6 | 11.8% | 103 | 6.4% |
| 18-24 | 12 | 6.7% | 110 | 11.4% | 4 | 13.8% | 70 | 18.1% | 16 | 31.4% | 212 | 13.2% |
| 25-30 | 18 | 10.1% | 71 | 7.4% | 2 | 6.9% | 40 | 10.3% | 8 | 15.7% | 139 | 8.6% |
| 31-40 | 60 | 33.7% | 152 | 15.8% | 3 | 10.3% | 101 | 26.1% | 13 | 25.5% | 329 | 20.4% |
| 41-60 | 69 | 38.8% | 329 | 34.1% | 13 | 44.8% | 94 | 24.3% | 5 | 9.8% | 510 | 31.7% |
| >60 | 14 | 7.9% | 247 | 25.6% | 2 | 6.9% | 51 | 13.2% | 3 | 5.9% | 317 | 19.7% |
| Total | 178 | 100.0% | 965 | 100.0% | 29 | 100.0% | 387 | 100.0% | 51 | 100.0% | 1610 | 100% |

Table 4.6 Number of male and female interviewees

| Gender | Garden | | Park | | Playground | | Plaza | | Sports ground | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Percentage | Count | Percentage | Count | Count | Count | Percentage | Count | Percentage | Count | Percentage |
| Male | 83 | 46.6% | 487 | 50.5% | 20 | 103 | 103 | 41.1% | 42 | 82.4% | 791 | 49.1% |
| Female | 95 | 53.4% | 478 | 49.5% | 9 | 212 | 212 | 58.9% | 9 | 17.6% | 819 | 50.9% |
| Total | 178 | 100% | 965 | 100% | 29 | 139 | 139 | 100% | 51 | 100% | 1610 | 100% |

Table 4.7 Number of interviewees in different occupation groups

| Occupation | Garden | | Park | | Playground | | Plaza | | Sports ground | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage |
| Manager | 12 | 6.7% | 40 | 4.1% | 0 | 0.0% | 21 | 5.4% | 1 | 2.0% | 74 | 4.6% |
| Professionals | 22 | 12.4% | 62 | 6.4% | 2 | 6.9% | 37 | 9.6% | 0 | 0.0% | 123 | 7.6% |
| Clerk | 30 | 16.9% | 59 | 6.1% | 0 | 0.0% | 24 | 6.2% | 6 | 11.8% | 119 | 7.4% |
| Skilled labor | 12 | 6.7% | 59 | 6.1% | 4 | 13.8% | 21 | 5.4% | 2 | 3.9% | 98 | 6.1% |
| Student | 12 | 6.7% | 139 | 14.4% | 9 | 31.0% | 82 | 21.2% | 22 | 43.1% | 264 | 16.4% |
| Service worker | 20 | 11.2% | 78 | 8.1% | 2 | 6.9% | 47 | 12.1% | 4 | 7.8% | 151 | 9.4% |
| Sales | 16 | 9.0% | 37 | 3.8% | 1 | 3.4% | 37 | 9.6% | 3 | 5.9% | 94 | 5.8% |
| Housewife | 27 | 15.2% | 188 | 19.5% | 3 | 10.3% | 59 | 15.2% | 2 | 3.9% | 279 | 17.3% |
| Retired | 20 | 11.2% | 215 | 22.3% | 5 | 17.2% | 41 | 10.6% | 8 | 15.7% | 289 | 18.0% |
| Other | 7 | 3.9% | 88 | 9.1% | 3 | 10.3% | 18 | 4.7% | 3 | 5.9% | 119 | 7.4% |
| Total | 178 | 100.0% | 965 | 100.0% | 29 | 100.0% | 387 | 100.0% | 51 | 100.0% | 1610 | 100.0% |

Table 4.8 Number of interviewees in different education groups

| Education | Garden | | Park | | Playground | | Plaza | | Sports ground | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage | Count | Percentage |
| Primary | 16 | 9.0% | 236 | 24.5% | 7 | 24.1% | 53 | 13.7% | 3 | 5.9% | 315 | 19.6% |
| Secondary | 91 | 51.1% | 435 | 45.1% | 13 | 44.8% | 191 | 49.4% | 30 | 58.8% | 760 | 47.2% |
| College | 26 | 14.6% | 79 | 8.2% | 2 | 6.9% | 41 | 10.6% | 5 | 9.8% | 153 | 9.5% |
| University | 45 | 25.3% | 215 | 22.3% | 7 | 24.1% | 102 | 26.4% | 13 | 25.5% | 382 | 23.7% |
| Total | 178 | 100.0% | 965 | 100.0% | 29 | 100.0% | 387 | 100.0% | 51 | 100.0% | 1610 | 100.0% |

Aside from the general profile of visitors in quiet open spaces, significant differences were identified across different types of open spaces. Middle-aged and elderly people over 60 years, including professionals, skilled workers, housewives, and retirees, are the major users of parks. Most of them have at least reached secondary education. This group of visitors prefers less strenuous and passive activities, such as leisurely walking and resting. In gardens and plazas, people aged 41–60 years account for a large portion of users. They use these areas to rest or chat with friends. Some 21.2% of the visitors in plazas are students; this figure is comparably higher than that in gardens. Understandably, unlike gardens, plazas are usually more open and more easily accessible; they also offer greater mobility and opportunities for group activities, especially after school and on weekends. Playgrounds and sports grounds are more frequently used by young students and children accompanied by parents or grandparents. Active and energetic activities attract a large proportion of the young population. A detailed analysis of the activities performed in different types of open spaces is presented in the next section.

#### 4.4.2.2 Activities undertaken in open spaces

Different kinds of open spaces accommodate different activities and meet different social needs in accordance with stipulated population-based standards within each district. Activities undertaken in open spaces can be differentiated as active or passive. Active open spaces are designed for markets, festival celebrations, art shows, plays, and sports activities, whereas passive ones are for sitting, reading, meeting, and relaxing. Temporal variation is another factor that deserves consideration. On weekdays, nearby sitting-out areas are preferred for informal and passive recreational activities, giving people a sense of psychological release from stress. On weekends, recreational activities (e.g., family get togethers and social group activities) are more active, taking place in large urban parks, gardens, and plazas. Open space is a symbol of the community, society, or culture. Outdoor experience in open spaces provides links between generations and different categories of people through planning and organizing the activities (Cordell *et al.*, 1990).

The main activities undertaken by visitors in different types of open spaces are presented in Table 4.9. The activities vary across different types of open spaces, regardless of whether the activities are active or passive, undertaken alone or together with others. In parks, which are the most popular open spaces in the city area, scenic appreciation and keeping the family accompanied are the two major activities (Figure 4.15). Middle-aged or elderly people visit parks for morning exercises, jogging, or playing chess and card games. In gardens and plazas, transition is an important function for local residents. Resting and meeting friends are the other two main purposes of visits. Young students prefer to go to sports grounds for ball games after school.

Table 4.9 Main activity undertaken by visitors in different types of open spaces

| Type | *N | Percentage (% of a particular type) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Walking | Sports | Meeting friends | Transition | Rest | Accompany others | Group visit | Other | Total |
| Park | 964 | 14.7 | 16.2 | 5.8 | 22.8 | 11.6 | 10.8 | 5.2 | 12.9 | 100 |
| Playground | 29 | 10.3 | 24.1 | 3.4 | 37.9 | 13.8 | 6.9 | 0 | 3.6 | 100 |
| Sports ground | 51 | 4.0 | 48.0 | 10.0 | 10.0 | 20.0 | 4.0 | 0 | 4.0 | 100 |
| Plaza | 387 | 8.2 | 4.9 | 8.0 | 26.0 | 10.3 | 9.5 | 8.5 | 24.3 | 100 |
| Garden | 179 | 10.7 | 5.1 | 3.9 | 51.7 | 7.3 | 5.6 | 3.9 | 11.8 | 100 |

*N-- Sample size

Visitation habits in different types of open spaces also differ across visitors. On weekends and holidays, park visitors may come from distant places for family activities. In gardens, majority of the visitors are local or nearby residents who come more frequently; walking is their major activity. Gardens are also used as a convenient connection to transportation nodes. In playgrounds, children and their accompanying family members spend time on outdoor fun. Sports grounds mainly attract young people either on weekday afternoons or weekends.

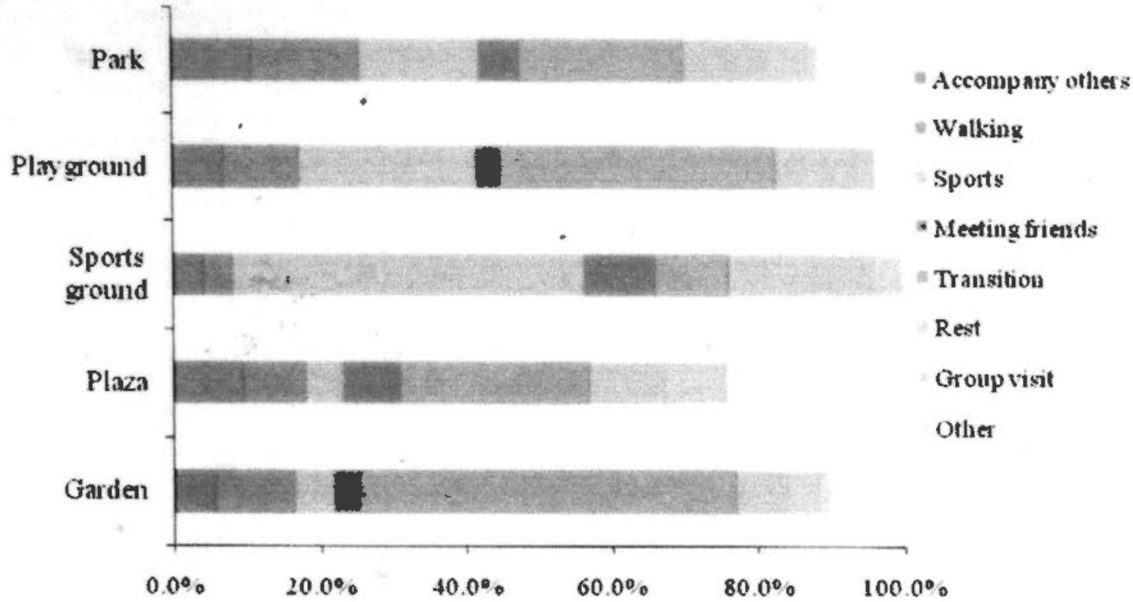



Figure 4.15 Activities undertaken in different types of open spaces (%)

Visitors prearrange their preferred activities based on the resources provided by open spaces, such as tables, chairs, exercise facilities, trails, and semi-enclosed chatting sites. More recently, interpretative uses, such as leisurely walking, photography, sightseeing, and nature appreciation and exploration, have become increasingly popular. The government and some private stakeholders have also been actively promoting particular activities in open spaces. Scenic attractions, visits to special areas, and relaxing family occasions are reported extensively by the media, attracting many visitors on weekends and public holidays.

The use of open spaces in Hong Kong shows that different open spaces have different carrying capacities and recreational possibilities. The appeal of quiet open spaces, relaxing activities, beautiful sceneries, fresh air, and natural sounds is apparent. Transportation and accessibility are also important considerations among other miscellaneous factors. Activities undertaken within open spaces may distract the attention of visitors; hence, striking a balance between expectations and provisions, as well as between supply and demand, is not easy. However, if this balance is properly managed, it will enhance acoustic experiences in open spaces.

## 4.5 Summary

The study began with noise mapping in 6 of the 18 urban districts in Hong Kong. For each district, a noise exposure contour map was produced using digital terrain and building maps, traffic data, noise mapping software LIMA 5.0, and GIS software ArcView. Based on the noise maps, areas exposed to road traffic noise less than 60 dB (A) $L_{Aeq}$ were identified and delineated with surrounding land uses and population density. The identified quiet areas are mostly open spaces that come in various shapes and sizes. They are either concentrated in hilly and remote areas with low accessibility, or sporadically scattered among tall buildings. Some open spaces, such as large urban parks and small sitting-out areas, are even located in the central part of the city. The two types of quiet open spaces have different purposes. Large open spaces attract various groups for particular activities; the small ones—found among large residential housing complexes—are easily accessible to nearby residents.

As elaborated in Chapter 3, the quiet areas were further overlain with land use maps to locate quiet open spaces. Taking into account the type, degree of public access and enjoyment, and use of the area, in-depth study sites were determined. Subsequently, field reconnaissance and on-site observations were conducted. In total, 25 open spaces, including urban parks, gardens, sports grounds, playgrounds, sitting-out areas, and plazas, were selected for further soundscape study. The findings are discussed in the following chapters. Information on the profile of visitors and their status are used to investigate factors affecting the subjective evaluation of acoustic quality. This is beneficial to soundscape design, which caters to the satisfaction of target subjects.

In the design of the study, noise mapping is the first stage in predicting general traffic noise intrusion in six administrative districts, locating quiet open spaces, and delineating their spatial characteristics. Noise mapping provides information on the selection of in-depth study sites. It also establishes a solid foundation for disseminating and managing areas of high acoustic quality. Protecting the acoustic environment and creating areas of high acoustic quality are pragmatic ways of moving forward.

*Evaluation of soundscape is rather complicated, involving interactions between various sound sources and between acoustic and other factors .*

------ *Urban Sound Environment,* Kang, 2007: 45

# Chapter 5

# Characterization of Urban Open Spaces Soundscape

This chapter begins with an overview of the acoustic environment of urban open spaces in Hong Kong, and then details the acoustic environment in different types of open spaces in terms of sound intensity, sound source, frequency spectrum, and psychoacoustic attributes. Although the acoustic profile is not sufficient in describing acoustic quality fully, it can at least provide an indication of the acoustic environment to which people are exposed and provide background information for understanding the perception of visitors.

## 5.1 Introduction

To characterize the acoustic environment of soundscapes in urban open spaces in Hong Kong, field recordings were conducted simultaneously with sound walks. In total, 25 open spaces were selected as in-depth study sites where 210 recordings were taken at 70 locations situated in different functional zones. Sound was recorded using a binaural microphone system in conjunction with a SONY DAT recorder. Sound clips were saved in tapes. To determine acoustic and psychoacoustic profiles, further analysis was conducted in the laboratory using the Brüel & Kjær 2250 Investigator. The acoustic parameters analyzed in this study include $L_{Aeq}$ [dB], $L_{AFmax}$ [dB], $L_{AFmin}$ [dB], $L_{Ceq}$ [dB], and $L_{Zeq}$ [dB] corresponding to each frequency band, LAE [dB], $L_n$ [dB], etc., whereas the psychoacoustic metrics include stationary loudness [sones], roughness [asper], fluctuation strength [vacil], tone-to-noise ratio [dB], prominence ratio [dB], and Zwicker sharpness [acum].

The chief difficulty in characterizing soundscapes in urban open spaces lies in the multiplicity of sound sources and in the appreciation of their predominance. The representation of frequency versus the equivalent sound level provides a visual translation of auditory impressions. Sound events can be identified in a qualitative way that supplements observations made during sound walks. Statistical techniques, including descriptive statistics and ANOVA, were adopted to describe the acoustic characteristics of soundscapes in different types of open spaces. Canonical discriminant analysis, following one-way ANOVA in analyzing psychoacoustic data, was conducted to identify important predictors in discriminating acoustic environments in different types of open spaces.

The work reported in this chapter focuses on the characterization of physical acoustic environments, which supplements the noise mapping results reported in Chapter 4. Noise mapping results only portray the level of exposure to road traffic noise, without taking into account other sounds from various sources in the urban environment. Therefore, field recording is crucial in describing the actual soundscape that is influenced by all sound sources. Psychoacoustic analysis is used to describe the psychological quality of sound. These acoustic and psychoacoustic attributes are further related to the subjective evaluation of acoustic quality, which is discussed in detail in Chapter 6.

## 5.2 Sound Intensity of Open Spaces

In this thesis, the acoustic environment of open spaces is expressed both quantitatively and qualitatively. Field recording allows for quantitative analysis, whereas sound walks and field observations provide qualitative data. While the generally accepted quantitative indicators are not sufficient to qualify whether a given sound is annoying or damaging, it can present a sonic image of the acoustic environment.

### 5.2.1 General distribution of sound level

We conducted field recordings and sound walks in 25 selected sites covering six different types of open spaces—gardens, sitting-out areas, parks, playgrounds, plazas, and sports grounds. Each of these types exhibits certain locational, social, and acoustic characteristics. For example, Charter garden, located in the Central and Western District, is located on the east side of Legislative Council building. Due to its particular location, Charter garden is sometimes used as a location for political rallies and demonstrations. This bestows certain acoustic characteristics that cannot be found elsewhere. Hong Kong Park, a large public park beside Cotton Tree Drive, offers a natural and relaxing environment in the midst of Hong Kong's hectic business center. It can host different kinds of social activities, such as exhibitions and sports competitions; it can even serve as a relaxing place to rest. Kowloon Park is a large park at the heart of Tsim Sha Tsui commercial district. It can be likened to an oasis among tall buildings and heavy traffic flow. It has a jogging track through Chinese-style gardens and a large swimming pool. The aviary inside the park provides opportunity for visitors to be circled by appealing birdsongs. Located inside residential communities, Sha Tin Park is on the west bank of Shing Mun River, which brings sound from flowing water. With trees, shrubs, and a waterfall, Sha Tin Park provides an ideal and accessible environment for all to take a rest. Studying and describing the acoustic environment of these areas are beneficial for interpreting sounds as perceived soundscapes.

Figure 5.1 presents the frequency distribution of sound exposure level [$L_{Aeq}$ (dB)] in selected open spaces in Hong Kong. The histogram resembles a normal distribution with one third of the sound level ranging from 61 to 64 dB $L_{Aeq}$. Only 10% of the recordings are below 55 dB $L_{Aeq}$, the recommended criterion by the World Health Organization for outdoor environment (World Health Organization, 1999). With a sound level beyond 55 dB $L_{Aeq}$, speech or communication may possibly be disrupted, but active outdoor activities will not significantly be disturbed.

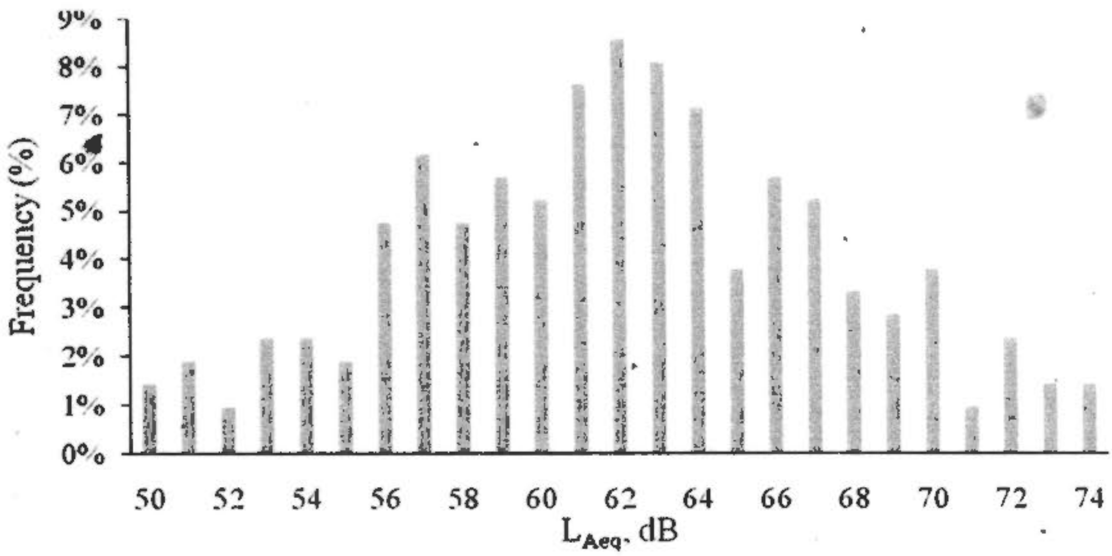



Figure 5.1 Sound levels in urban open spaces of Hong Kong based on 210 sets of 15-min sound recordings in the 25 study sites

At first glance, the data may suggest that urban open spaces in Hong Kong do not provide a desirable acoustic environment. This situation can be ascribed to Hong Kong's noisy acoustic background produced by high levels of road traffic noise. With sound from the intensive traffic network, the overall sound level in open spaces in Hong Kong can hardly be as low as in other countries.

Table 5.1 summarizes 210 sets of sound recordings obtained from different locations in various open spaces. To examine whether sound levels are significantly different across types of open spaces, one-way ANOVA was conducted. The results show a statistically significant difference at $p < 0.05$ level in sound level across the six types of open spaces [F (5, 204) = 10.058].

Table 5.1 Sound level of different open spaces in Hong Kong based on field 15-min field recordings in 25 study sites

| Type | *N | Mean $L_{eq}$ [dB (A)] | Std. Dev. [dB (A)] | $L_{eq,10}$ [dB (A)] | $L_{eq,90}$ [dB (A)] | Nominal size of open space [$1000m^2$] |
|---|---|---|---|---|---|---|
| Park | 130 | 61.0 | 5.2 | 68.1 | 54.0 | 20 |
| Playground | 14 | 61.0 | 5.4 | 66.3 | 55.1 | 10-15 |
| Sports ground | 5 | 61.0 | 3.6 | 62.2 | 59.2 | 10-15 |
| Sitting-out area | 10 | 63.6 | 5.4 | 70.0 | 57.2 | <10 |
| Plaza | 21 | 65.7 | 4.3 | 70.0 | 59.9 | <10 |
| Garden | 30 | 67.2 | 3.5 | 72.6 | 63.4 | 5-10 |

*N= Number of 15-min sound recordings

Generally speaking, parks, playgrounds, and sports grounds are comparably quieter than gardens and plazas according to the sound recordings. In terms of variability, parks have the widest range of sound level, whereas sports grounds have the narrowest. This is attributable to the activities taking place in these places. At sports grounds, sounds from running, shouting, and ball beating are relatively less time variant when a match is ongoing. In parks, different activities could happen unexpectedly, bringing along different sound events and variations.

Taking into account Hong Kong's local context and adopting 60 dB $L_{Aeq}$, rather than the WHO recommended 55 dB $L_{Aeq}$, as the cut-off value for quieter open spaces, one third of the study sites are exposed to a sonic environment with sound levels less than 60 dB $L_{Aeq}$. Data in Table 5.2 and the curve in Figure 5.2 demonstrate the percentage of areas in each range of sound level, as well as the accumulative curve in each unit.

Table 5.2 Noise level distribution in different types of open spaces based on 15-min field sound recordings

| $L_{Aeq}$, dB | park | garden | plaza | playground | sports ground | sit-out area |
|---|---|---|---|---|---|---|
| Below 55 | 13.1% | 0.0% | 0.0% | 14.3% | 0.0% | 0.0% |
| 55-60 | 33.8% | 3.3% | 14.3% | 35.7% | 60.0% | 40.0% |
| 61-65 | 36.9% | 36.7% | 33.3% | 28.6% | 20.0% | 30.0% |
| 66-70 | 13.9% | 40.0% | 42.9% | 14.3% | 20.0% | 20.0% |
| 71-75 | 2.3% | 20.0% | 9.5% | 7.1% | 0.0% | 10.0% |

The percentage of areas with sound exposure levels less than 60 dB $L_{Aeq}$ is notably higher in sports grounds, playgrounds, and parks than in gardens and plazas. This can be ascribed to their particular locations and people's visiting habits.

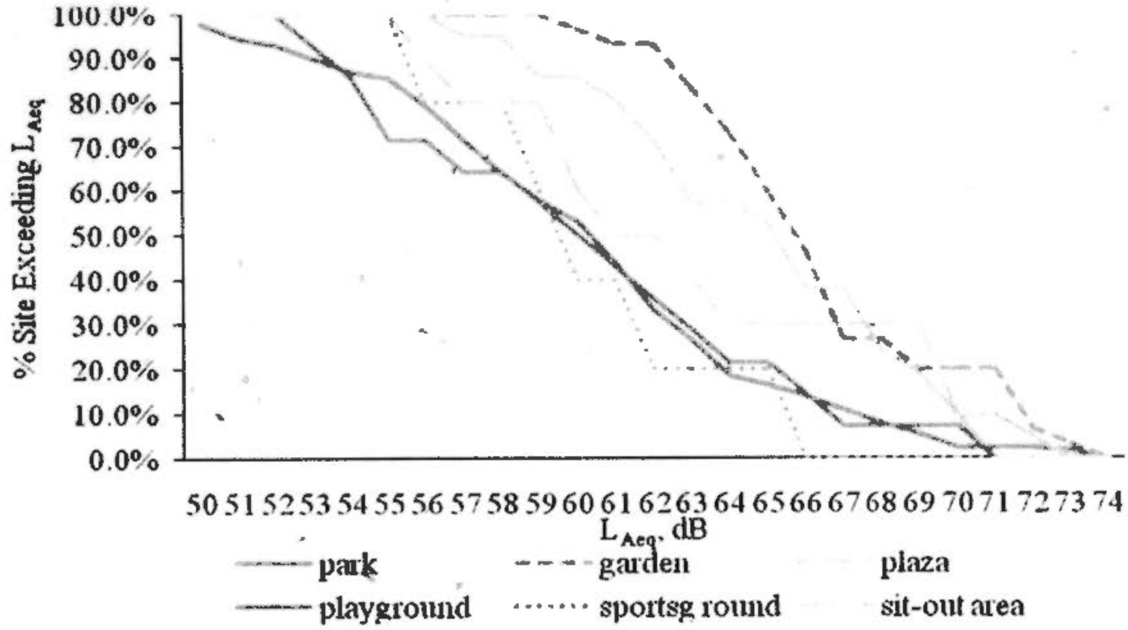
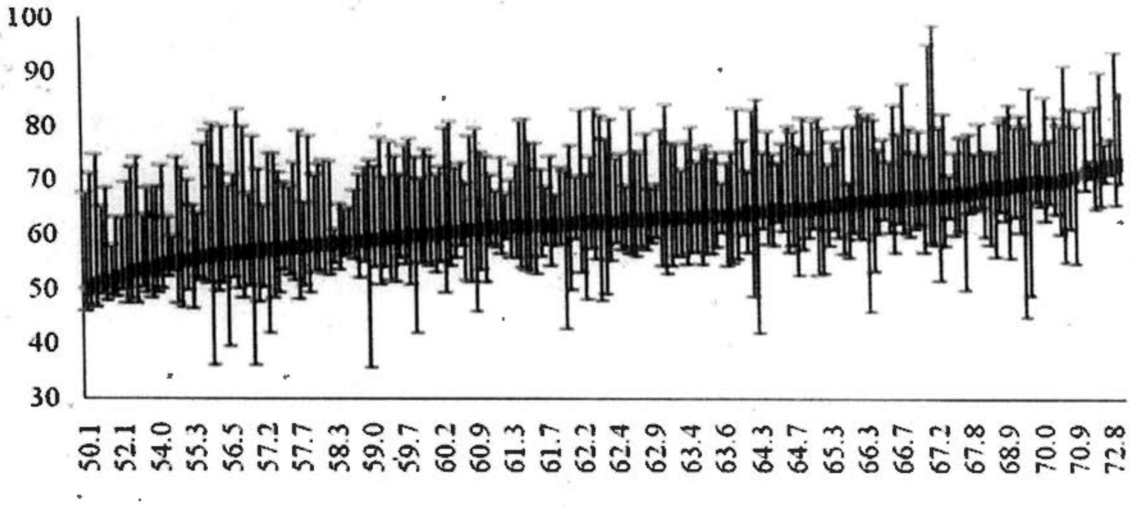



Figure 5.2 Cumulative frequency curves of noise in different types of open spaces based on field 15-min field recordings

In Hong Kong, gardens and plazas are likely to be small in size and situated next to main roads. The lack of buffer space makes it difficult for traffic noise to attenuate, resulting in a noisy environment. Parks by contrast are usually larger and hence quieter because of the availability of sufficient space for easier noise attenuation. Meanwhile, large urban parks can be divided into different functional zones; some parts in inner areas are far from road traffic noise and are therefore quieter. Playgrounds are usually located farther away from the main roadways for safety reasons, and sound from children is not particularly strong.

### 5.2.2 Variation in sound level

Figure 5.3 shows the mean sound level and sound level variations found in 210 sound recordings. Sound levels variations in relation to the duration of recordings (i.e., 15 minutes at each location) significantly determine human responses. A high sound level, if kept at a steady level, may not be as irritating as an impulsive sound of a lower equivalent sound energy level (Prasher and Axelsson, 2000). The results obtained in this study show that the largest range of fluctuation is at around 50 dB $L_{Aeq}$.




# Blue short line: the maximum sound level; Red short line: the minimum sound level

Figure 5.3 Variation of sound level (dB, $L_{Aeq}$,) during the 15-min recordings at 25 selected study sites

Differences in noise level variations across different types of open spaces were explored using one-way between-groups ANOVA. Table 5.3 provides the descriptive statistics on the variability of sound levels for the six types of open spaces. According to Levene's test, the assumption of equal variances is violated; hence, a parametric test is inappropriate. An equivalent nonparametric test was subsequently applied. ANOVA indicated that there is a significant difference among the mean variation values of the six types of open spaces: $F$ (5, 204) = 2.579, $p < 0.05$. Post-hoc comparisons using Tukey HSD indicated that the mean values for gardens, parks, and sports grounds are significantly different from one another.

Table 5.3 Variation of measured sound level in the selected 25 study sites

| Type | Mean | Std. Deviation | Exceeded for 10% of all the 15-min recordings | Exceeded for 90% of all the 15-min recordings |
|---|---|---|---|---|
| Park | 21.0 | 7.7 | 30.3 | 11.5 |
| Playground | 21.1 | 7.7 | 24.5 | 15.2 |
| Sports ground | 32.1 | 3.8 | 34.1 | 29.4 |
| Sitting-out area | 20.3 | 6.5 | 28.9 | 14.3 |
| Plaza | 20.9 | 5.4 | 27.6 | 13.0 |
| Garden | 18.7 | 10.1 | 26.8 | 9.1 |

[Unit: $L_{Aeq}$, dB]

Sports grounds exhibit the widest range in sound level variation, whereas gardens have the narrowest. The differences can be attributed to the fact that in sports grounds, occasional peaks can be caused by sound from special events, such as shouting, balls bouncing, and friction between shoes and the ground. In gardens, sound comes from background traffic noise and human voices, which are relatively less time variant. Among the open spaces, parks exhibit a larger standard deviation value, representing the various activities that parks host.

### 5.3 Sound Sources

Sound source is an important factor shaping the soundscape evaluation of visitors. Visitors tend to perceive the acoustic environment by identifying the sources of sound and interpreting information carried by sound. Sound sources in the city are complex, which can be broadly categorized according to whether or not the sounds are generated by human activities (Brown, 2009). Sounds that are not generated by human activities include natural sounds and sounds from domesticated animals. Natural sounds are sub-categorized as (1) water-related sounds, such as sounds from geysers and waterfalls, (2) sounds from wind blowing, such as the flipping sound of trees and leaves, and (3) sounds from birds and insects. Domesticated animal sounds are generally from animals associated with human activities or facilities. Human-generated sounds include traffic noise, sounds from human movement, human voices, and sounds from instruments, electro-mechanical sounds, social and communal sounds, and other human sounds (e.g., coughing sound). To have a wide coverage of different kinds of sound sources, open spaces with more kinds of sound sources are appropriate for the study of sound preference and soundscape evaluation.

From observations made during sound walks, traffic noise is the most frequently audible sound, which can be heard in most of the study sites. Traffic noise significantly influences Hong Kong's urban acoustic environment. A large percentage of open spaces in Hong Kong are bounded by traffic roads, immediately or within a short distance. In this way, traffic noise dominates the soundscape of urban open spaces in Hong Kong. Even places not immediately connected with traffic roads are also influenced by city murmurs from traffic and crowds. Traffic noise is therefore a common feature of many urban open spaces.

Despite the great influence of road traffic noise, the soundscape of urban open spaces remains to be shaped by the existence of many natural sounds. especially during summer and autumn. Gardens located in the busy Central, for example, are usually framed by mature trees at their edges, with small ponds and large fountains at the center. Sounds from water, birds, and the wind, including the consequent rustling of leaves, play an important role in masking traffic noise from nearby roads.

Table 5.4 shows the dominant sound sources identified by the field staff during sound walks to the study sites. Human voice and transport noise are the two dominant sound sources; the latter is attributable to the compact urban setting and dense roadway network in Hong Kong. Despite the dominance of two man-made sounds, the results also show that natural sounds are not inaudible, particularly in gardens and playgrounds where sounds from birds and water are common and prevalent. This is a reflection of the setting where the provision of trees and greenery also attracts birds. The table demonstrates the diversity of sound sources in Hong Kong's urban open spaces. By and large, the acoustic environment varies with the mixture and balance of natural and man-made sounds. Different combinations of sounds fashion soundscape characteristics in different types of open spaces.

Table 5.4 Dominant sound in different types of open spaces

| Type | Sound Source (% of a particular type of open space) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Water | Insect | Birds | Human Voice | Traffic Noise | Sports | Others* | Total |
| Park | 17.0 | 9.7 | 23.3 | 15.8 | 14.3 | 2.1 | 17.8 | 100 |
| Playground | 7.1 | 0.0 | 28.6 | 10.7 | 39.3 | 14.3 | 0.0 | 100 |
| Sports ground | 0.0 | 0.0 | 15.7 | 19.6 | 41.2 | 15.7 | 7.8 | 100 |
| Sitting-out area | 25.0 | 0.0 | 2.1 | 50.0 | 6.2 | 2.1 | 14.6 | 100 |
| Plaza | 15.0 | 0.3 | 2.9 | 46.3 | 13.9 | 1.5 | 20.1 | 100 |
| Garden | 8.9 | 1.1 | 8.9 | 33.0 | 34.6 | 0.0 | 13.4 | 100 |

*Others sounds include sounds from construction, amplified music, children shouting etc and others

Sounds can also be interpreted as sounds in the foreground or background. It is observed from sound walks that in small open spaces, traffic noise is strongly experienced in the background, whereas foreground natural sounds are weakly experienced. With reference to the model of prominence by Hedfors (Hedfors and Berg, 2003b), most of the soundscapes of small open spaces are crowded. In large open spaces, due to the availability of space in some areas, such as the center of a large park, background sounds are weak whereas foreground sounds are strong. Such soundscapes are clear.

## 5.4 Sound Frequency Spectrum

This study also looks into the frequency spectrum of sounds in urban spaces. This investigation is relevant because sound disturbance is dependent not only on the level but also on the frequency of sounds. Sounds in urban environments are never of pure tone and may be composed of many different frequencies. Previous studies have indicated that lower-frequency sounds can produce considerable masking effects over higher-frequency sounds, and the masking effect becomes more significant when the signal frequency is closer to the masking sound (Kang, 2007). These acoustic features render some sounds prominent while some are inaudible, creating various kinds of acoustic environments in different places.

### 5.4.1 Frequency spectrum

The soundscape of urban open spaces can be understood in various ways, one of which is through a comparison of the frequency spectra of different types of open spaces. The field recording produced 210 sets of data; hence, it is not possible to present the whole set of frequency spectra clearly in one diagram. As such, this study highlights only those with unique features. To facilitate the elucidation of spectral characteristics, only measurements from two measurement locations for each of the six types of open spaces are presented in Figure 5.4. In total, twelve study sites were involved. In each of the twelve study sites, different functional zones were further identified (a total of 52 recording locations).

Figure 5.4 presents a 3D visualization graph generated from the frequency spectra of the 52 recording locations. It shows the distribution of sound levels across the frequency spectra. Sound sources are identified with the one-third octave band spectral curves. This reveals the unique acoustic characteristics of each location. These curves supplement the sound walk observations.

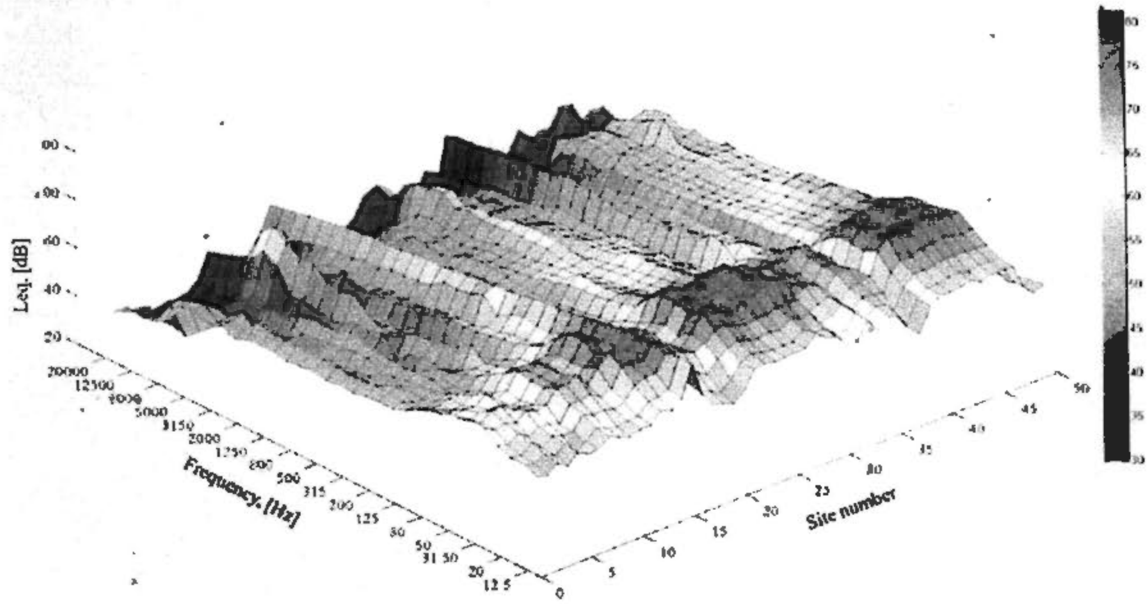


Figure 5.4 Frequency spectrums of 12 study sites: 2 sites from each of the six types of open spaces amounting to 52 recording locations

It can be seen that high sound levels are observed at lower frequency bands in the range of 31.5 to 80 Hz. This can be attributed to background traffic noise, which is ubiquitous and dominant in Hong Kong's acoustic environment. The peak sound level at the band spectrum is observed at as low as 31.5 Hz instead of 100 Hz, which is the typical one-third octave band spectrum of traffic noise. This might be from several factors, including distance, geometric divergence, and atmospheric attenuation, which may possibly result in decreased peak sound levels and lowered corresponding frequency bands.

Variations in sound levels at medium to higher octave bands reflect diversified sound sources, both from natural sources and human beings. Generally speaking, the peak around 2 to 4 kHz is from birds. Bird sounds dominate in summer and early autumn. The sound from flowing water is manifested in the round curve stretching from 1 to 4 kHz. The human voice is broadly protrusive with a peak at 1 kHz. These sound elements contribute to the unique acoustic features of each study site.

### 5.4.2 Interpretation of frequency spectra

Aside from the identification of unique sound sources, a comparison of spectra could help us discover differences and similarities between soundscapes in open spaces. Frequency spectra can give reliable evidence of the presence of individual sound components. To support a better interpretation of the frequency spectra, it is necessary to recognize the typical frequencies of some common sounds. For instance, the second to the fifth octave band, ranging from 32 to 512 Hz, is the rhythm frequency where the lower and upper bass notes lie. The frequency spectrum from 512 to 2048 Hz in the sixth to seventh octave band defines human speech intelligibility and gives a horn-like or tinny quality to sound. The eighth to ninth octave band, covering frequencies from 2048 to 8192 Hz, gives presence to speech, where labial and fricative sounds lie. Sounds from nature are miscellaneous, including the sound of water flowing, which dominates the spectrum in the first and second octave bands. Birdsongs share similar octave bands with the human voice.

The soundscapes of different sites can be depicted by examining the frequency spectrum curves. The one-third octave band spectral curves at low, medium, and high frequency ranges reveal the presence of sound components. At different study sites, the presence of different combinations of sound sources, such as birdsongs, flowing water, flipping sounds of trees and leaves, and human chatting, diversify the pitch of soundscapes in urban open spaces.

- Urban parks

Figure 5.5 shows some unique frequency spectra of Kowloon Park and Victory Park, which were selected as two representatives of large urban parks in Hong Kong. Within each park, there are different sub-zones serving different functions, and their respective curves are shown in different colors.

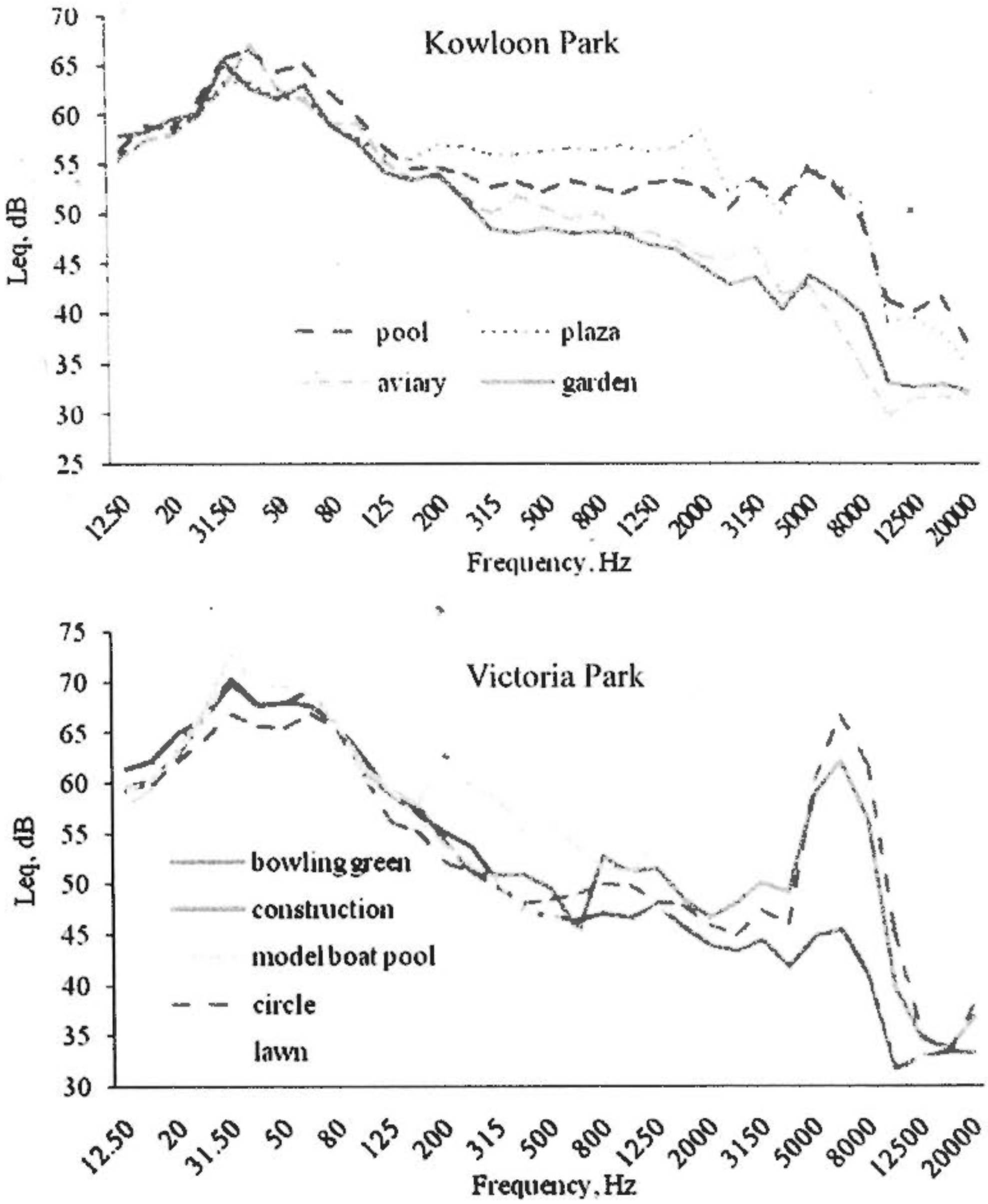



Figure 5.5 Frequency spectrum of urban park

In Kowloon Park, four major functional zones were sampled, including the swimming pool, central plaza, aviary, and small gardens inside. The sound level across the lower frequency band in the garden and aviary is a little higher with a sharp peak at around 50 to 80 Hz (Figure 5.5). This can be attributed to the intrusion of traffic noise because they are near Nathan Road, the main thoroughfare in Kowloon. The sound level at the middle range is much higher in the plaza, and the curve is more fluctuant. The central plaza is usually crowded with people chatting, singing, and playing. These sounds intermingle with birdsongs and fountain sounds. The pitch is hence more diversified, particularly at medium and high frequency ranges.

In comparison with Kowloon Park, the frequency spectrum curves of Victoria Park are more fluctuant. Inside the park, the sound level is extremely high in the model boat pool, reflecting the combined effect of sounds from model boats, flowing water, and human beings. The peak sound level lies at 800 Hz to 12.5 kHz. This reflects the prominence of birdsongs at high frequency bands. The field measurements were taken in summer when cicadas and birds are commonly found in parks where trees or vegetation are dense and suitable for nesting.

The protrusive peak and valleys in the curve can be partly due to the construction work taking place inside the park during the recording period. Construction sounds are distinct and prominent against the peaceful background, but the influence becomes less significant with increasing distance from the construction sites. Bowling greens and the central lawn are farther away; hence, the impact of the construction noise is not obvious. Moreover, not many people stay without any shade against the sun at these sites and not many events take place in the sunny afternoon. As such, there are not many sound components added to the background, making the sites much quieter compared with other places. The general trend is reflected by smooth curves in the frequency spectrum.

- Gardens

This study selected Charter Garden and Harcourt Garden to represent gardens in the city. Both are located at the heart of the central business district. Albeit seriously influenced by noise from nearby busy roads, they still form a unique mini belt of greenery in the packed city center. Of the two gardens, Harcourt Garden has a relatively lower sound level. This might be partly ascribed to the elevated topography of the east edge of Harcourt garden, which blocks traffic noise from nearby roads.

Inside the garden, trees, vegetation, fountains, and well-designed noise barriers provide an effective way of reducing exposure to noise from outside and creating a pleasing acoustic environment inside. A large fountain near the north entrance of Charter Garden significantly masks noise from the road and shifts the attention of visitors to artificial sounds. Such design as an example changes the original acoustic environment and promotes pleasant sound variations.

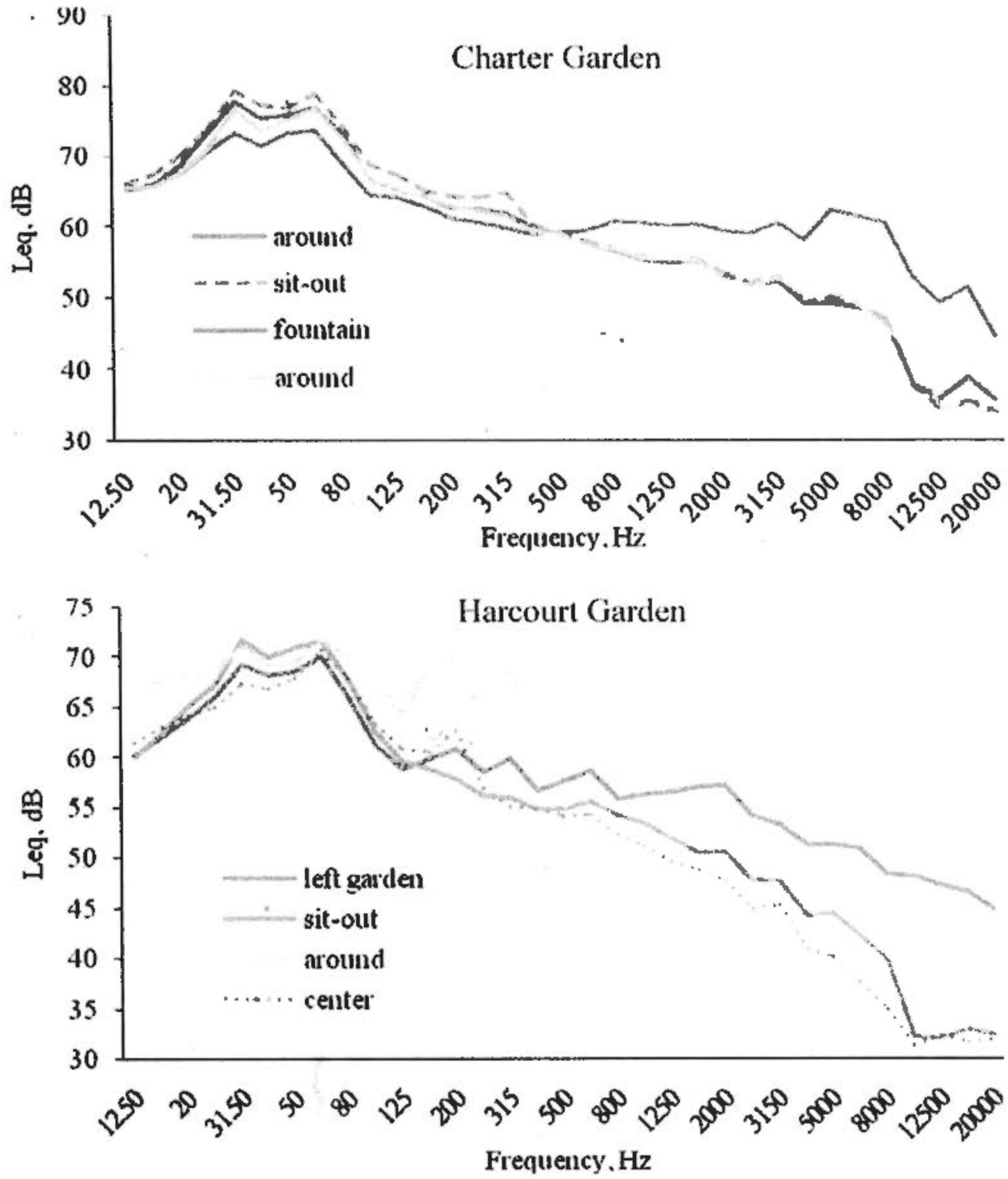



Figure 5.6 Frequency spectrums of gardens

Frequency spectra patterns in different locations of Charter Garden are quite similar, except near the fountain. At lower frequency bands below 100 Hz, there are no significant variations among the four study sites. The sound level's highest point in this range is from passing vehicles at surrounding major roads. Above the frequency of around 500 Hz, the curve corresponding to the place near the fountain starts to rise gradually while the other three keep a smooth and round downward curve toward the trench at 12.5 kHz and 20 kHz. The peak around 800 Hz implies that water flow is the prominent sound at medium to high frequency bands, and the peak sound level at 5 to 8 kHz results from the presence of birdsongs rather than from water. Nevertheless, water flow still plays an important role in shaping variations in the sonic environment.

The frequency spectrum of Harcourt Garden is different from that of Charter Garden. In different locations, sound levels corresponding to the same frequency band are quite different. For example, the curves for the small garden, sitting-out area, and the center, albeit following similar patterns, deviate in sound levels at particular frequency bands. This is the case especially at lower frequency bands. This may be a reflection of the same sound—nearby traffic noise with a different sound level.

At medium to high frequency bands, the sound level peaks at around 500 to 800 Hz, probably representing human conversations. The recording was carried out at around lunchtime, at which time Harcourt Garden is packed with office workers; hence, chattering is prominent. Birdsongs account for the higher spectral band, in the range from 2 to 4 kHz. The curve in green is higher than the other three curves in terms of sound level in this band because birdsongs are much louder when walking around the garden compared with when staying at the central part and other quieter locations.

- Plaza

Two plazas were selected for this study. The first one, Status Square in Central, is like a pedestrian square in the midst of the central business district of Hong Kong. Surrounded by tall buildings in the eastern and western sides, leaving the other two sides immediately connected with the busy traffic roads, Status Square has a special acoustic environment in terms of sound elements.

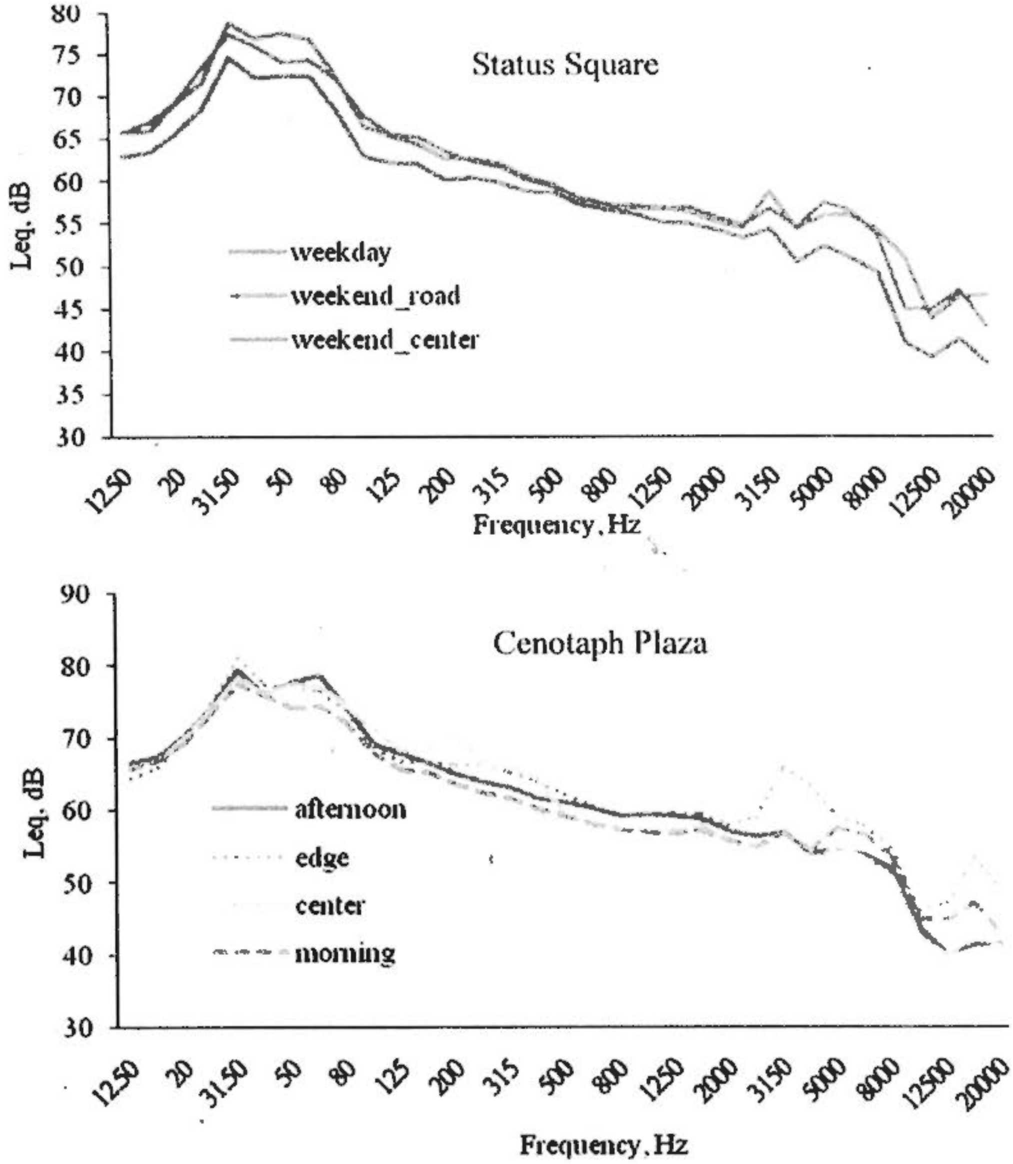



Figure 5.7 Frequency spectrums of squares

The frequency spectrum of Status Square is shown in Figure 5.7. As the ideal rendezvous for maids on Sundays, Status Square is the traditional meeting place for Filipina domestic workers. Crowded with people chatting, eating, singing, shouting, and playing, Status Square has different acoustic environments on weekdays and weekends, as revealed by sound recordings taken on weekdays and weekends.

As shown in Figure 5.7, the sound level on weekends is much higher than on weekdays. The daily traffic flow on the adjoining roads is not significantly different between weekdays and weekends; hence, any remarkable difference in sound level between the two is attributed to human voice and human activities. With regard to the frequency spectra, there is no significant difference at low frequency bands, reflecting the little difference between passing vehicles on the adjoining roads on weekdays and weekends. Noticeable differences can be observed at medium and high frequency bands caused by people shouting, amplified music, and occasional construction work.

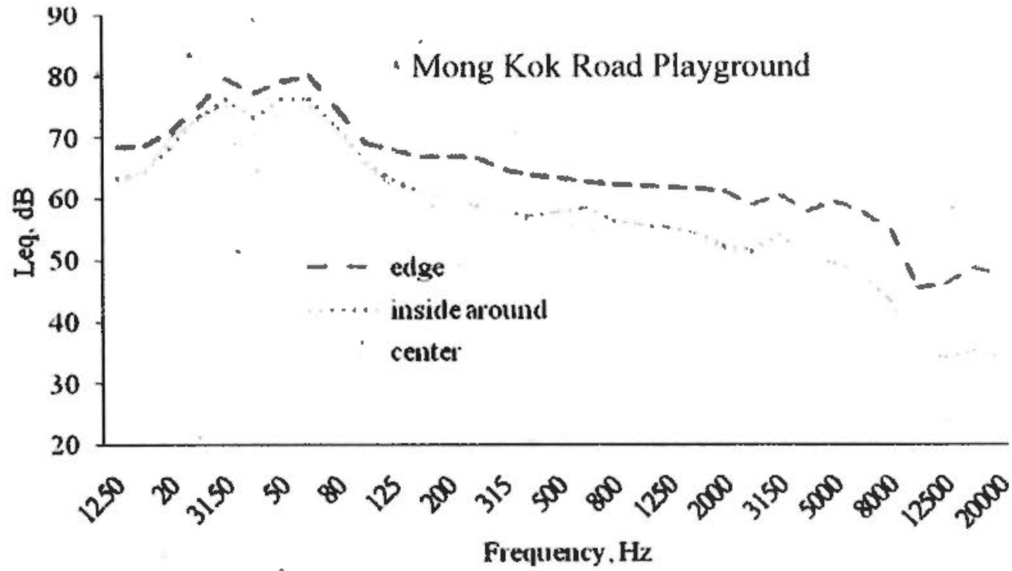
The second plaza, Cenotaph, is located at the other side of Charter Road, opposite to Status Square. The two study sites are close to each other. There are some similarities between Cenotaph and Status Square, particularly in terms of the influence of road traffic noise. However, there are also differences in term social functions and activities. It is evident that the frequency spectrum of Cenotaph Plaza exhibits similar acoustic characteristics with Status Square in terms of sound level and spectral pattern at lower and higher octave bands with certain less prominent variations at medium frequency bands. An abrupt rise in sound level at around 200 Hz in the sub-zone of the central sitting-out area could be the sound of the lawn being watered. At the same time, the peak at the higher frequency bands around 3150 to 5000 Hz can be attributed to the sound of birds and cicadas nesting and living in the trees.

In general, the figure for Cenotaph Plaza appears to be smooth and round in the morning and afternoon. At lower frequency bands, the sound level is a little bit higher in the afternoon, whereas at high frequency bands, the sound level is higher in the morning. Sound sources are more diversified in the morning, especially at frequencies around 5 kHz and 12.5 kHz, caused by chirping birds and shrilling cicadas, respectively. The distinct peak of the sound level at around 4 kHz on the edge may be due to an extraneous factor (i.e., the sound of the traffic signal ringing intermittently).

- Playground

In Hong Kong, playgrounds are favorite spots for children. There are facilities, such as chin-up bars, slides, jungle gyms, playhouses, and mazes, which help develop children's coordination and strength. The acoustic environment of playgrounds may change with time and location. In this study, two playgrounds located in different districts were selected for comparison and analysis—Mong Kok Road Playground, which is situated inside an old commercial and residential community; and Lockhart

Road Playground, which is surrounded by tall commercial buildings and narrow streets. Similarities between the two study sites are their exposure to the adjoining busy traffic road and the highly dense population within the vicinity. The major difference is the facilities provided in the two sites. The mini football field standing on the east side of Lockhart Road provides a place for football matches, creating more man-made sounds. Figure 5.8 shows the frequency spectra of different locations at the two study sites.



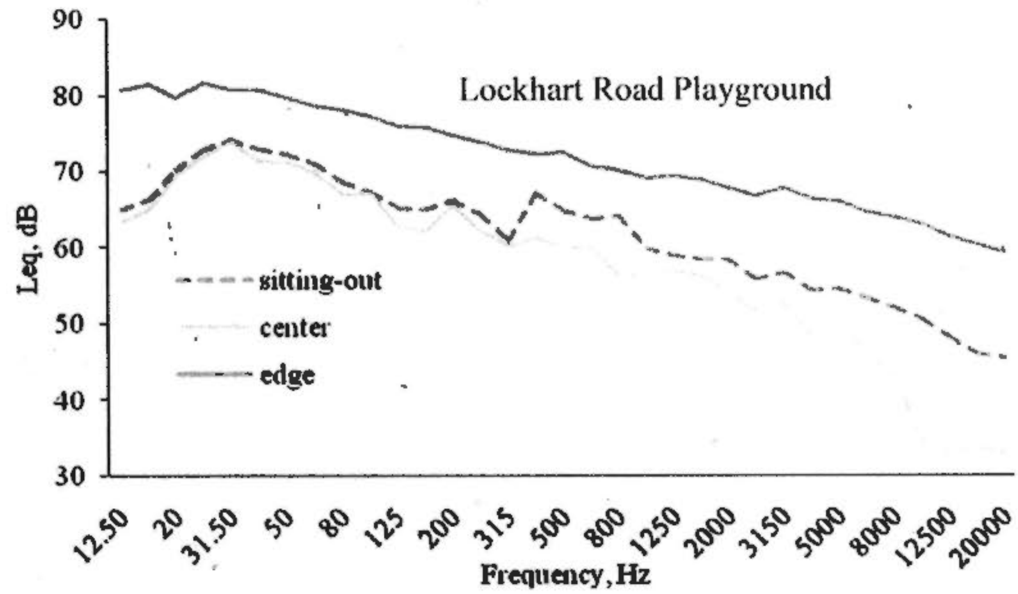




Figure 5.8 Frequency spectrum of playground

The curve of Mong Kok Road Playground is displayed in Figure 5.8. The sound level in the periphery is relatively higher than that in the two other locations. The significant difference of almost 10 dB implies that trees and walls surrounding the edge function as noise barriers that noticeably reduce the influence of traffic noise. The sharp rise to the peak sound level around medium frequency bands may be explained by sounds from nearby construction work. With birdsongs, sound level rises back at higher frequency bands.

Lockhart Road Playground is situated in Wan Chai District, next to the narrow Lockhart Road and the tall building of Harcourt House. The line in purple demonstrates the higher sound level on its edge, the same as that found in Mong Kong Road Playground. The frequency spectrum shows the dominance of traffic noise and its masking effect on other sound sources. At medium frequency bands around 500 Hz to 800 Hz, human voice is the prominent sound in the sitting-out area where traffic noise diminishes with increased distance from its source.

In general, there are few sound events in playgrounds than in any of the above types of open spaces. This is expected because playgrounds are smaller in size than urban parks and gardens, and they mainly serve nearby residents and passers-by.

- Sports ground

For sports grounds, two sites Macpherson and Shek Kip Mei sports grounds were selected. Macpherson sports ground is in Mong Kok District at the junction of Sai Yee Street and Shantung Street. It is situated in one of the busiest mixed commercial and residential regions in Hong Kong. The sounds in this sports ground comes from various sources: nearby residential buildings, commercial stores, and retail businesses along the street abutting the sports ground. The sports facilities also attract people and the games they play also generate sound.

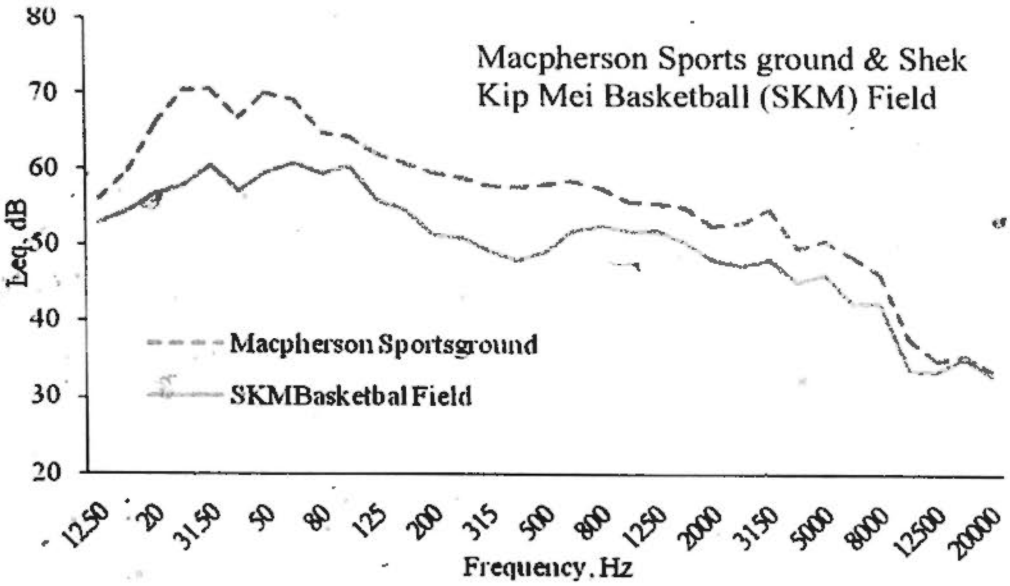



Figure 5.9 Frequency spectrum of sports ground

According to the one-third octave band spectral curve of Macpherson sports ground in Figure 5.9, variations in sound level across the frequency bands are not significant, which seems paradoxical with respect to the messy and yet dynamic surrounding acoustic environment. However, the influence from outside is diminished by increased distance and the obstruction of the wall on the edge. Meanwhile, prominent sounds from activities inside the sports ground mask those from the outside. For instance, at medium frequency bands around 500 Hz, a rise in sound level is caused by shouting, cheering, and whistling. The sounds are so clear and shrill that they prominently occupy the higher octave band.

Shek Kip Mei sports ground is inside a park in Sham Shui Po District. The surrounding area is an old residential community, which is not as compact and noisy as Mong Kok District. The red curve at the bottom of Figure 5.9 shows the overall sound level of Shek Kip Mei sports ground, which is much lower than that of Macpherson sports ground. One possible reason is the location of Shek Kip Mei sports ground, which sits on a hill that acts as a noise barrier blocking large amounts of traffic noise from adjacent roads. The elevated topographical feature is effective in controlling and reducing the intrusion of road traffic noise. Except for human sounds similar to those found at Macpherson, the rise in sound level at medium to high frequency bands is also suspected to be caused by cicadas and birds in densely grown trees.

- Sitting-out area

Compared with other types of open spaces, sitting-out areas are usually smaller in size and simple in function. They are sometimes found inside housing estates enclosed by box-like buildings, or next to pedestrian corridors providing people seats, or even located in all kinds of places where there is no long-term land use.

To elucidate the acoustic characteristics of popular sitting-out areas, two representative areas were selected—one inside Lai Kok Estate (LK Estate) and the other inside Shek Kip Mei Estate (SKM Estate). Both of them are located in Sham Shui Po District, which is generally considered an old residential district. The first study site inside LK Estate is larger in size and farther away from main roads, whereas the second study site inside SKM Estate is relatively smaller and is abutted by roads on two sides. Due to their respective peripheral environments, distinct patterns have been observed in these two sites (Figure 5.10).

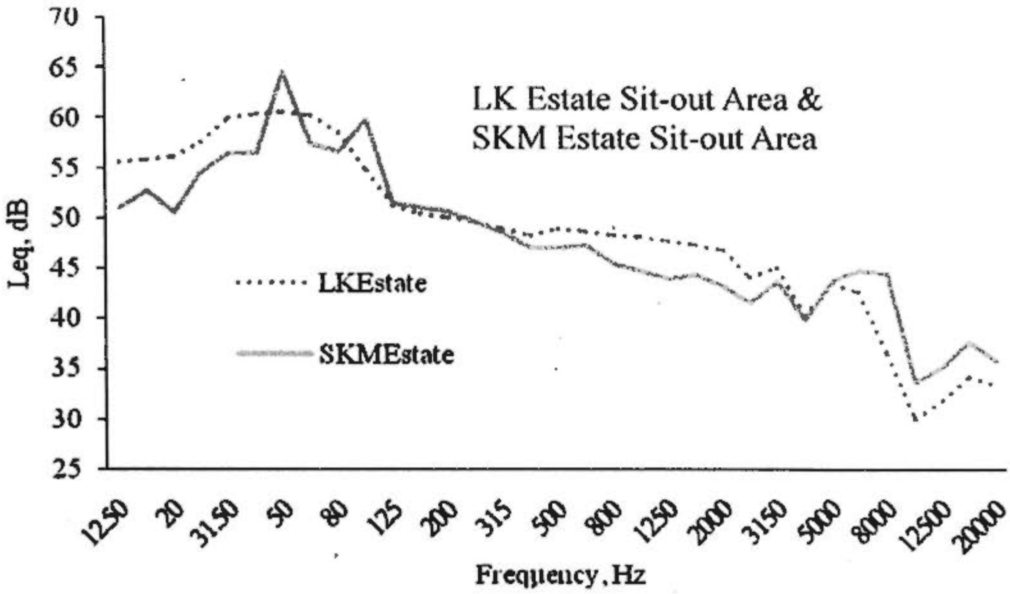



Figure 5.10 Frequency spectrum of sitting-out areas

The frequency spectrum curve of LK Estate has a smooth rise at low frequency bands, representing background traffic noise. After that, the curve is flattened out across the range of medium frequency, and there is a peak at higher frequency bands attributable to birdsongs and cicadas. The curve for the SKM Estate is even more fluctuating. This study site is more influenced by traffic noise as reflected by the sharp rise in sound level at lower frequency bands. Sitting-out areas are usually located immediately next to main roads or narrow streets with heavy traffic flow; therefore, the influence of traffic noise is more significant compared with larger open spaces where sufficient space is available for sound attenuation before high sound exposure levels are reached. Residential building blocks are too close to each other; hence, sounds from households become another important source causing fluctuations at medium frequency bands (Figure 5.10). Similar to the LK Estate, sounds from wildlife, prominently occupying the higher frequency zone, override other sound sources in SKM Estate. The increase in sound level at frequency bands from 5000 to 8000 Hz further demonstrates the prominence of sounds from birds and insects.

## 5.5 Analysis of Psychoacoustic Parameters

Sound recordings were subjected to psychoacoustic analysis. This was undertaken because the ability of our hearing system to receive information is determined not only by the qualitative relation between sound and impression, but also by the quantitative relation between acoustic stimuli and hearing sensations. The science of psychoacoustics, the study of the hearing system as a receiver of acoustic information, has gained much attention recently (Fastl and Zwicker, 2007). Psychoacoustics are also defined as "the relationship between parameters of acoustic waves and attributes of auditory events" (Bodden, 1997). They have been commonly used to evaluate specific qualities of sound, especially for manufacturing products. The technique has also been applied to the evaluation of global and environmental sounds (Genuit, 2000; Genuit and Fiebig, 2005). Psychoacoustic analyses are believed to be related the subjective perception of sound, either as annoyance or pleasantness, with respect to the hearing sensation of humans.

Genuit (2005) applied knowledge of psychoacoustics and cognitive perception to describe annoyance reaction to environmental noise. Predicting the subjective response to mixture of different sounds in a real environment is indeed complicated. However, advancements have been made relating psychoacoustic ratings to subjective evaluation. Psychoacoustic indices can be taken as an instrumental tool to predict psychoacoustic properties. Different psychoacoustic indices have been used in acoustic researches, among which loudness, fluctuation strength or roughness, sharpness, and pitch strength are international standards. Although it is still far from simulating human sound perception and evaluation in all its facets, psychoanalysis allows for an instrumental prediction of attributes of hearing events.

### 5.5.1 Psychoacoustic metrics

Loudness belongs to the category of intensity sensations. Roughness is a modulation-based metric that may be described as "grating." A rough sound usually brings an unpleasant hearing impression. Sharpness is a parameter used to evaluate timbre. It is an indication of spectral balance between low and high frequencies. The more high frequencies a signal contains, the higher is its sharpness. Pitch strength is the distinctness of pure tones in a complex noise. Audible pure tones in broadband noise may be annoying, although its contribution to total loudness may not be significant (Kang, 2007).

Further indices on the quality of speech, which are still under investigation, can be considered as heuristic approaches to identify the characteristic quantities of sound signals. With continuous improvements in existing indices and the development of new ones, psychoacoustic indices can serve as sophisticated tools for sound evaluation (Bodden, 1997). Nevertheless, in the past years, psychoacoustic indices are rather popular in sound quality evaluation because it demonstrates that instruments have the ability to predict perceptual attributes with sufficient accuracy. Further development and standardization of psychoacoustic indices, as well as supporting analysis tools, are fundamentally based on corresponding psychoacoustic research.

### 5.5.2 Comparison between different types of open spaces

In this study, sound recordings were analyzed to obtain some psychoacoustic measures, including Zwicker loudness, sharpness, roughness, and fluctuation strength using Brüel & Kjær PULSE Sound Quality software. Table 5.5 shows the mean values (M) and standard deviations (SD) of psychoacoustic data across different types of open spaces.

Table 5.5 Means and Standard Deviations of psychoacoustic attributes in different types of open spaces

| Type | Loudness [sones] | | Roughness [asper] | | Fluctuation [vacil] | | Sharpness [acum] | |
|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD | M | SD |
| Garden | 24.90 | 3.89 | 0.59 | 0.08 | 1.35 | 0.22 | 1.55 | 0.25 |
| Park | 27.47 | 7.67 | 0.57 | 0.01 | 1.33 | 0.10 | 2.15 | 0.25 |
| Playground | 20.07 | 1.24 | 0.63 | 0.04 | 1.59 | 0.14 | 1.44 | 0.06 |
| Plaza | 20.37 | 1.22 | 0.73 | 0.06 | 1.81 | 0.06 | 1.38 | 0.33 |
| Sports ground | 22.26 | 3.34 | 0.68 | 0.06 | 1.74 | 0.17 | 1.48 | 0.15 |
| Mean | 25.00 | 6.08 | 0.61 | 0.07 | 1.45 | 0.23 | 1.78 | 0.39 |

To compare the psychoacoustic properties of soundscapes, one-way ANOVA was conducted; the results are shown in Table 5.6. ANOVA assumes that samples are obtained from populations of equal variances. This means that the variability of scores for each of the groups is similar. To test this, SPSS performs Levene's test for equality of variances. For loudness, the assumption of homogeneity of variance is violated; therefore, Brown–Forsythe's $F$ is reported. There is a significant difference between different types of open spaces on the measured loudness, $F(4, 30.06) = 4.29$, $p < 0.05$. For roughness, fluctuation, and sharpness, Levene's tests are non-significant; the variances are roughly equal and the assumption is tenable. Table 5.6 shows the statistically significant differences found among different types of open spaces on roughness [$F(4, 32) = 8.961$, $p = 0.000$], fluctuation [$F(4, 32) = 12.292$, $p = 0.000$], and sharpness [$F(4, 32) = 17.356$, $p = 0.000$].

Table 5.6 Summary of One-way ANOVA comparison of psychoacoustic attributes

| Source | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Roughness | | | | | |
| Between Groups | 0.09 | 4 | 0.022 | 8.961 | 0.000 |
| Within Groups | 0.08 | 32 | 0.002 | | |
| Total | 0.17 | 36 | | | |
| Fluctuation | | | | | |
| Between Groups | 1.204 | 4 | 0.301 | 12.292 | 0.000 |
| Within Groups | 0.783 | 32 | 0.024 | | |
| Total | 1.987 | 36 | | | |
| Sharpness | | | | | |
| Between Groups | 3.819 | 4 | 0.955 | 17.356 | 0.000 |
| Within Groups | 1.76 | 32 | 0.055 | | |
| Total | 5.58 | 36 | | | |
| | Statistic | df1 | df2 | Sig. | |
| Loudness | 4.202 | 4 | 6.678 | .051 | |
| Welch | 4.287 | 4 | 30.059 | .007 | |
| Brown-Forsythe | 4.202 | 4 | 6.678 | .051 | |

Because the psychoacoustic parameters are significantly different in different types of open spaces, further comparisons are required to determine where the differences lie. The output for post hoc tests shown in Table 5.7 specifies the subsets of groups that have the same means. Interpreted from the column for roughness, the first subset contains parks, gardens, and playgrounds; the second subset contains gardens, playgrounds, and sports grounds; and the third includes playgrounds, sports grounds, and plazas. Therefore, significantly different means can be observed between the groups of parks and sports grounds, as well as between the groups of gardens and sports grounds. Similar results were found for fluctuation. Regarding sharpness, plazas are different from all the other types of open spaces.

Table 5.7 Subsets of groups with statistically similar means by Turkey's test

| Type | Roughness | | | Fluctuation | | Sharpness | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 1 | 2 |
| Park | .568 | | | 1.329 | | 1.380 | |
| Garden | .594 | .594 | | 1.346 | | 1.440 | |
| Playground | .625 | .625 | .625 | 1.590 | 1.590 | 1.484 | |
| Sports ground | | .677 | .677 | | 1.736 | 1.551 | |
| Plaza | | | .725 | | 1.805 | | 2.145 |
| Sig. | .513 | .171 | .066 | .170 | .337 | .849 | 1.000 |

* Subset for alpha = 0.05

### 5.5.3 Discriminant analysis based on psychoacoustic variables

Discriminant analysis was performed following the ANOVA test discussed in the last section, to identify what psychoacoustic characteristics differentiate soundscapes of different types of urban open spaces. In ANOVA, we manipulated membership to different types of open spaces and investigated its effect on psychoacoustic characteristics. Significant differences have been identified in terms of loudness, roughness, fluctuation, and sharpness. However, ANOVA is not a good way of looking at relationships between dependent variables and determining the relative importance of dependent variables in differentiating between categories. Therefore, discriminant analysis, as a follow-up step, was performed to identify what combination of psychoacoustic parameter types best describe the nature of differences among the different types of open spaces, how the dependent variables discriminate the types of open spaces, and their significance in the process of discrimination.

In this study, the following psychoacoustic parameters are used: stationary loudness [sones], roughness [asper], fluctuation strength [vacil], tone-to-noise ratio [dB], prominence ratio [dB], Zwicker sharpness mean [acum], and Zwicker sharpness standard deviation [acum]. Table 5.8 shows initial statistics from the discriminant analysis. Five discriminant functions were revealed. The first function explains 75.4% of the variance, with a canonical correlation of 0.664. Thus, the first discriminant function is more closely related to the discrimination between groups.

Table 5.8 Eigenvalues for Canonical Discriminant functions

| Function | Eigenvalue | % of Variance | Cumulative % | Canonical correlation |
|---|---|---|---|---|
| 1 | .787a | 75.4 | 75.4 | .664 |
| 2 | .163a | 15.6 | 91.1 | .374 |
| 3 | .058a | 5.6 | 96.7 | .235 |
| 4 | .032a | 3.1 | 99.7 | .177 |
| 5 | .003a | .3 | 100.0 | .052 |

a. First 5 canonical discriminant functions were used in the analysis.

Table 5.9 shows the significance tests of the functions. In combination, the five discriminant functions significantly differentiate the types of open spaces, $\chi^2$ (35) =120.554, $p < 0.05$. Therefore, the differences found between different types of open spaces can be explained in terms of the five underlying dimensions in combination. Only the first discriminant function is statistically significant; hence, the coefficient for the first function is interpreted. Overall, the prediction of group membership is acceptable: Wilks's $\Lambda$, which is analogous to $1 - \eta^2$ or the percentage of variance in the discriminant scores that is not explained by group membership is 0.439, thus 56.1% of the variance in discriminant scores is due to between-group differences.

Table 5.9 Significance tests of the discriminant functions based on Wilks' Lambda

| Test of Functions | Wilks' Lambda | Chi-square | df | Sig. |
|---|---|---|---|---|
| 1 through 5 | .439 | 120.554 | 35 | .000 |
| 2 through 5 | .785 | 35.484 | 24 | .062 |
| 3 through 5 | .913 | 13.349 | 15 | .575 |
| 4 through 5 | .966 | 5.040 | 8 | .753 |
| 5 | .997 | .390 | 3 | .942 |

Table 5.10 provides the standardized discriminant function coefficients, allowing for a comparison of the extent to which each of the predictor variables contributes to the ability to discriminate between categories. Loudness contributes the largest to the first function, and a higher value on discriminant Function 1 was seen for the type of open space with a lower loudness value. Integrated with the consideration of eigenvalue, in which the measurement of the first function discriminates between different types of open space better, loudness contributes more to discrimination.

Table 5.10 Standardized canonical discriminant function coefficients

| Variable | Function | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Loudness | -.857 | .190 | .037 | .727 | .033 |
| Roughness | .091 | .314 | 1.071 | .089 | -.716 |
| Fluctuation | .561 | .340 | -.477 | .210 | .689 |
| Tone-to-Noise Ratio | .363 | 2.785 | -2.193 | .675 | -1.623 |
| Prominence Ratio | -.449 | -2.585 | 1.902 | -.539 | 2.098 |
| Zwicker Sharpness Mean | .758 | -.205 | -.143 | .238 | -.555 |
| Zwicker Sharpness Standard Dev. | .044 | -.325 | -.071 | .371 | .322 |

The structure matrix table is shown in Table 5.11. It provides a different measure of the contribution of each variable to the discriminant function. These values are comparable to factor loadings and indicate the substantive nature of the function.

Two variables, loudness and tone-to-noise ratio, are with the largest correlations with Function 1. The correlation between loudness scores and Function 1 scores is 0.478, while the correlation between tone-to-noise ratio scores and Function 1 scores is -0.492. The asterisk next to loudness indicates that it has the largest correlation with Function 1 when compared across discriminant functions, whereas tone-to-noise ratio has the largest correlation with Function 4 when compared across discriminant functions.

Table 5.11 Structure matrix: pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions

| Variable | Function | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Loudness | .478* | .465 | .294 | .430 | .429 |
| Roughness | .345 | -.534* | -.206 | .513 | -.448 |
| Fluctuation | .319 | .516 | .748* | .197 | .136 |
| Tone-to-Noise Ratio | -.492 | -.080 | .030 | .804* | -.189 |
| Prominence Ratio | .381 | -.265 | -.016 | .592* | .326 |
| Zwicker Sharpness Mean | -.002 | .224 | -.006 | -.212 | .632* |
| Zwicker Sharpness Standard Dev. | .007 | .387 | -.145 | -.219 | .537* |

* Largest absolute correlation between each variable and any discriminant function.

Figure 5.11 graphically illustrates the function scores for each sample, grouped according to the experimental condition to which the open spaces belong. The centroids, which are shown as blue squares, are the mean scores on each of the discriminant functions for the members of one group. Note that the means for discriminant Function 2 are much closer together than the means for discriminant Function 1. This is consistent with earlier information that open spaces have different discriminant Function 1 scores, which significantly discriminate different types of open spaces.

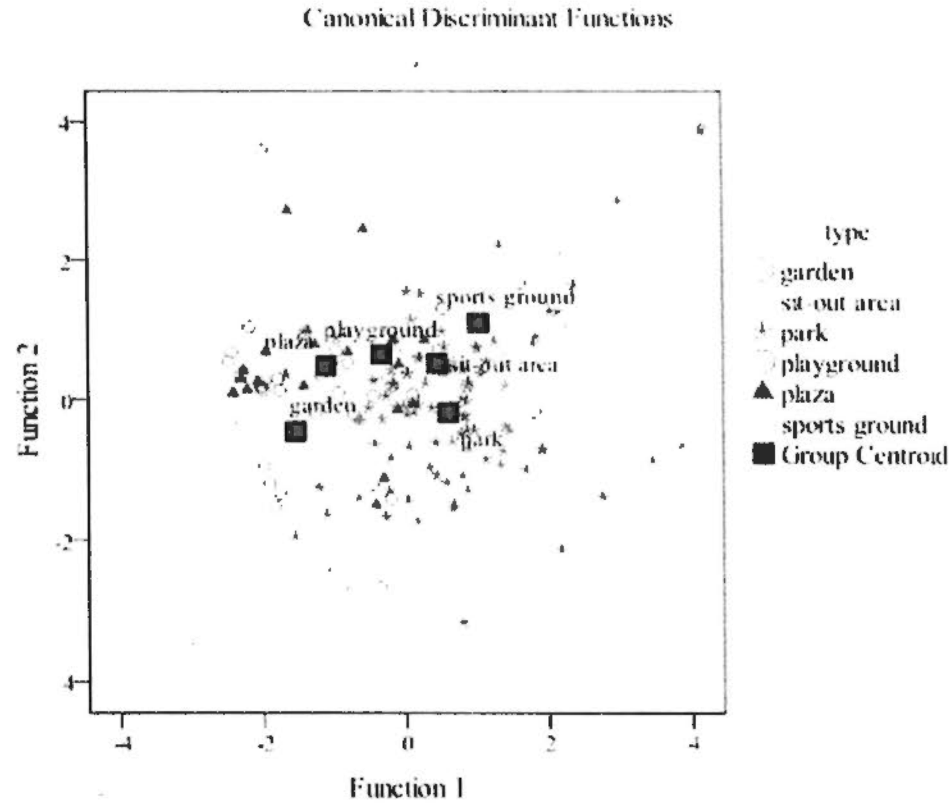



Figure 5.11 Canonical discriminant analysis of psychoacoustic attributes by assigning the type of place as the grouping variable

So far conclusions on the association between psychoacoustic variables and types of open spaces have been reached. Among the seven variables, only loudness is related to group membership; the other six variables are not closely related to group membership. Table 5.12 summarizes the success of discriminant functions in discriminating different types of open spaces. Overall, 65.6% of the sample is correctly classified into their diagnosis group. At individual group level, 89.8% of parks, 52.2% of gardens, 42.1% of plazas, and 25% of sports grounds have been correctly classified.

Figure 5.12 Classification results of discriminant analysis

| Type | | Predicted Group Membership | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | garden | park | playground | plaza | sports ground | |
| Original (%) | garden | 52.2 | 17.4 | 0.0 | 30.4 | 0.0 | 100.0 |
| | park | 3.4 | 89.8 | 1.1 | 3.4 | 2.3 | 100.0 |
| | playground | 0.0 | 66.7 | 8.3 | 25.0 | 0.0 | 100.0 |
| | plaza | 15.8 | 42.1 | 0.0 | 42.1 | 0.0 | 100.0 |
| | sports ground | 0.0 | 75.0 | 0.0 | 0.0 | 25.0 | 100.0 |

*** 65.6% of original grouped cases correctly classified.**

### 5.6 Summary

The primary objective of this chapter is to unravel the acoustic characteristics of urban open space soundscapes in Hong Kong. In this chapter, we found that in different types of open spaces, the acoustic environment differs in terms of sound intensity, sound source, sound frequency spectrum, and psychoacoustic profiles.

In terms of sound intensity, most urban open spaces are exposed to sound levels higher than 60 dB $L_{Aeq}$. Large parks are relatively quieter, whereas small gardens are noisier. Sports grounds exhibit the widest range of sound level variation, whereas gardens have the narrowest. Both sound walk observations and frequency spectrum analysis are important ways to identify sound sources. Despite the dominance of traffic noise in urban areas, the soundscapes of urban open spaces are also shaped by the existence of natural sounds, such as sounds from water, birds, the wind, and man-made sounds, including those from talking, walking, and laughing. Different combinations of sounds fashion soundscape characteristics in different types of open spaces.

ANOVA was adopted to compare psychoacoustic attributes in different types of open spaces. Results show significant differences in terms of loudness, roughness, fluctuation, and sharpness. To further identify which psychoacoustic parameter best differentiates the different types of urban open space soundscapes, canonical discriminant analysis was conducted. Among the psychoacoustic parameters, loudness contributes the most in the discrimination of soundscapes in different types of open spaces.

The establishment of the fact that acoustic profiles are statistically significant factors influencing the characteristics of soundscapes in urban open spaces of Hong Kong has further linked to Chapter 6, which aims to assess how visitors perceive and evaluate physical acoustic environments.

*Environmental sounds can be said to have both denotations and connotations at the same time—they can carry both general and personal meanings.*

------ *Cognitive Maps and Auditory Perception*,
Uimonen, 2002: 173

# Chapter 6

# Visitors' Perception of the Acoustic Quality of Urban Open Spaces

For a long time, quantitative and measurable attributes have been used to explain how humans evaluate their surrounding sonic environment. It was not until the late 1960s when Schafer introduced the multidisciplinary concept of soundscape, which does not depend on quantitative attributes alone. The concept of soundscape has introduced subjective factors, including the meaning of sound. Chapter 5 presented the physical characteristics of soundscapes in urban open spaces. This chapter focuses on visitors' perception of the acoustic quality of urban open spaces in Hong Kong.

## 6.1 Introduction

As stated in Chapter 1, one of the objectives of this research is to explain visitors' evaluation of the acoustic quality of urban open spaces in Hong Kong. To achieve this, a two-stage procedure was adopted. The first stage attempted to identify quiet open spaces by noise mapping techniques for intensive study. The second stage aimed to describe the acoustic characteristics of these sites based on data obtained through sound recordings and interviews with visitors. Following these steps, a total of 25 study sites were selected, where 210 sets of sound recordings were collected and 1,610 visitors were successfully interviewed.

The 15-minute sound recordings were played back in the laboratory where audio signals were transferred to a Brüel & Kjær model 2250 investigator in conjunction with Application Software Type 7820 for the determination of metrics, such as $L_{Aeq}$

and 1/3 octave frequency spectrum in one-second intervals. In the on-site interviews, visitors were asked about their visiting habits, degree of liking of environmental quality in general and acoustic quality in particular, preferred individual sounds, and rating of a range of semantic attributes of the acoustic environment. In this study, a five-point numeric scale was employed for the subjective evaluation of the quality of sounds and soundscapes, where "1" represents the most negative opinion and "5" the most positive response. Both sets of data were processed and analyzed using Statistical Package of the Social Sciences (SPSS) Software. A number of statistical techniques, including correlation, regression, and ANOVA, were utilized for data analysis.

This chapter analyzes the survey data, paying particular attention to two main issues. One is the explanation of social and demographic factors affecting visitors' preference for different sounds and quality of soundscapes; the other is the evaluation of a conceptual framework proposed by Lex Brown (Brown, 2006a; Brown, 2007a) to account for variations in the human assessment of outdoor acoustic environments.

As elaborated in Chapter 2, the elucidation of socio-demographic factors influencing the human perception of acoustic quality is controversial in soundscape research (Raimbault and Dubois, 2005; Roy and Snader, 2008; Yu and Kang, 2008; Jeon *et al.*, 2010; Yu and Kang, 2010). Among the more recent studies, the work undertaken by Kang and his team is noteworthy. They conducted a series of large-scale surveys and objective measurements in urban open spaces in Europe and China, and investigated the effects of socio-demographic factors, such as age, gender, occupation, education, and residential status, on soundscape evaluation in terms of sound preference and sound level evaluation. Acoustic comfort is considered an overall criterion (Yang and Kang, 2005a). Their work has demonstrated that whereas age and educational level are two factors that universally and significantly influence sound preference, occupation and residential status are not significant determinants of sound preference evaluation (Yu and Kang, 2010). In terms of sound level evaluation (Yu and Kang, 2008), the effects of socio-demographic factors are generally not significant, although the two interrelated factors of occupation and education correlate with sound level evaluation more than other factors. In more recent studies, general and specific artificial neural network models have been used for subjective sound level, acoustic comfort evaluation (Yu and Kang, 2009), and soundscape evaluation (Yu and Kang, 2005b; 2006). These models are also useful in urban soundscape studies.

As an alternative to disentangling the complex process of human perception and evaluation of outdoor environment, Brown proposed a relatively simple conceptual framework for evaluating the quality of soundscapes (Brown, 2006a; Brown, 2007b). He suggested the use of a two-by-two matrix to depict the subjective evaluation of acoustic quality, taking into account the level of sounds experienced on one hand, and whether or not particular sounds heard are wanted or unwanted on the other (Brown, 2006b). Brown's simple framework underpins the significance of context because a sound that is acceptable in one situation may appear "out of place" in another. To what extent Brown's framework is applicable to different places is yet to be validated by empirical data and large-scale field surveys.

In other words, this chapter aims to study the human perception of acoustic quality in urban open spaces in terms of the influence of socio-demographic factors, acoustic factors, and psychoacoustic factors. Based on data from large-scale field interviews, relationships between the subjective evaluation of acoustic quality and various socio-demographic factors were investigated. Brown's framework, which highlights the importance of wanted and unwanted sounds in determining the perceived acoustic quality of a particular place, was utilized. Ordinal logistic regression (OLR) models were developed to predict sound preferences, and a number of factors that are vital to soundscape evaluation were identified. The results provide urban planners with a useful tool for predicting acoustic quality from the perspective of visitors.

## 6.2 Effects of Socio-demographic Factors on Sound Preference in Urban Open Spaces

Identifying sounds and their corresponding characteristics is only the first task in human evaluation of soundscapes. Socio-demographic factors can influence visitors' awareness and perception of sounds, and thus shape their judgment of overall acoustic quality. In the surveys of this study, visitors were asked to respond to two questions: one on urban open spaces in Hong Kong in general, and the other on open spaces where the interviews were conducted. The first question asked respondents to rate their degree of liking of sounds commonly heard in urban open spaces in Hong Kong. The second question asked respondents about the kind of sound they would like and would not like to hear in a particular open space. Based on data collected, appropriate statistical techniques were employed to evaluate the influence of visitors' socio-demographic characteristics on their preferred sounds.

### 6.2.1 Preferred sound in the urban open spaces of Hong Kong in general

In the search for factors influencing sound preferences, two questions were posed on a five-point numeric scale. First, visitors were asked to indicate their degree of preference for each of nine nominated sounds commonly heard in urban open spaces in Hong Kong. Second, they were asked to name their most favored sound heard at the study site. As shown in Table 6.1, responses to the first question indicate that birdsongs, wind sounds, and water sounds are the three most preferred sounds, whereas mechanical sounds from construction and road traffic are the least preferred. Between these two preferences is the human voice.

The observed differential preference is significant across different open spaces according to one-way ANOVA ($p < 0.05$). This is true for all sounds, except for construction noise. It is noteworthy that man-made sounds are relatively more preferred in plazas than in other open spaces. This can be explained by visitors' expectation that public places are where people gather and meet. People take it for granted that these places would be noisy or are not necessarily quiet; hence, they are generally more tolerant of noise.

The foregoing findings are also echoed in the results shown in Table 6.2, in which visitors were asked to nominate their most favorite sounds at the study site. Similar to the results obtained by previous studies (Yang and Kang, 2005b), birdsongs and water sounds are generally more preferred to other sounds. Generally, natural sounds are more preferred in urban open spaces, and sounds from construction and traffic are generally not welcomed. Such results are expected because natural sounds tend to be balanced, aesthetically rich, and pleasing; these sounds give people a sense of calmness. On the other hand, man-made sounds, including voices, footsteps, and conversations, are more likely to be characterized by distortion, broad-band noise, and discomfort (Carles *et al.*, 1999). When visitors choose a place to use, sound preferences do play an important role. A high-quality acoustic environment attracts and makes people feel better.

Table 6.1 Mean human preference for different sound sources in different open spaces on a scale of 1 to 5

| | *N | Bird | Insect | Wind | Water | Church Bell | Machine | Traffic | Human voice | Children shouting |
|---|---|---|---|---|---|---|---|---|---|---|
| Park | 964 | 4.47 | 3.85 | 4.29 | 4.29 | 3.17 | 1.29 | 1.35 | 2.53 | 3.15 |
| Playground | 77 | 4.03 | 3.21 | 3.83 | 3.86 | 2.76 | 1.38 | 1.66 | 2.72 | 3.07 |
| Sports ground | 51 | 4.35 | 3.82 | 4.18 | 3.96 | 2.63 | 1.10 | 1.20 | 2.33 | 2.73 |
| Plaza | 339 | 4.54 | 3.99 | 4.45 | 4.54 | 3.48 | 1.27 | 1.32 | 2.81 | 3.19 |
| Garden | 179 | 4.41 | 3.85 | 4.39 | 4.14 | 3.09 | 1.32 | 1.36 | 2.63 | 3.03 |
| Average | | 4.47 | 3.87 | 4.33 | 4.31 | 3.21 | 1.29 | 1.34 | 2.6 | 3.13 |

*N= Number of respondents
#1: dislike most; 5: like most

Table 6.2 The most favored sound nominated by visitors in different open spaces

| Type | *N | Most favored sound for a particular open space (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Wind | Water | Insect | Birds | Soft music | Children | Human voice | Footstep | Sports | Others | Total |
| Park | 964 | 8.9 | 25.6 | 7.4 | 46.2 | 3.4 | 2.4 | 1.9 | 0.3 | 1.9 | 2.0 | 100 |
| Playground | 77 | 0 | 0 | 0 | 68.0 | 0 | 0 | 0 | 0 | 32.0 | 0.0 | 100 |
| Sports ground | 51 | 12.0 | 4.0 | 0 | 68.0 | 0 | 0 | 4.0 | 0 | 12.0 | 0.0 | 100 |
| Plaza | 339 | 11.6 | 47.2 | 0 | 17.3 | 2.3 | 2.3 | 10.3 | 0.7 | 1.3 | 7.0 | 100 |
| Garden | 179 | 7.7 | 37.7 | 2.3 | 39.2 | 0 | 0 | 6.9 | 3.1 | 1.5 | 1.6 | 100 |

*N= Number of respondents

### 6.2.2 Influence of socio-demographic factors on sound source preference

Judging different sounds can be difficult, considering that one has to evaluate a constellation of sound events and variations caused by subjective perceptions. With reference to a host of factors, a number of studies have reported the effects of various socio-demographic factors on sound evaluation (Job, 1988; Yu and Kang, 2006). Noise annoyance is not related to gender but is rather somewhat related to age (Miedema and Vos, 1999). People with higher educational levels and occupational status are more easily annoyed by noise. Studies on acoustic comfort have found significant differences across different age groups. Teenagers are most dissatisfied with the acoustic environment, whereas older people are most satisfied (Yang and Kang, 2005a). With regard to sound preferences, distinct differences have been found across age groups and gender (Yang and Kang, 2005b). Individual sound evaluation is related to age and educational level, two factors that significantly influence sound preference, although the impacts may vary with the type of urban open space and sounds being heard (Yu and Kang, 2010).

#### 6.2.2.1 Relationship between socio-demographic factors and preference for different sound sources in Hong Kong urban open spaces

Based on interviews in different types of urban open spaces in Hong Kong, a systematic analysis of the influence of socio-demographic factors on sound preference was made. Table 6.3 presents a summary of the relationship between socio-demographic factors and sound preference. Mechanical sounds and traffic noise are less significantly correlated with socio-demographic factors. These two types of sounds are generally not preferred by most visitors; hence, no significant difference can be identified across different groups. The evaluation of sounds from insects, wind, church bell, and children shouting is more closely related with socio-demographic factors. The preference for sound from insects is influenced by age, occupation, education, and activities undertaken, whereas wind sound evaluation is affected by age, gender and occupation. Children's voice is evaluated differently across different ages, gender, and specific activities.

The role of activity undertaken merits special mentioning. It is an important factor influencing visitors' state of listening and, consequently, their corresponding perception of acoustic environments (Jennings, 2009). Different kinds of facilities and environments are provided in different types of open spaces; therefore, visitors can choose that which can meet their particular expectations. Table 6.3 shows that the relationship between activity and the subjective evaluation of individual sounds is relatively strong in five out of nine different sounds at statistically significant levels. This is particularly the case in plazas, where the human evaluation of sounds from insects, church bell, machines, traffic, and human voice is significantly associated with the activities conducted by visitors.

Table 6.3 Effects of socio-demographic factors on the sound source evaluation in terms of the significant levels

| Socio-demographic Factor | | Sound Source Evaluation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Bird | Insect | Wind | Water | Church Bell | Machine | Traffic | Human Voice | Children Shouting |
| Age | Park | 0.128** | 0.186** | 0.154** | 0.086** | -0.101** | 0.033 | 0.035 | 0.086** | 0.137** |
| | Playground | -0.108 | 0.047 | -0.225 | -0.091 | -0.160 | -0.189 | -0.038 | 0.212 | 0.547** |
| | Sports ground | 0.018 | 0.275 | -0.300* | -0.056 | -0.212 | -0.181 | -0.238 | -0.305* | 0.060 |
| | Plaza | 0.156* | 0.254** | 0.056 | -0.092 | -0.046 | 0.051 | 0.114* | 0.041 | 0.143* |
| | Garden | 0.001 | 0.053 | 0.026 | -0.014 | -0.091 | 0.013 | -0.054 | -0.030 | -0.164* |
| | All | 0.093** | 0.176** | 0.075** | 0.004 | -0.075** | 0.055* | 0.058* | 0.030 | 0.137** |
| Gender | Park | 0.019 | 0.090 | -0.084 | -0.061 | -0.223** | -0.005 | 0.044 | 0.029 | -0.081 |
| | Playground | -0.272 | -0.828 | -0.894* | -0.522 | -0.350 | 0.228 | 0.467 | 0.083 | -0.383 |
| | Sports ground | 0.159 | 0.056 | 0.349 | 0.222 | 0.087 | -0.016 | -0.032 | 0.000 | -0.198 |
| | Plaza | 0.016 | 0.019 | -0.067 | 0.029 | 0.055 | 0.050 | 0.043 | -0.028 | -0.122 |
| | Garden | -0.091 | -0.044 | -0.072 | -0.027 | -0.135 | 0.044 | -0.008 | -0.050 | -0.077 |
| | All | -0.012 | 0.020 | -0.106** | -0.074* | -0.191** | 0.012 | 0.042 | -0.022 | -0.116* |
| Occupation | Park | 0.046 | 0.080* | 0.095** | 0.006 | -0.129** | -0.015 | -0.025 | 0.041 | 0.051 |
| | Playground | -0.357 | -0.202 | -0.270 | -0.238 | -0.178 | -0.005 | -0.051 | 0.167 | 0.204 |
| | Sports ground | -0.079 | 0.047 | -0.284* | -0.108 | -0.155 | -0.073 | -0.137 | -0.250 | 0.015 |
| | Plaza | 0.108* | 0.100* | 0.071 | -0.035 | -0.172** | 0.034 | -0.035 | -0.020 | 0.051 |
| | Garden | 0.095 | 0.167* | 0.158* | 0.004 | -0.084 | 0.061 | 0.047 | -0.039 | -0.062 |
| | All | 0.048 | 0.075** | 0.061* | -0.017 | -0.143** | 0.010 | -0.018 | -0.006 | 0.043 |

#data are shown in terms of the Spearman correlations (two-tailed) for factors with more than 2 scales except for activity, where Pearson Chi-square is used and the level of significance is shown in the table; and mean differences (t-test, two-tailed) for factors with 2 scales.
#Symbols * and ** indicate significant correlations or differences, with * representing $p< 0.05$ and ** representing $p<0.01$.

Table 6.3 (*Continued.*)

| Demographic Factor | | Sound Source Evaluation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Bird | Insect | Wind | Water | Church Bell | Machine | Traffic | Human Voice | Children Shouting |
| Education | Park | -0.026 | -0.038 | -0.056 | 0.002 | 0.154** | -0.013 | -0.042 | -0.028 | -0.023 |
| | Playground | 0.126 | 0.030 | 0.122 | 0.110 | 0.085 | -0.305 | -0.361 | -0.334 | -0.246 |
| | Sports ground | 0.014 | -0.277* | 0.246 | -0.085 | 0.142 | -0.072 | 0.184 | 0.156 | 0.047 |
| | Plaza | -0.052 | -0.135* | 0.009 | 0.036 | 0.071 | -0.049 | -0.050 | -0.088 | -0.104* |
| | Garden | -0.076 | -0.046 | -0.027 | 0.026 | 0.023 | 0.056 | 0.044 | 0.092 | 0.059 |
| | All | -0.033 | -0.063* | -0.016 | 0.015 | 0.123** | -0.025 | -0.041 | -0.025 | -0.040 |
| Activity | Park | 0.000** | 0.511 | 0.075 | 0.000** | 0.046* | 0.255 | 0.342 | 0.188 | 0.001** |
| | Playground | 0.682 | 0.510 | 0.918 | 0.080 | 0.582 | 0.794 | 0.302 | 0.335 | 0.796 |
| | Sports ground | 0.320 | 0.945 | 0.084 | 0.180 | 0.627 | 0.214 | 0.333 | 0.729 | 0.063 |
| | Plaza | 0.150 | 0.000** | 0.238 | 0.070 | 0.000** | 0.000** | 0.000** | 0.012* | 0.070 |
| | Garden | 0.950 | 0.068 | 0.767 | 0.456 | 0.614 | 0.423 | 0.493 | 0.747 | 0.030* |
| | All | 0.000** | 0.000** | 0.520 | 0.000** | 0.000** | 0.112 | 0.475 | 0.000** | 0.003 |

#### 6.2.2.2 Differences in sound source preference among different socio-demographic groups

We further explored the effects of socio-demographic factors on sound evaluation. To study differences across groups, ANOVA and t-tests were utilized. Table 6.4 shows the mean differences in individual sound preferences across age groups. Preferences for five out of nine individual sounds have been found to be significantly different across age groups. Notably, with an increase in age, people become more attracted to sound from nature. For example, visitors who are older than 60 have a higher preference for birdsongs, insect chirping, and wind-induced fluttering sounds from trees and leaves. With regard to culture-related sounds, such as church bell ringing, younger and older visitors hold different opinions. Dynamic and rousing sounds in urban open spaces seem more acceptable to young people. On the other hand, elderly people have higher preference for the sound of children shouting. The emotional attributes of some sounds possibly account for this difference. Elderly people are more tolerant or even appreciative of sounds that children make.

Table 6.4 Significant mean differences in terms of individual sound sources between different age groups

| Sound Source | Age (i) | M | SD | Age (j) | M | SD | Mean Difference | Sig. |
|---|---|---|---|---|---|---|---|---|
| Bird | <18 | 4.31 | 0.714 | >60 | 4.57 | 0.656 | -0.259 | 0.004 |
| Insect | <18 | 3.70 | 1.128 | >60 | 4.17 | 0.880 | -0.469 | 0.000 |
| | >60 | 3.53 | 1.055 | 31-40 | 3.91 | 0.872 | -0.381 | 0.000 |
| | | | | 41-60 | 3.88 | 0.980 | -0.639 | 0.000 |
| | 25-30 | 3.70 | 0.990 | >60 | 4.17 | 0.880 | -0.470 | 0.000 |
| Wind | 18-24 | 4.26 | 0.763 | >60 | 4.47 | 0.659 | -0.209 | 0.011 |
| | 31-40 | 4.28 | 0.660 | | | | -0.186 | 0.011 |
| | 41-60 | 4.32 | 0.724 | | | | -0.149 | 0.050 |
| Church bell | <18 | 3.43 | 0.986 | >60 | 3.03 | 1.054 | 0.402 | 0.009 |
| | 31-40 | 3.31 | 0.951 | | | | 0.288 | 0.006 |
| Children shouting | <18 | 2.75 | 0.849 | 31-40 | 3.15 | 0.958 | -0.398 | 0.003 |
| | | | | 41-60 | 3.21 | 0.952 | -0.464 | 0.000 |
| | | | | >60 | 3.25 | 0.979 | -0.506 | 0.000 |
| | 18-24 | 2.99 | 0.882 | 41-60 | 3.21 | 0.952 | -0.221 | 0.047 |
| | | | | >60 | 3.25 | 0.979 | -0.263 | 0.021 |

* M=Mean; SD=Standard Deviation;

There are also some significant differences between male and female visitors in sound preference (Table 6.5). Male and female visitors have similar preferences for sounds from birds and insects, as well as for mechanical sounds, traffic noise, and human voice. The difference lies in the preference for sounds from wind blowing, water flowing, church bell ringing, and children shouting. It seems that female visitors are more attracted to sounds from moving objects, either air or water. Compared with male visitors, female visitors are more sensitive to changes, suggesting the presence of on-going activities and closeness to a more active social environment. Female visitors also have a higher preference for sounds with particular emotional effects. For example, they prefer culturally approved sounds, such as church bell ringing and children's shouting, due to their emotional connotations.

Table 6.5 Significant mean differences in individual sound source preference between male and female visitors (t-test, 2-tailed)

| Sound Source | t | df | Sig. (2-tailed) | Mean Difference | Male | | Female | |
|---|---|---|---|---|---|---|---|---|
| | | | | | M | SD | M | SD |
| Wind | -3.019 | 1607 | 0.003 | -0.106 | 4.27 | .733 | 4.38 | .679 |
| Water | -2.056 | 1607 | .040 | -0.074 | 4.28 | .760 | 4.35 | .693 |
| Church bell | -3.675 | 1607 | .000 | -0.191 | 3.11 | 1.053 | 3.30 | 1.036 |
| Children shouting | -2.450 | 1607 | .014 | -0.116 | 3.07 | .937 | 3.19 | .961 |

Preferences for birdsongs, insect chirping, church bell ringing, and children shouting differ across occupations (Table 6.6). Moreover, it is interesting to note that preferences for most of the sounds significantly differ across age groups. It is reasonable to assume that age and occupation are interrelated variables in terms of sound evaluation. Chi-square test for independence was conducted. Results indicate a significant association between age and occupational status [$\chi2$ (45, n=1610) = 2187.99, p = 0.000, Cramer's V= 0.521]. Therefore, the influence of occupational status cannot be purely analyzed without considering the interaction effect between age and occupation.

Table 6.6 Significant mean differences in individual sound source reference between visitors with different occupational status

| Sound Source | Occu(i) | M | SD | Occu(j) | M | SD | Mean difference | Sig. |
|---|---|---|---|---|---|---|---|---|
| Bird | 5 | 4.39 | 0.666 | 8 | 4.57 | 0.564 | -0.184 | 0.027 |
| Insect | 5 | 3.62 | 1.061 | 8 | 3.94 | 0.913 | -0.314 | 0.007 |
| | | | | 9 | 4.10 | 0.922 | -0.476 | 0.000 |
| | 7 | 3.73 | 1.007 | 9 | 4.10 | 0.922 | -0.367 | 0.048 |
| Church bell | 2 | 3.55 | 0.968 | 8 | 3.00 | 0.98 | 0.549 | 0.000 |
| | | | | 9 | 3.05 | 1.05 | 0.501 | 0.000 |
| | | | | 10 | 1.08 | 0.099 | 0.477 | 0.013 |
| | 3 | 3.50 | 0.973 | 8 | 3.00 | 0.98 | 0.492 | 0.001 |
| | | | | 9 | 3.05 | 1.05 | 0.444 | 0.003 |
| | 6 | 3.36 | 1.049 | 8 | 3.00 | 0.98 | 0.361 | 0.021 |
| Children shouting | 5 | 2.91 | 0.899 | 8 | 3.29 | 0.913 | -0.385 | 0.000 |
| | | | | 9 | 3.22 | 0.972 | -0.313 | 0.004 |

Note: Occupation: 1: manager; 2: professional; 3: clerk; 4: skilled labor; 5: student; 6: service worker; 7: sales; 8: housewife; 9: retired; 10: other.

Preferences for five out of nine individual sounds significantly differ across different educational levels (Table 6.7). With increasing educational level, people tend to be more appreciative of culture-related sounds, such as church bell ringing. In the evaluation of natural sounds, only wind was described differently by different groups; visitors with lower educational levels have a higher preference for wind sounds. Moreover, visitors with higher educational levels are less tolerant of man-made sounds.

Table 6.7 Significant mean differences in individual sound source reference between visitors with different educational attainment

| Sound Source | Edu(i) | M | SD | Edu (j) | M | SD | Mean difference | Sig. |
|---|---|---|---|---|---|---|---|---|
| Wind | 1 | 4.41 | 0.692 | 2 | 4.29 | 0.724 | 0.127 | 0.037 |
| | | | | 3 | 4.22 | 0.700 | 0.19 | 0.031 |
| Church bell | 1 | 3.12 | 1.073 | 4 | 3.46 | 1.078 | -0.337 | 0.000 |
| | 2 | 3.11 | 1.032 | 4 | 3.46 | 1.078 | -0.349 | 0.000 |
| Machine | 1 | 1.36 | 0.688 | 2 | 1.26 | 0.542 | 0.102 | 0.043 |
| | | | | 4 | 1.24 | 0.533 | 0.115 | 0.044 |
| | 2 | 1.26 | 0.542 | 3 | 1.39 | 0.610 | -0.135 | 0.042 |
| | 3 | 1.39 | 0.61 | 4 | 1.24 | 0.533 | 0.149 | 0.036 |
| Traffic | 1 | 1.44 | 0.704 | 2 | 1.31 | 0.570 | 0.128 | 0.008 |
| | | | | 4 | 1.31 | 0.574 | 0.129 | 0.025 |
| Children shout | 1 | 3.30 | 0.921 | 2 | 3.05 | 0.936 | 0.248 | 0.001 |

Education: 1=primary; 2= secondary school; 3= college; 4= university and above

In summary, socio-demographic factors significantly influence sound preferences. Natural sounds are generally favored, whereas mechanical sounds are described as unpleasant and not enjoyable. Young people generally prefer lively sounds, whereas their older counterparts prefer peaceful sounds. Preferences for sounds from wind blowing, water flowing, church bell ringing, and children shouting significantly differ across gender. Female visitors are more sensitive to the emotional aspects of sounds. Occupation is correlated with age; therefore, sound source evaluation should be analyzed by paying attention to the interaction effect between them. Educational background is also related with age, but the corresponding effect size is comparatively small. With increasing education attainment, people tend to be more appreciative of culturally approved sounds.

## 6.3 Effects of Socio-demographic Factors on Subjective Evaluation of the Acoustic Quality of Urban Open Spaces

Human perception of the acoustic environment is related more with personal factors than physical sound itself. Objective measurements can be made on specific sounds, but personality factors are among the most difficult to quantify. In general, a sound can be responsible for both positive and negative psychological effects. Previous studies (White, 1975) have suggested that sound effect is essentially conditioned by demographic factors and those related to sound-producing activities. More recently, numerous field works have reported the correlation between noise exposure measures and social surveys of reaction to noise (Job, 1988). Such examination of noise indices is complemented by respondents' related variables, such as age, gender, and social and economic status (Öhrström *et al.*, 2006a), as well as attitudes toward sound (Yu and Kang, 2008; 2010). Results from these studies demonstrate the influence of a number of factors, including social, demographic, and behavioral factors, as well as sonic experiences in sound evaluation. However, these studies are largely based on residential areas and noise annoyance (Öhrström *et al.*, 2006b). Soundscape study does not only consider noise, but more importantly, also the positive emotions conveyed by sounds. The next section explores the effects of various socio-demographic factors on subjective acoustic quality evaluation.

### 6.3.1 Subjective evaluation of the acoustic quality in different types of open spaces

The preceding chapters presented the use of a questionnaire in eliciting responses in relation to five types of open spaces in Hong Kong, namely, parks, playgrounds, sports grounds, plazas, and gardens. Figure 6.1 shows respondents' acoustic quality evaluation (mean scores) of open spaces where the interviews were conducted. Of the five open spaces, parks received the highest score, whereas gardens the lowest score. The scores are quite reasonable because gardens are comparatively smaller and more closely located to roadways than parks. The lack of buffer space makes gardens more exposed to road traffic noise, and traffic may render other preferred sound less recognizable. On the other hand, the larger buffer space in parks makes traffic noise less noticeable, such that the presence of other sounds is more prominent, making parks more pleasant to users.

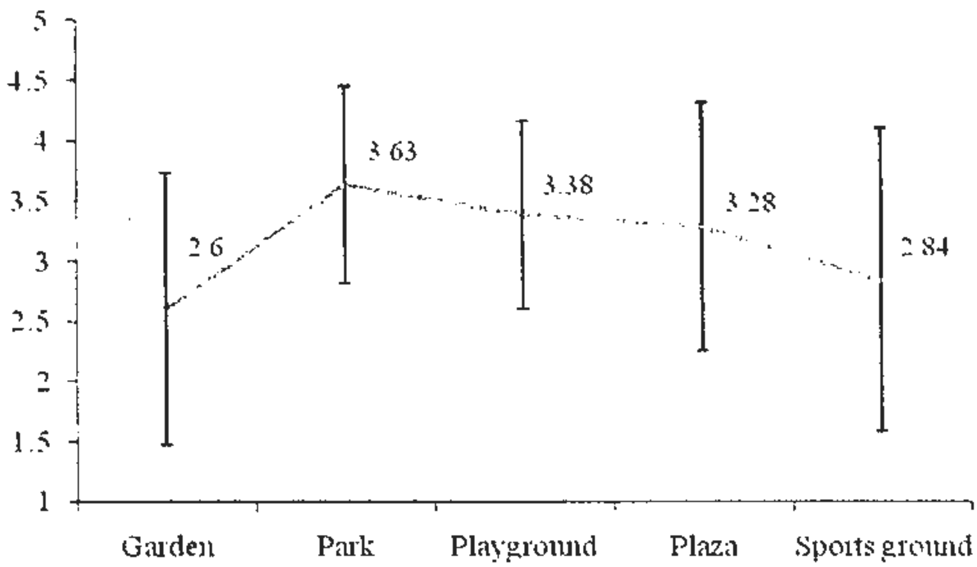



Figure 6.1 Subjective evaluation of acoustic quality with standard deviation
(Human preference was in terms of the degree the acoustic environment was liked, where 1 dislike most and 5 = like most)

Based on respondents' subjective evaluation, acoustic quality significantly differs across the five types of open spaces [$F$ (4, 276) = 53.569, $p$ = 0.000]. The following section shows why the impact of socio-demographic factors on the subjective evaluation of acoustic quality should be analyzed separately according to each particular type of open space.

### 6.3.2 Relationship between overall environmental quality and the acoustic quality

In the perception and evaluation of the environment, one aspect is rarely considered: human judgment is based on multisensory representations. To examine how visitors appraise the acoustic quality of urban open space soundscapes, interviewees were asked to evaluate, on a five-point numerical scale, the quality of the overall environment and soundscape of the open space they visited at the time of interview.

There is a close relationship between visitors' subjective evaluation of the overall environmental quality and their evaluation of the acoustic environment ($r$=0.594, $p$ < 0.05, n=1610; Figure 6.2). The statistically significant correlation indicates that the acoustic environment is an important component of the physical environment of open spaces, highlighting the significance of soundscapes.

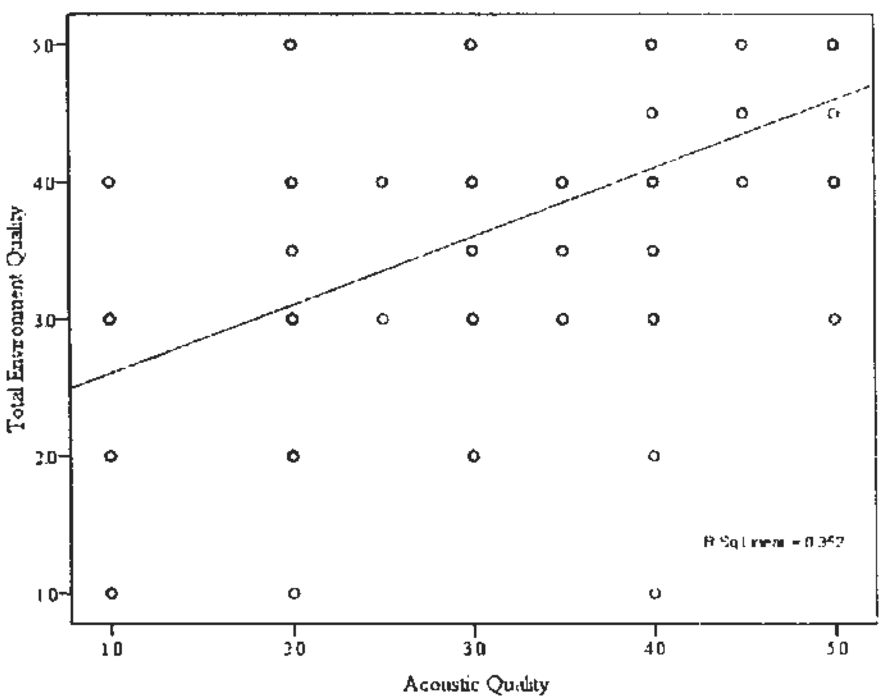



Figure 6.2 Relationship between evaluation of the total environment quality and the acoustic quality

Therefore, improvements in acoustic quality can enhance holistic environmental quality. This coincides with previous findings on the interaction between visual and audio judgment in evaluating the quality of an environment (Southworth, 1969; Björk, 1995; Tamura, 1997; Hedfors and Berg, 2003b; Uimonen, 2005). The evaluation of acoustic quality is interrelated with the perception of the holistic environment.

### 6.3.3 Semantic attributes of the acoustic environment and their relationship with acoustic quality

To determine attributes of the acoustic environment preferred by visitors, respondents were also asked to provide ratings, using a five-point bipolar semantic differential rating scale, on the "quietness," "naturalness," and "joyfulness" of soundscapes in the particular open spaces they visited. Table 6.8 shows the correlation between acoustic quality and these three perceptual attributes.

Table 6.8 Correlation between acoustic quality and perceptual attributes of the soundscape

| | Acoustic Quality | |
|---|---|---|
| | Pearson correlation coefficient | $p$ |
| Quietness | 0.792 | 0.000* |
| Naturalness | 0.606 | 0.000* |
| Joyfulness | 0.655 | 0.000* |

*statistically significant with confidence interval > 95%

A few observations can be made from Table 6.8. First, there is a close relationship between acoustic quality and quietness, probably reflecting the expectation of finding a quiet environment in urban open spaces. Second, in addition to quietness, visitors also treasure other attributes, such as the naturalness and joyfulness of soundscapes. This suggests that visitors enjoy sounds from natural sources, such as those from birds and water. Previous research has shown that natural sounds may bring joyful and positive feelings (Carles *et al.*, 1999; Truax, 1999; Lam *et al.*, 2010).

To determine the extent to which quietness contributes to a good acoustic environment, linear regression analysis was conducted on the subjective ratings of the acoustic environment and measured sound pressure levels. The scatter plot in Figure 6.3 indicates a general negative correlation between sound level and acoustic quality, yielding the following regression equation:

$$\text{Acoustic quality} = -0.064\, L_{Aeq} + 7.441\ (R^2 = 0.093,\ p < 0.001)$$

However, it should be noted that the $R^2$ value is small, indicating that only 9.3% of the variance in acoustic quality is explained by sound level. This result indicates that the subjective evaluation of acoustic quality is determined by factors other than sound exposure level. As such, further investigation is warranted.

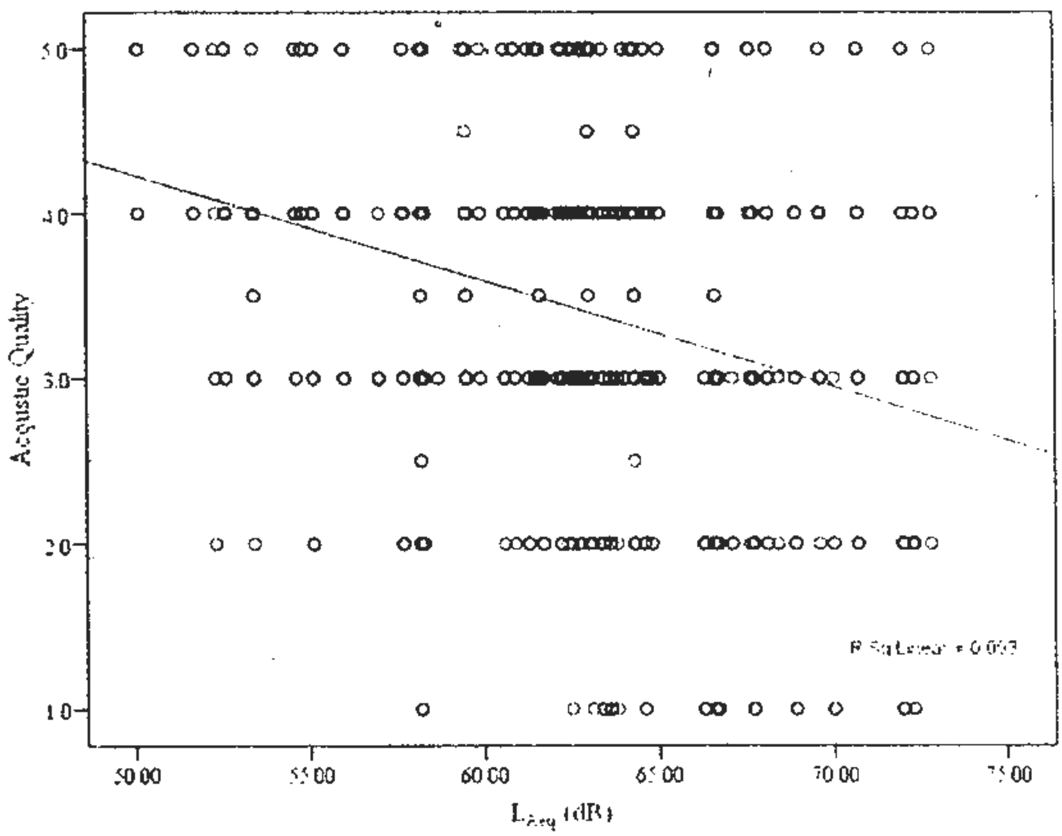



Figure 6.3 Scatter plot of sound pressure level and acoustic quality

### 6.3.4 Influence of socio-demographic factors on subjective evaluation of the acoustic environment quality

This section explains how socio-demographic factors influence the subjective evaluation of acoustic quality.

### 6.3.4.1 Correlation between socio-demographic factors and subjective evaluation of the acoustic environment quality

The correlations between acoustic quality evaluation and respondents' socio-demographic background are shown in Table 6.9. It is interesting to note that the influence of socio-demographic factors on acoustic quality evaluation is not the same as that on sound preference. In the evaluation of overall acoustic quality, the influence of age is less important, whereas preferences for five out of nine individual sounds significantly differ across age groups. There are also no significant differences in acoustic quality evaluation between males and females in the five types of open spaces. In terms of educational level, differences exist. With higher educational levels, people tend to be more appreciative of culture-related sounds, but when it comes to the evaluation of acoustic quality, significant differences exist only in the evaluation of sports grounds and gardens. The influence of occupational status is even less important. Similar to findings on sound preference, activities undertaken are significantly related with the subjective evaluation of acoustic quality.

Table 6.9 Correlation between subjective acoustic quality and socio-demographic factors

| Type | Factors | | | | |
|---|---|---|---|---|---|
| | Age | Gender | Occupation | Education | Activity |
| Park | 0.048 | -0.070 | -0.013 | -0.003 | 0.905 |
| Playground | -0.034 | -0.417 | -0.206 | 0.330 | 0.676 |
| Sports ground | -0.354* | -0.056 | -0.225 | 0.530** | 0.019* |
| Plaza | -0.057 | 0.021 | -0.035 | 0.088 | 0.056 |
| Garden | 0.025 | -0.258 | 0.207** | -0.190** | 0.067 |
| Overall | 0.047 | -0.071 | 0.044 | -0.017 | 0.000** |

[1] Significant levels of the Spearman correlations (two-tailed) are tabulated for factors with more than 2 scales;

[2] Pearson Chi-square is used with the level of significance for the factor of activity;

[3] Mean differences (t-test, two-tailed) are used for factors with 2 scales;

[4] Marks * and ** indicate significant correlations or differences, with * representing $p < 0.05$ and ** representing $p < 0.01$

### 6.3.4.2 Differences in acoustic quality evaluation between different socio-demographic groups

To explain the relationship between reported acoustic quality and demographic factors, several statistical analyses have been performed. For all tests of significant differences, $p < 0.05$ was adopted.

According to one-way ANOVA results, acoustic quality evaluation significantly differs across age groups [$F$ (5, 1604) = 3.989, $p$ = 0.001]. Elderly people above 60 are the most satisfied group (average score = 3.608), whereas the 31-40 age group is the most dissatisfied (average score = 3.309) (Figure 6.4).

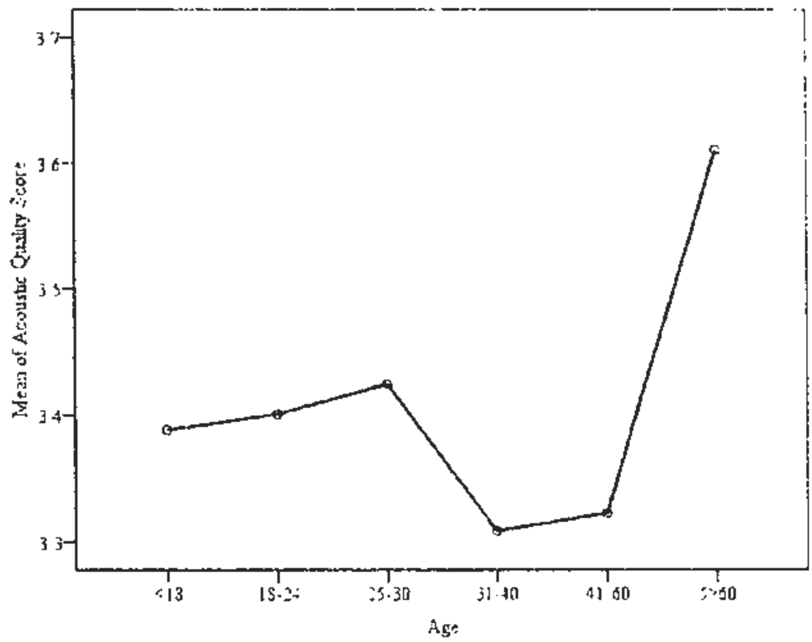



Figure 6.4 Mean acoustic quality score given by different age groups

Based on independent-samples t-test results, acoustic quality evaluations does not significantly differ across gender [Males ($M$ = 3.363, $SD$ = 1.014); Females ($M$ = 3.435, $SD$ = 0.957); $t$ (1596) = -1.458, $p$= 0.145 (two-tailed)]. The mean scores given by females are slightly higher than those given by males, but the magnitude of differences is very small (mean difference = -0.072, 95% CI: -0.1681 to 0.0248; eta squared = 0.001). Considering the larger standard deviation, males tend to give a wider range of subjective acoustic scores.

Two-way ANOVA was conducted to further explore the interaction effect between age and gender. Results show that the interaction effect between age and gender is not statistically significant [$F$ (5, 1598) = 1.38, $p$ = 0.227; Table 6.10 and Table 6.11].

There is a statistically significant main effect for age [$F$ (5, 1598) = 4.12, $p$ = 0.001], although the effect size is small. Post-hoc comparisons using Tukey HSD test indicate that the mean scores for the 31–40 group ($M$ = 3.31, $SD$ = 1.03) and 41–60 age group ($M$ = 3.32, $SD$ = 0.97) are significantly different from the >60 group ($M$ = 3.61, $SD$ = 0.94). The main effect for gender is statistically significant [$F$ (1, 1598) = 4.02, $p$ = 0.045] but the effect size is too small. The mean scores are plotted in Figure 6.5.

Table 6.10 Two-way ANOVA for acoustic scores as a function of age and gender

| Variable and source | df | MS | F | $\eta^2$ |
|---|---|---|---|---|
| Acoustic quality scores | | | | |
| Age | 5 | 3.96 | 4.12** | 0.013 |
| Gender | 1 | 3.86 | 4.02* | 0.003 |
| Age*Gender | 5 | 1.33 | 1.38 | 0.004 |
| Error | 1598 | 0.96 | | |

*$p$ < 0.05, **$p$ < 0.001

Table 6.11 Descriptive statistics for the interaction effect of age and gender

| Age | Male | | | Female | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | M | SD | N | M | SD | N | M | SD | N |
| <18 | 3.23 | 1.00 | 65 | 3.66 | 0.91 | 38 | 3.39 | 0.98 | 103 |
| 18-24 | 3.42 | 1.02 | 98 | 3.39 | 0.98 | 114 | 3.40 | 1.00 | 212 |
| 25-30 | 3.39 | 1.04 | 75 | 3.47 | 0.91 | 64 | 3.42 | 0.98 | 139 |
| 31-40 | 3.30 | 1.11 | 121 | 3.32 | 0.99 | 208 | 3.31 | 1.03 | 329 |
| 41-60 | 3.21 | 0.99 | 248 | 3.43 | 0.94 | 262 | 3.32 | 0.97 | 510 |
| >60 | 3.62 | 0.94 | 184 | 3.60 | 0.93 | 133 | 3.61 | 0.94 | 317 |
| Total | 3.36 | 1.01 | 791 | 3.44 | 0.96 | 819 | 3.40 | 0.99 | 1610 |

*M=Mean; *SD= Standard deviation;

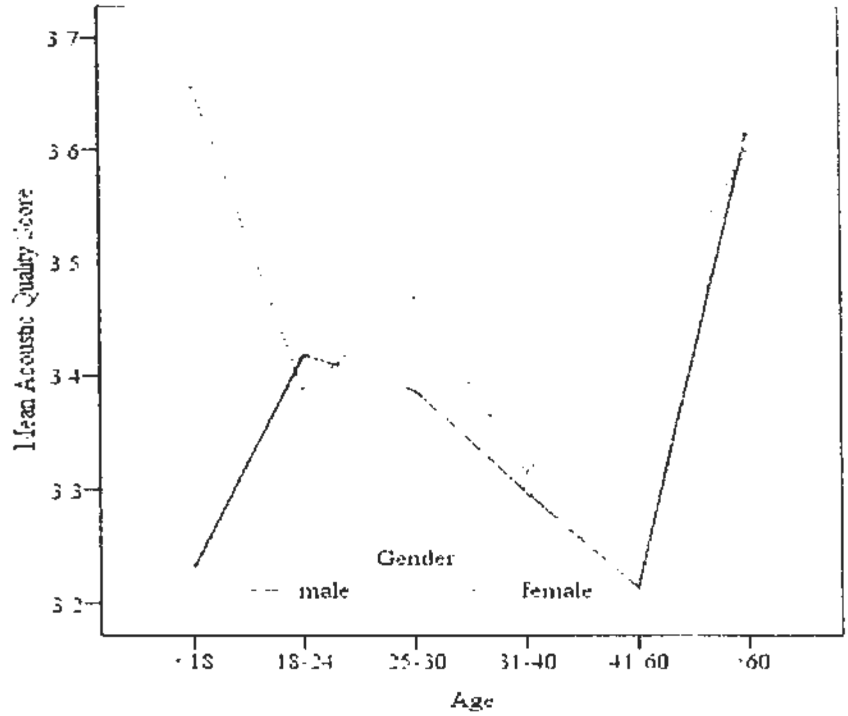
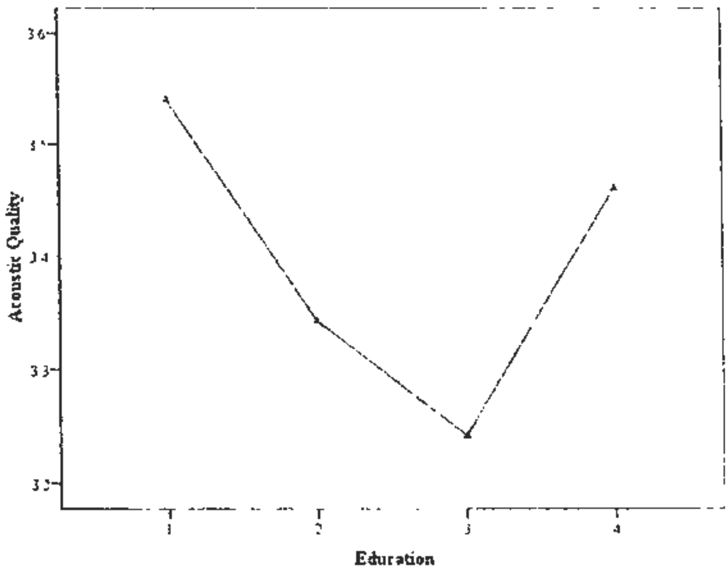


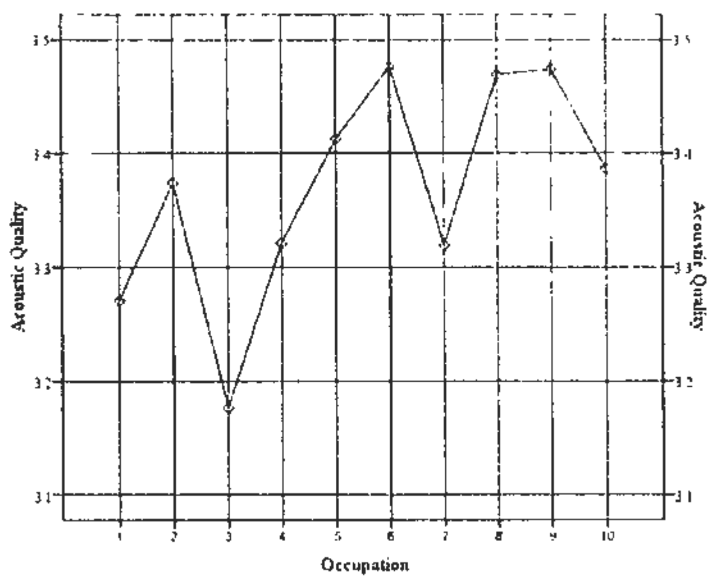

Figure 6.5 Mean acoustic quality score by different age and gender

Based on one-way ANOVA results, acoustic quality evaluation does not significantly differ across ten occupations [$F(9, 1135) = 1.412$, $p = 0.177$]. In terms of educational background, a significant difference exists [$F(3, 1607) = 4.746$, $P = 0.003$]. However, despite reaching statistical significance, actual differences in mean scores among the groups are quite small; the mean scores range from 3.242 to 3.538. The effect size is also small ($eta^2 = 0.09$). Post-hoc comparisons using Tukey HSD indicate that the mean score for Group 1 (primary school and below; $M = 3.538$, $SD = 0.905$) is significantly different from Group 2 (secondary school; $M = 3.343$, $SD$ 1.001) and Group 3 (college; $M = 3.242$, $SD = 0.958$).




Note: 1=primary; 2= secondary; 3= college; 4=university and above

Figure 6.6 Mean acoustic quality score by different education background




Note: Occupation: 1: manager; 2: professional; 3: clerk; 4: skilled labor; 5: student; 6: service worker; 7: sales; 8: housewife; 9: retired; 10: other.

Figure 6.7 Mean acoustic quality score by different occupation groups

The interaction effect between occupation and education was tested by two-way ANOVA. Results show a statistically significant difference [$F$ (26, 1571) = 1.84, $p$ = 0.006; Table 6.12). This indicates that the effect of occupation on acoustic quality evaluation depends to some extent on educational level. By inspecting the profile plots in Figures 6.8 and 6.9, interpretations can be made for the acoustic quality evaluations given by respondents with different jobs and educational backgrounds. The effect is considered small to medium (eta$^2$= 0.17). There is a statistically significant main effect for education [$F$ (3, 1571) = 3.30, $p$ = 0.020], but the effect size is small (partial eta squared = 0.006). The main effect for occupation is not statistically significant [$F(9, 1571) = 1.33, p = 0.215$].

Table 6.12 Two-way ANOVA for acoustic quality scores as a function of occupation and education

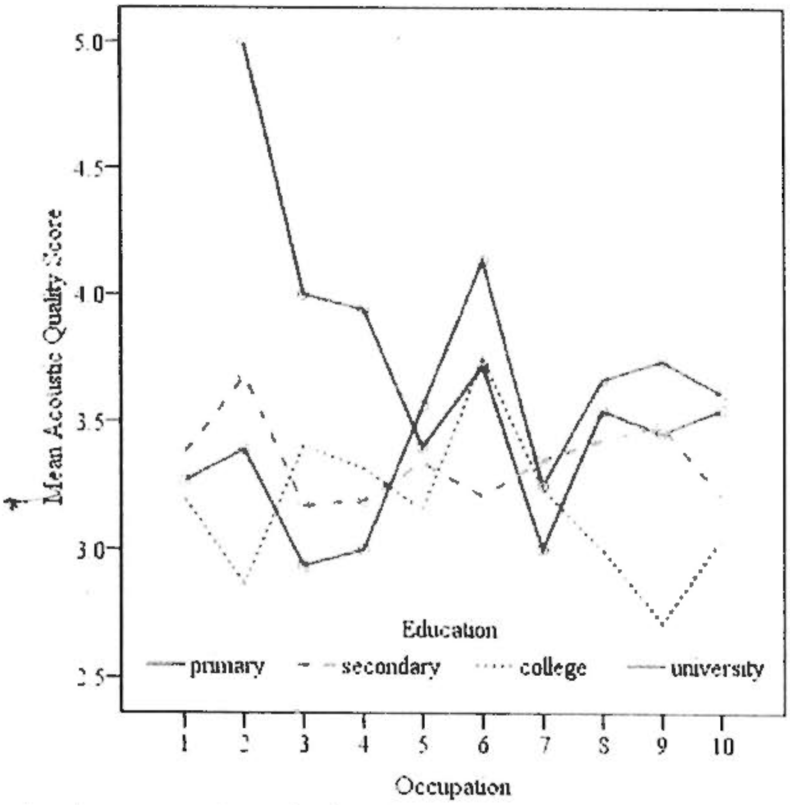
| Variable and source | df | MS | F | $\eta^2$ |
|---|---|---|---|---|
| Acoustic quality scores | | | | |
| Occupation | 9 | 1.27 | 1.33 | 0.008 |
| Education | 3 | 3.14 | 3.30* | 0.006 |
| Occupation*Education | 26 | 1.74 | 1.84** | 0.29 |
| Error | 1571 | 0.95 | | |

*$p < 0.05$, **$p < 0.001$

Table 6.13 Descriptive statistics for the interaction effect of occupation and education

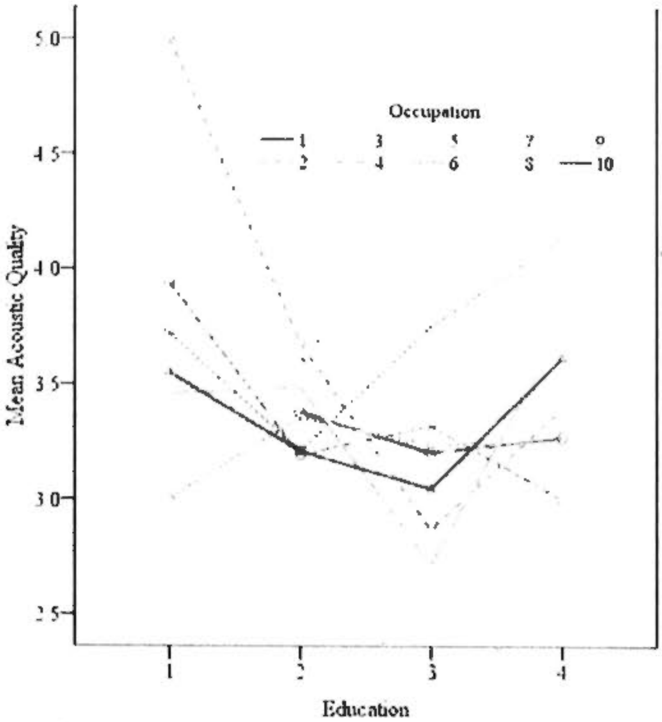
| Occupation | Primary | | | Secondary | | | College | | | University | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | N | M | SD | N | M | SD | N | M | SD | N | M | SD | N |
| 1 | / | / | / | 3.38 | 1.19 | 8 | 3.20 | 1.23 | 10 | 3.27 | 1.09 | 56 | 3.27 | 1.11 | 74 |
| 2 | 5.00 | / | 1 | 3.68 | 0.77 | 14 | 2.87 | 1.12 | 15 | 3.39 | 1.05 | 93 | 3.37 | 1.05 | 123 |
| 3 | 4.00 | 0.00 | 2 | 3.17 | 1.11 | 58 | 3.41 | 0.80 | 27 | 2.94 | 1.04 | 32 | 3.18 | 1.03 | 119 |
| 4 | 3.94 | 1.03 | 17 | 3.19 | 0.94 | 63 | 3.32 | 1.01 | 11 | 3.00 | 1.15 | 7 | 3.32 | 1.01 | 98 |
| 5 | 3.40 | 0.74 | 15 | 3.34 | 1.06 | 112 | 3.16 | 0.96 | 29 | 3.56 | 0.98 | 108 | 3.41 | 1.01 | 264 |
| 6 | 3.72 | 1.09 | 18 | 3.21 | 1.02 | 91 | 3.75 | 1.02 | 20 | 4.14 | 0.86 | 22 | 3.48 | 1.06 | 151 |
| 7 | 3.00 | / | 1 | 3.35 | 1.13 | 70 | 3.24 | 0.59 | 19 | 3.25 | 0.96 | 4 | 3.32 | 1.02 | 94 |
| 8 | 3.54 | 0.77 | 104 | 3.43 | 0.90 | 165 | 3.00 | 1.15 | 4 | 3.67 | 0.82 | 6 | 3.47 | 0.85 | 279 |
| 9 | 3.46 | 0.98 | 126 | 3.48 | 1.00 | 133 | 2.71 | 0.95 | 7 | 3.74 | 0.79 | 23 | 3.47 | 0.98 | 289 |
| 10 | 3.55 | 0.89 | 31 | 3.21 | 0.90 | 46 | 3.05 | 0.96 | 11 | 3.61 | 0.76 | 31 | 3.39 | 0.88 | 119 |
| Total | 3.54 | 0.91 | 315 | 3.34 | 1.00 | 760 | 3.242 | 0.96 | 153 | 3.46 | 1.02 | 382 | 3.40 | 0.99 | 1610 |

M=Mean; SD= Standard deviation;
Occupation: 1: manager; 2: professional; 3: clerk; 4: skilled labor; 5: student; 6: service worker; 7: sales; 8: housewife; 9: retired; 10: other.
/= Not applicable




Occupation: 1: manager; 2: professional; 3: clerk; 4: skilled labor; 5: student; 6: service worker; 7: sales; 8: housewife; 9: retired; 10: other.

Figure 6.8 Mean acoustic quality score by different occupation and education




Education: 1=primary; 2= secondary school; 3= college; 4= university and above

Figure 6.9 Mean acoustic quality score by different education and occupation

Based on the foregoing statistical analysis, the interrelationships between some demographical factors, such as age and occupation, age and educational level, and occupation and educational level, are observed. In terms of perceived acoustic quality, age and educational level are closely related with acoustic quality evaluation. Gender and the interaction effect between occupation and education may also influence acoustic quality evaluation, but the effect size is small. The results highlight the need for further exploration into the relationship between acoustic quality evaluation and socio-demographic factors to determine not only the effect of individual factors but also the interactions between them.

In summary, acoustic quality evaluation in terms of socio-demographic factors indicates that elderly people above 60 are the most satisfied group, and people aged 31-40 are the most dissatisfied. Gender is not a significant factor affecting soundscape evaluation, although in some cases, females tend to give higher evaluation scores than males. The largest difference between males and females is in the age group below 18, whereas the smallest difference is in the age group above 60. Those with primary or university degrees are prone to giving the highest evaluation scores, whereas those with college background give the lowest. The significant effect of occupation has not been identified; its influence should be studied by different categories.

The impact of activities on perceived acoustic quality was confirmed by ANOVA. Acoustic quality evaluation significantly differs according to the activities undertaken by respondents [$F\ (16, 186) = 4.785$, $p = 0.000$]. Furthermore, activities were regrouped into two categories: active or passive. Based on independent-sample t-test results, acoustic quality evaluation significantly differs between those engaged in active activities and those engaged in passive activities [Active ($M = 3.49$, $SD = 0.94$); Passive ($M = 3.29$, $SD = 1.02$); $t\ (1360) = -3.96$, $p = 0.000$ (two-tailed)]. However, the magnitude of the difference in means is very small (mean difference = -0.20, 95% CI: -0.30 to -0.10; eta square = 0.01). People who are taking part in passive activities tend to pay more attention to the surrounding acoustic environment, and they are less tolerant of sounds that are not comfortable. On the other hand, those with active behavior are attracted by other factors rather than the acoustic environment itself; thus, they provide higher acoustic quality evaluation scores.

## 6.4 Test of Brown's Conceptual Framework of acoustic quality evaluation

Interview data collected in this study were used to test the framework of soundscape evaluation proposed by Brown (Brown, 2006a). The crux of Brown's framework lies in the notion that a sound that is preferred in one place may not be preferred in another because of contextual differences. A case in point is the human voice. Earlier results have shown that while the human voice is not a preferred sound in parks, it is accepted in public squares. Along this line of reasoning, Brown (Brown, 2006b; Brown, 2007a) proposed a two-by-two matrix categorizing acoustic quality according to overall sound levels and the presence of wanted or unwanted sounds. It is hypothesized that the ratings of acoustic quality are differentiated by these two criteria.

To obtain the data required to test the hypothesis, the respondents were asked about the kinds of sound they liked and disliked in urban open spaces in general, and any previous experience with such sounds at the particular study site. Given that any particular study site may have both wanted and unwanted sounds, it is impractical to categorize an area, as suggested by Brown (2006b), with wanted or unwanted sound. Therefore, this study focused only on whether a particular site has, or does not have, wanted sounds. In subsequent data analysis, "presence" is defined by the existence of one or more "wanted sounds," whereas overall sound level is differentiated by the median level of sound measured at the 25 study sites. Using this method, the median sound level was found at 62.3 dB $L_{Aeq}$. The subjective ratings of acoustic quality were classified accordingly into four scenarios: areas exposed to high sound level with or without wanted sounds and areas exposed to low sound level with or without wanted sounds. Table 6.14 presents the subjective evaluation scores of acoustic quality in the four scenarios based on sound exposure level and the presence or absence of wanted sounds.

Table 6.14 Mean evaluation scores of the acoustic quality of four soundscape

| | | Acoustic Quality | |
|---|---|---|---|
| | | With wanted sounds | Without wanted sounds |
| Sound level | Low *(< 62.3 dB $L_{Aeq}$) | 3.73 (0.78) #N=582 | 2.96 (0.86) #N=55 |
| | High *(≥ 62.3 dB $L_{Aeq}$) | 3.40 (1.02) #N=777 | 2.56 (0.88) #N=196 |

* Figures in parenthesis are standard deviation;
# N = sample size
$ on a scale of 1 to 5 (1= dislike most; 5 = like most)

Table 6.14 demonstrates that areas with lower sound exposure levels are given higher scores than those with relatively higher sound levels. Similarly, the ratings are also higher in places with wanted sounds than those without. It is noteworthy that in places with wanted sounds but with relatively high noise levels, the mean rating of acoustic quality is higher than that in places without wanted sounds but with lower overall sound levels. Differences among the four scenarios are statistically significant [$F(3, 1606) = 84.14, p < 0.001$].

The findings support the earlier results in section 6.3.3 that the influence of the quietness factor is of limited importance in the subjective evaluation of acoustic quality. Subjective assessment of the acoustic quality of an open space is determined by the congruence of sounds to a particular context, that is, whether sounds are "wanted" in a particular place.

While the data of this study do not directly validate Brown's framework, the finding that the presence or absence of wanted sound is an important determinant of subjective evaluation of acoustic quality has significant bearing on soundscape design. For a long time, the management of the acoustic environment in cities has relied on "noise control," aiming to "reduce" the level of "unwanted sound." The findings of this study suggest that an alternative approach is warranted. Mere reduction in noise levels has a very limited effect. It is equally important to provide the physical setting and greenery conducive to the creation of sounds that signify naturalness. Further research is needed to study how urban open spaces should be designed and managed to nurture and enhance natural acoustic environments.

Brown's simple but useful framework for evaluating the acoustic quality of different soundscapes introduces an alternative approach in understanding the highly complex process of human evaluation of acoustic quality. As previously mentioned, this is one of the few studies that provide concrete data to test and support Brown's framework. In the following section on the prediction of soundscape evaluation, we further demonstrate whether the presence of wanted and unwanted sounds can enhance the performance of the prediction model, given that all the other variables, including socio-demographic factors, visiting habits, and preference for individual sounds, are held constant. Any improvement in the model can demonstrate the value of the framework and its appropriateness for integration into soundscape evaluation models.

## 6.5 Ordinal Logistic Regression Analysis of Subjective Evaluation of Acoustic Quality in the Urban Open Spaces

In Brown's simple framework, context plays an important role in determining the acceptability of a sound in one situation. The context is determined by a host of factors, including the characteristics of the place and the physical environment, visitors' personal expectations, activities undertaken, and social settings. How these factors affect the subjective evaluation of acoustic quality was initially analyzed using Pearson chi-square test, Spearman correlation, t-test and ANOVA, and then by ordinal logistic regression (OLR) to identify factors that may affect acoustic quality in urban open spaces.

### 6.5.1. OLR Model for evaluation of acoustic quality

We used logistic regression analysis to examine the relationship between subjective acoustic quality, the dependent variable, and a host of independent variables. It was utilized because of its interpretability and ease of use (Eftekhar *et al.*, 2005). The candidate variables for predicting subjective acoustic quality are listed in Table 6.15.

Table 6.15 Candidate independent variables for OLR prediction models of evaluation of acoustic quality

| Independent Variable | Sub-category | Abbr. | Level of measurement | Range |
|---|---|---|---|---|
| Residence | *Local* | / | Binary | 1 for local |
| | *Un-local* | / | | 2 for un-local |
| Visiting Habit | *Frequency* | / | Nominal | 1 to 6 |
| | *Time* | / | Nominal | 1 to 5 |
| Demographic Factors | *Age* | / | Ordinal | 1 to 6 |
| | *Gender* | / | Binary | 1 for male; 2 for female |
| | *Occupation* | / | Nominal | 1 to 10 |
| | *Education* | / | Ordinal | 1 to 4 |
| Activity | / | / | Nominal | 1 to 18 |
| $L_{Aeq}$ [dB] | / | / | Scale | 50 to 75 |
| Presence of Wanted Sound | / | *PWS* | Binary | 1 for no; 2 for yes |
| Presence of Unwanted Sound | / | *PUS* | Binary | 1 for no; 2 for yes |
| Total Environmental Quality | / | *TEQ* | Scale | 1 to 5 |

To select appropriate predictor variables for subsequent OLR analysis, a correlation analysis was performed on the relationship between subjective acoustic quality and a host of independent variables, including age, gender, occupation, education background and activity, visiting habits, measured sound exposure level, and presence of wanted and unwanted sounds (Table 6.15). The results in Table 6.16 show that not all independent variables are significantly related to the subjective evaluation of acoustic quality; only those that are statistically significant were used in the OLR analysis.

Table 6.16 demonstrates that the importance of different factors varies significantly according to the types of open spaces. Given such variations, it is postulated that the relationship between subjective evaluation of acoustic quality and related factors may vary across different types of urban open spaces. Hence, OLR was performed at two levels: a general one pooling together all open spaces, and a specific one covering five individual open spaces one at a time. The independent variables selected for OLR models are listed in Table 6.17.

Table 6.16 Effects of various factors on the acoustic quality evaluation

| Type | Factors | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residence | Frequency | Time | Activity | Age | Gender | Occupation | Education | $L_{Aeq}$ | PWS | PUS | TEQ |
| Park | 0.120** | 0.014 | 0.041 | 0.905 | 0.048 | -0.0697 | -0.013 | -0.003 | -0.039 | -0.907** | 0.472** | 0.567** |
| Playground | 0.200 | 0.244 | -0.374* | 0.676 | -0.034 | -0.417 | -0.206 | 0.330 | -0.605* | -0.440 | -0.440 | 0.595* |
| Sports ground | 0.154 | 0.380** | -0.427** | 0.019* | -0.354* | -0.056 | -0.225 | 0.530** | -0.846** | -2.034** | -0.491 | 0.669** |
| Plaza | 0.061 | 0.020 | -0.156** | 0.056 | -0.057 | 0.021 | -0.035 | 0.088 | -0.573** | -0.747** | 0.692** | -.667** |
| Garden | -0.203** | -0.038 | -0.007 | 0.067 | 0.025 | -0.258 | 0.207** | -0.190** | -0.360** | 0.108 | 0.587 | 0.444** |
| Overall | 0.043 | -0.005 | -0.109** | 0.000** | 0.047 | -0.071 | 0.044 | -0.017 | 0.305** | -0.894** | 0.598** | 0.594** |

# Data are shown in terms of the significant levels of the Spearman correlations (two-tailed) for factors with more than 2 scales except for activity, where Pearson Chi-square is used and the level of significance is shown in the table, and mean differences (t-test, two-tailed) for factors with 2 scales. Marks * and ** indicate significant correlations or differences, with * representing $p< 0.05$ and ** representing $p<0.01$.

Table 6.17 Predictor variables used in OLR prediction models for evaluation of acoustic quality

| Model | | Independent Variables |
|---|---|---|
| General model for all types of open spaces | | Visiting time<br>Activity<br>TEQ<br>PWS<br>$L_{Aeq}$ [dB]<br>PUS |
| Specific models for individual type of open space | Park | Residence<br>TEQ<br>PWS<br>PUS |
| | Playground | Visiting Time<br>TEQ<br>$L_{Aeq}$ [dB] |
| | Sports ground | Visiting frequency<br>Visiting time<br>Activity<br>Age<br>Education<br>$L_{Aeq}$ [dB]<br>PWS<br>TEQ |
| | Plaza | Visiting time<br>TEQ<br>$L_{Aeq}$ [dB]<br>PWS<br>PUS |
| | Garden | Residence<br>Occupation<br>Education<br>TEQ<br>$L_{Aeq}$ [dB] |

# PWS: Presence of Wanted Sounds; PUS: Presence of Unwanted Sounds; TEQ–Total Environmental Quality

### 6.5.2. Interpretation of the OLR model

Results of the OLR analysis are given in Table 6.18, in which the odds ratio of significant independent variables affecting acoustic quality is presented. Odds ratio measures how a certain predictor increases or decreases the likelihood of the outcome. If the odds ratio is less than 1, it has a decreasing effect; if it is larger than 1, it has an increasing effect. For example, an odds ratio of 2 indicates that the outcome has a two-time more chance to occur. Based on the results (Table 6.18), total environment quality (TEQ) is an important factor in all models, except for sports grounds. Thus, it greatly enhances the subjective evaluation of acoustic quality.

Table 6.18 Effects of different independent variables in predicting subjective evaluation of acoustic quality in different types of open spaces using Ordinal Logistic Regression models

| Type of Open Space | | Independent Variable | Odds Ratio Exp [B] |
|---|---|---|---|
| General model for all types of open spaces | | TEQ | 4.871 |
| | | PWS | 2.453 |
| | | $L_{Aeq}$ | 0.897 |
| | | PUS | 0.398 |
| Specific models for individual type of open space | Park | TEQ | 4.898 |
| | | PWS | 4.775 |
| | | PUS | 0.427 |
| | Playground | Visiting time | 17.138 |
| | | TEQ | 5.030 |
| | Sports ground | Age | 3.611 |
| | Plaza | TEQ | 6.234 |
| | | $L_{Aeq}$ | 0.670 |
| | | PUS | 0.439 |
| | Garden | TEQ | 3.637 |
| | | $L_{Aeq}$ | 0.848 |

* PWS: Presence of Wanted Sounds; PUS: Presence of Unwanted Sounds; TEQ=Total Environmental Quality; Visiting Time: before 10am, from 10am to pm, after 4pm, randomly and others; Visiting Frequency: every day, weekend, several times within a week, occasionally, once a week and others;
# Independent variables are listed with p-value less than 0.05

Sound exposure level, expressed as $L_{Aeq}$ [dB], is a significant predictor that can undermine subjective acoustic quality scores both for the general model and for specific open spaces, such as gardens and plazas. Notably, the presence of wanted sound (PWS) and the presence of unwanted sound (PUS) may enhance or diminish, respectively, subjective acoustic quality evaluation. In parks and plazas, visitors tend to care more about the presence of wanted and unwanted sounds. To ascertain the importance of the two predictor variables, PWS and PUS, further analysis was undertaken, comparing the predictive power of OLR models, including or excluding these predictor variables. The results are shown in Table 6.19.

Table 6.19 Performance of the ORL Models for different types of open spaces

Performance of the ORL Models for different types of open spaces

| Model | #With/Without WS and US | Model Fitting | Goodness-of-fit | Pseudo R-Square (Nagelkerke) | Parallel Lines |
|---|---|---|---|---|---|
| Park | Yes | 0.000** | 1.000 | 0.403 | 1.000 |
| | No | 0.000** | 0.196 | 0.349 | 1.000 |
| Plaza | Yes | 0.000** | 1.000 | 0.639 | 1.000 |
| | No | 0.000** | 1.000 | 0.626 | 0.998 |
| Sports ground | Yes | 0.000** | 1.000 | 0.831 | 0.966 |
| | No | 0.000** | 1.000 | 0.825 | 1.000 |
| General | Yes | 0.000** | 1.000 | 0.476 | 0.989 |
| | No | 0.000** | 1.000 | 0.439 | 1.000 |

# WS: Wanted Sound; US: Unwanted Sound;

* representing $p < 0.05$, ** representing $p < 0.01$.

& Chi-square score tests for Model Fitting, Goodness-of-Fit and the Parallel Lines assumption are shown in terms of level of significance.

The performance of the model can be measured by pseudo R-square (Nagelkerke) (Table 6.19), which can be likened to multiple R-square. It is apparent that if the predictive power of the regression is significantly reduced if the two predictor variables of "Presence of Wanted Sounds (PWS) and Presence of Unwanted Sounds (PUS)" are not included in the prediction models, by as much as 2% to 13.4% of the original. This finding highlights the importance of PWS and PUS as predictor variables and affirms Brown's conceptual framework regarding the subjective evaluation of acoustic quality. Other statistics shown in Table 6.19, including model fitting and goodness-of-fit tests, indicate the appropriateness of constructed models and the non-violation of proposed assumptions.

In summary, both the general model for all types of open spaces and specific models for individual types of open space meet the required accuracy and explanation power. In the interpretation of the models, the importance of a number of factors, including TEQ, PWS, and PUS, is highlighted. Two factors, TEQ and PWS, have a positive, enhancing effect on subjective acoustic quality evaluation. On the other hand, two factors, sound exposure level and PUS, have a negative effect on the subjective evaluation of acoustic quality. These findings have great implications on the practice of soundscape design; they help urban planners predict subjective evaluation of acoustic quality.

## 6.6 Discussion

Two observations from the results merit further discussion. Firstly, this study has established that sound level is negatively related to the subjective evaluation of the acoustic quality of urban open spaces in Hong Kong, despite the association is weak. This has also been reported by some previous studies (Fiebig and Genuit, 2010; Jeon *et al.*, 2010). This study has provided data, based on intensive on-site interviews, substantiating the applicability in Hong Kong urban open spaces of the hypothesis that a weak negative relationship exists between acoustic quality evaluation and sound level. However, it is interesting to note that the same relationship was not observed in a separate study undertaken by Lam and his team in the countryside of Hong Kong (Lam *et al.*, 2010). In their study, no statistically significant relationship between $L_{Aeq}$ and subjective ratings of the countryside acoustic quality was found ($r = -0.0003$, $p = 0.951$, $n=518$). The apparent difference in the findings of these two studies can be ascribed to at least two factors. Primarily, the context of the two studies is different. This study was undertaken in Hong Kong's urban open spaces, whereas Lam's earlier study was conducted in Hong Kong's countryside. Secondarily, the overall sound levels in the places where the studies were undertaken are also different. Unlike Lam's earlier study, this research was undertaken within the city of Hong Kong where sound levels are high and noise is a common problem among urban inhabitants. It is not surprising that quietness is a factor, albeit a weak one, influencing the subjective evaluation of acoustic quality. This observation is consonant with the findings of Kang (Yang and Kang, 2005b; Yu and Kang, 2010) on urban open spaces in Europe, showing that sound pressure is a determinant of acoustic discomfort only above a certain level (Yang and Kang, 2005a).

The second finding that merits special attention is the validation of the simple but useful framework earlier proposed by Brown for evaluating the acoustic quality of different soundscapes. Brown's two-dimensional framework provides a simple approach toward understanding the highly complex process of acoustic quality evaluation. The present case study in Hong Kong provides an opportunity to test this framework. As previously mentioned, this is one of the few studies that provide concrete data to test and support Brown's framework. However, further work is needed to search for other factors that may also affect the human evaluation of the acoustic quality of urban open spaces. These may be socioeconomic or other situational factors. With a number of predictor variables, artificial neural networks may be an alternative approach in predicting the subjective evaluation of acoustic quality.

The validation of Brown's framework highlights the importance of context in the subjective evaluation of acoustic quality, which has significant bearing on soundscape design. For a long time, the management of acoustic environment in cities has relied on noise control, aiming to reduce the level of unwanted sound. The findings of this study suggest that an alternative approach is warranted. The results indicate that mere reduction in noise levels has a very limited effect. It is equally important to provide the physical setting and greenery conducive to the creation of sounds that signify naturalness. Further research is needed to study how urban open spaces should be designed and managed to nurture and enhance natural acoustic environments.

## 6.7 Summary

Understanding the subjective evaluation of acoustic quality is crucial to the study of soundscapes in urban open spaces. This chapter explained visitors' preference for individual sounds and their evaluation of the acoustic quality of urban open spaces.

First, statistical analysis, including correlation analysis, chi-square test, and ANOVA, were used to study sound preference. Birdsongs and sounds from wind and water are the three most preferred sounds, whereas mechanical sounds from construction and road traffic are least preferred. The preference for human voices lies between natural and mechanical sounds. Socio-demographic factors significantly influence sound preference. The analysis shows that young people prefer lively sounds, whereas elderly visitors prefer peaceful ones. Gender is not a significant factor affecting sound preference. Female visitors tend to be more sensitive to the emotional effects of sounds. With increasing educational levels, people tend to be more appreciative of culture-related sounds, such as church bell ringing.

Second, the influence of socio-demographic factors on the subjective evaluation of acoustic quality in urban open spaces has been studied. In general, parks are given the highest score in soundscape evaluation, whereas gardens the lowest. The close relationship between visitors' subjective evaluation of overall environmental quality and acoustic environment quality indicates that the acoustic environment is an important component of the holistic environment of open spaces, highlighting the significance of soundscapes. This study has identified the effects of demographic factors on the subjective evaluation of acoustic quality. With increasing age, people become more tolerant of noise; those who are over 60 are the most satisfied group. No significant difference was found between males and females, although some previous studies have demonstrated that males might be less tolerant than females when it comes to low-frequency noise. Occupation is an insignificant influencing factor, whereas educational background has some effect on perceived acoustic quality, although the effect size is quite small. Those who have received only primary education or university-level education are more likely to give higher acoustic quality evaluations.

Third, data obtained from this study support Brown's earlier postulation that the subjective evaluation of acoustic quality is dependent not only on sound level but also on the presence or absence of wanted sounds. This finding highlights the importance of place and visitors' motivation and activities in the subjective evaluation of acoustic quality. Congruence between sound and context creates a condition favorable to the subjective rating of acoustic quality.

Lastly, in this study, algorithmic models based on ordinal logistic regression analysis have been developed to predict subjective acoustic quality evaluation. The significant predictor variables include TEQ, sound exposure level, expressed as $L_{Aeq}$ [dB], presence of wanted sounds, and presence of unwanted sounds. Improvements in TEQ and the presence of wanted sounds, along with reductions in sound exposure level, enhance the subjective evaluation of acoustic quality. Findings from the interpretation of the models have implications on soundscape design. Urban planners may consider these models as applicable tools for predicting acoustic quality during the urban design process.

*City planning can no longer be content with noise control and abatement, but must pay attention to the character of the acoustic atmosphere…*

------ *The Journal of Acoustic Ecology*,
Gernot Böhme, 2000: 16

# Chapter 7 Conclusion

This chapter summarizes the research findings and their implications, as well as limitations of the current study and recommendations for future ones. As a soundscape study in a compact city such as Hong Kong, this research was launched with three research objectives, including:

a. Delineation of quiet urban open spaces in Hong Kong and determine their usage;
b. Characterization of the acoustic quality of soundscapes in the quiet urban open spaces;
c. Elucidation of visitors' perception of and preference for sounds, as well as their evaluations of the acoustic quality.

Research findings and recommendations from this research in the context of a congested and dynamic environment like Hong Kong can supplement the research findings from other areas in filling the knowledge gaps.

## 7.1 Summary of Findings

The importance of urban open spaces in enhancing the quality of life in the urban areas has been increasingly recognized in recent years. Human experience in open spaces is not limited to the landscape and facilities but also to the acoustic environment. This study delineated quiet urban open spaces in Hong Kong, reviewed their usages, characterized the physical acoustic environment and investigated how visitors evaluate the acoustic quality. In this study, the noise mapping technique was used to delineate quiet urban areas and to identify open spaces within such quiet areas. In total, 25 quiet open spaces in the urban area were subsequently selected for an in-depth study, comprised of acoustic measurements, sound walk and on-site interview program. A total of 1610 visitors had been successfully interviewed to find out their preference of individual sound sources, their degree of liking of the environmental quality and how the socio-demographic factors influence their evaluation. The major findings are summarized below under each of the three research objectives.

### 7.1.1. Location and usage of quiet open spaces in the urban region of Hong Kong

This study began with the assessment of noise levels arising from road traffic. Noise mapping technique has been applied to predict the traffic noise exposure. With the resultant noise contour maps, quiet areas with noise level below 60 dB (A) $L_{10,1h}$ were delineated. Overlying the land use and noise contour maps enabled identification of those urban open spaces situated in quiet urban areas and determination of their spatial attributes.

It has been found that in Hong Kong, the quiet areas in the city are situated mainly in two types of locations. The first is congregated in the hilly areas on the periphery of the city where the accessibility to urban inhabitants is low. The second type of quiet areas, which are smaller in size, are sporadically scattered in various parts of the city, some surrounded by tall buildings, others sandwiched between roadways and industrial land uses. This study has found that these two types of quiet open spaces serve different purposes and different visitors. Generally speaking, large open spaces attract visitors for particular activities, such as group visiting, festival celebrations, art shows and sports games. Smaller ones with patronage by nearby residents are more frequently used as resting place, place for playing chess or meeting with friends.

An examination of the spatial characteristics of the open spaces in quiet part of the urban areas revealed that the quiet urban open spaces have a few characteristics. Firstly, they are usually small in size some even smaller than 1000m$^2$. Secondly, some quiet open spaces are found in the center of large urban parks. Open spaces as an outdoor open-air space introduce nature into the urbanized concrete environment, provide opportunities for leisure and recreation and are thereby highly valued by the urban inhabitants. Urban open spaces in Hong Kong form a hierarchy comprised of different open spaces with varied functions and sizes catering for different groups of people seeking different facilities and services.

My questionnaire survey revealed that the proportion of male and female visitors is similar. While the open spaces are frequented by people of all ages, there are relatively more visitors aged between 41 and 60. The visitors have various educational background and occupational status. In large urban parks, the main group of visitors is housewives and retired persons. Most of them have secondary educational attainment. Clerks and secretaries are more likely to visit small gardens and take them as an excellent place for short rest or chatting with friends. Playgrounds and sports grounds are popular among young students coming for ball games after school.

### 7.1.2. Characteristics of soundscapes in quiet open spaces

The study has found that most of the area in the 25 urban open spaces selected for an in-depth study are exposed to sound levels higher than 55 dB $L_{Aeq}$, the criterion recommended by WHO for outdoor environment. The mean sound level in these selected open spaces varies with the type of open space with levels lower in larger open spaces than in gardens which are smaller.

Analysis of field recording for sound level and frequency spectrum revealed that road traffic noise is ubiquitous as indicated by sounds in the low frequency band. Presence of other sound sources, including birdsongs, sound from flowing water as well as human voice, are manifested in sound level in the medium to higher frequency bands. Different combinations of sound sources have diversified the soundscapes in urban open spaces. The same is revealed in the findings from the sound walk. In spite of the dominance of transportation noise, natural sounds are also commonly heard, particularly in gardens and playgrounds where sounds from birds, water are prevalent. This is a reflection of the presence of trees and greenery which attract birds for nesting.

The sound recordings were also subject to the analysis of the sound quality in terms of commonly used psychoacoustic parameters, including "loudness", "roughness", "fluctuation" and "sharpness". In general. Loudness makes a great contribution to distinguish the soundscapes of different types of urban open spaces. On the whole, sounds in parks are generally louder and sharper, while those in plazas are "rougher" and more "fluctuated". Plaza is significantly different from other types of open spaces in having the lowest value for "sharpness".

### 7.1.3. Understanding the subjective evaluation of the acoustic quality

On-site interviews unraveled how visitors evaluate the acoustic quality in different types of open spaces. Concerning the preference of individual sound sources, the sounds of birds, wind and water are the three most preferred sound sources; while, mechanical sounds from construction and road traffic are the least preferred. In between these two is human voice.

Socio-demographic factors have significant influences on human preference of sound sources. With the increase of age, people are more attracted to natural sounds, for instance, bird songs, insect chirping as well as flipping sounds of trees and leaves from wind blowing. In terms of gender, female visitors tend to be more sensitive to the emotional effects of sounds. The culturally annotated sounds like church bell and children's shouting are rated with higher scores by women visitors. Visitors with higher educational background tend to be less tolerant towards sounds from machine and traffic. Visitors with university and above education attainment are more appreciative of church bell sound.

The close relationship between visitors' evaluation of the overall environmental quality and the acoustic quality highlighted the significance of the acoustic environment as an important component of the total environment. Among the six types of open spaces in Hong Kong, parks are given the highest score, whereas garden the lowest.

The survey findings show that subjective evaluation of the acoustic quality is related to a number of factors. Affective attributes of a soundscape, including quietness, naturalness and joyfulness, are closely related with subjective evaluation of the acoustic quality. Besides quietness, visitors also appreciate the natural and joyful elements of the soundscape. The measured sound level is negatively correlated with subjective evaluation of the acoustic quality. Psychoacoustic metrics, such as "sharpness", "roughness" and "fluctuation strength" are not significantly associated with soundscape evaluation.

Analysis of the influence of socio-demographic factors on subjective evaluation of the acoustic quality revealed that elderly people are more tolerant towards noise. Those over 60 years old are the most satisfied group with the acoustic quality of the urban open spaces. Female visitors are more likely to give higher scores than males. Concerning the educational attainment, visitors who have received primary or university education are prone to give higher scores compared with those having secondary and college level education background. Occupation status has not been identified as a significant determinant of soundscape evaluation.

Data obtained in this study substantiate Brown's soundscape evaluation framework and lend support to the notion that subjective assessment of the acoustic quality in the open spaces is determined by whether or not the sounds heard are congruent with the context; or "wanted" in that particular place. Where there is congruence between the sound and the context, this is a condition conducive to a favorable subjective rating of the acoustic quality.

Prediction models for soundscape evaluation have been developed by using Ordinal Logistic Regression (OLR) techniques, with input variables including place of residence, visiting habits, demographic factors, presence of wanted sound and unwanted sound, $L_{Aeq}$ [dB], activity as well as the total environmental quality. The results show that the total environmental quality, sound exposure level, presence of wanted sound and unwanted sound are the key determinants of subjective acoustic quality, albeit the relationships may vary among different types of open spaces.

## 7.2 Implication for Soundscape Design

The research findings outlined in section 7.1 have portrayed the current status of soundscapes in the urban open spaces in Hong Kong, highlighted the characteristics that visitors prefer and identified factors which determine visitors' subjective evaluation of the acoustic quality. This section attempts to elucidate what implications these findings have on soundscape design in urban open spaces.

It has been identified in Chapter 4 that there are two types of quiet open spaces in Hong Kong which differ in terms of location, size and functions. To create an open space with high acoustic quality, the soundscape design should recognize the site, its existing environment and usage. Measures which can enhance the acoustic quality of these two types of urban open spaces may be different.

For the smaller open spaces surrounded by tall buildings or near roadways, sound marks are suggested. According to the findings from sound source preference test described in section 6.2, adding natural sounds, such as bird songs, insect chirps, the murmur of stream water and flipping of tree leaves, can improve the pleasantness of the soundscape. This can be achieved by planting a variety of vegetation, which not only functions as noise barrier to reduce traffic noise intrusion but also induces animals and songbirds to live and nest.

For larger open spaces located further away from residential communities, diversification of the soundscapes for different sub-zones is recommended. The on-site interview and sound walk have found that a host of activities are preformed in these large open spaces. It would be appropriate to design soundscapes congruent with the function of individual zones. In the activity zones where visitors do physical exercises, talk to friends and meet with family members, the acoustic environment can be designed to be active, vibrant and artificial. Even roaring sounds from children, cheers from ball games as well as laughing and shouting will not be considered as noise. In resting zones, the acoustic environment does not need necessarily to be quiet; however it has to be natural and relaxed which can inspire a peaceful and ease atmosphere. The buffer zones should be designed with a sonic profile being lively, pleasant and realistic, as a smooth transition between that of the noisy active zone and the quiet resting zone.

Apart from the above suggestions, one of the design challenges is to change the mindset from avoiding, preventing or reducing the harmful effects to preservation of "environmental acoustic quality where it is good" (Brown, 2006a). As substantiated in section 6.3, visitors' perception of high acoustic quality is not necessarily quiet and silent. The sound exposure level is not the key determinant of the perceived acoustic quality, and hence the mere reduction of noise by conventional control measures is insufficient to enhance acoustic quality. To create an area of high acoustic quality, it is important to preserve the diversity of sounds, particularly those visitors would like to hear such as those from moving water and nature. Non-mechanical human sounds, iconic sounds, should be clearly audible and not masked by other unwanted sounds. The soundscape approach opens up the possibility of adding sounds in order to improve the acoustic environment.

The close relationship between visual and auditory perception established in section 6.2, provides the theoretical basis for enhancing the holistic environmental quality through improvement of the acoustic environment. The main recommendation is that design and planning of urban open spaces must go beyond the evaluation of the visual aesthetics and be aligned with the acoustic design in which the auditory perceptions are evaluated, defined and prioritized.

Given the variety of the physical acoustic environment in the Hong Kong urban open spaces (section 5.2, 5.3 and 5.4) as well as the complex response of people with different socio-demographic background (section 6.2 and 6.3), it is suggested to take findings of testing Brown's framework one step further, emphasizing the significance of the congruence of sound with the context.

In addition to the above principles for soundscape design, it may be possible to evaluate subjective evaluation of acoustic quality by building prediction models using results from the Ordinal Logistic Regression analysis (section 6.5). This may be a useful tool to facilitate the design of urban open spaces in Hong Kong.

Brown has suggested a design approach for soundscape planning and management. A modified framework for soundscape design based on the findings from this study is presented graphically in Figure 7.1. Recommendations from this study which have bearing on soundscape design are highlighted in grey. Methodologies adopted in this study, including sound walk and field recording, are applicable in the first stage of soundscape design to establish the current status of the environment. The information obtained from on-site interview will be beneficial for the subsequent detailed soundscape design.

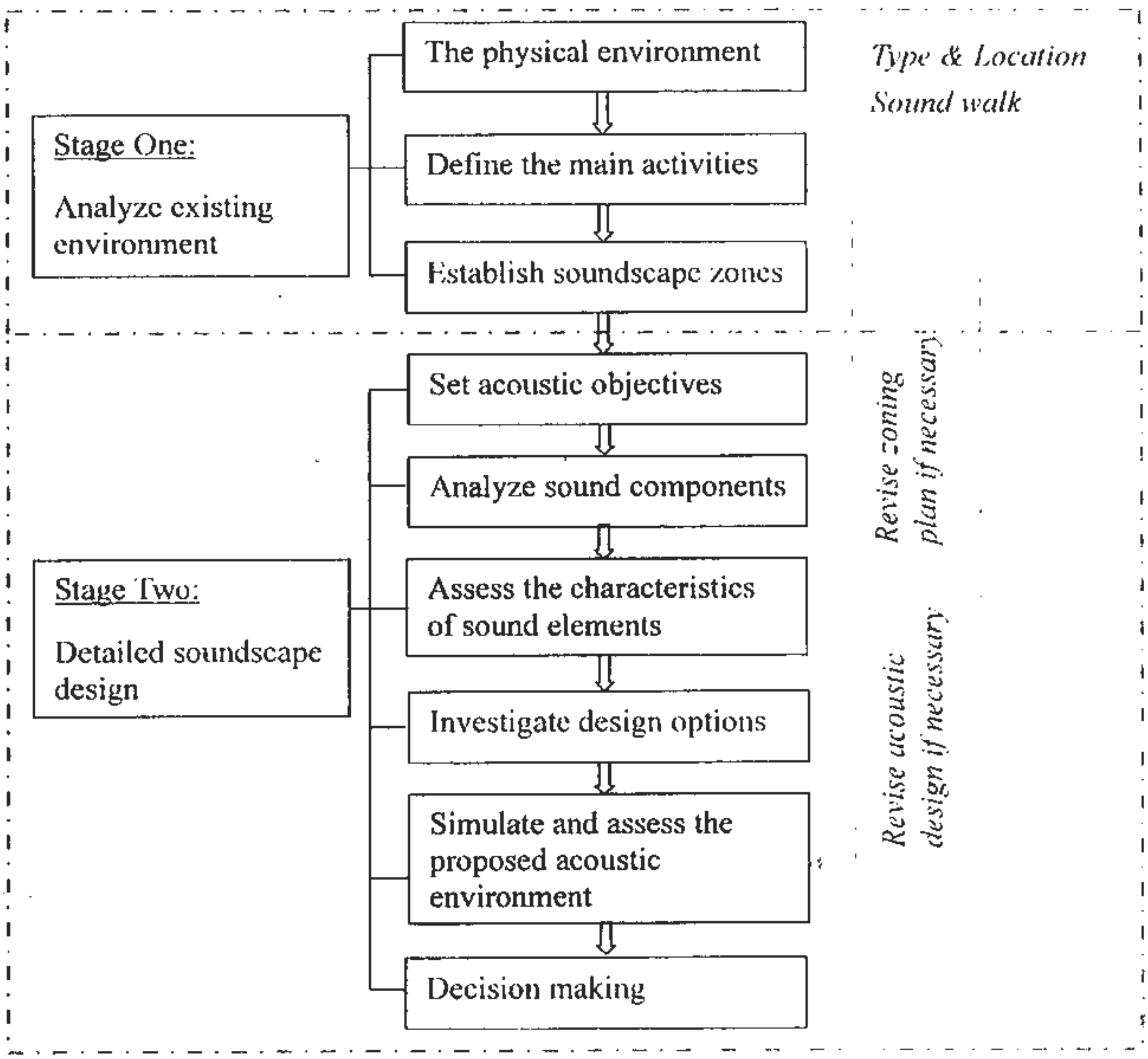



Figure 7.1 Flow chart for soundscape design of urban open spaces

[#] This flow chart is adapted from Brown (2004) and modified based on the findings of this study.

### 7.3 Limitation of This Study

The study of the soundscape of urban open spaces in Hong Kong, and exploration of the implications for soundscape design is an important and highly complex issue. In interpreting the findings of the study, the author is well aware of two possible limitations.

Firstly, this study started with noise mapping of traffic noise exposure level in 6 districts in Hong Kong. The noise mapping technique was used primarily to select appropriate study sites for subsequent in-depth study. The spatial attributes of the quiet open spaces so identified, in terms of their spatial relationship with peripheral land uses, beneficial population, accessibilities, to name a few, have not been fully investigated in this study. Further analysis by GIS-based spatial analysis tools, which may be the theme of a separate research, can be undertaken.

Secondly, due to resource constraints, the interview was not undertaken throughout the whole year. This precludes the findings being applied to all seasons. Furthermore, the number of types of open spaces and the variety of function zones in each, there may not be adequate sample size to cover all possible response from the visitors in different locations and seasons. More interviews can be undertaken to elucidate possible differential subjective response in each location and each season.

## 7.4 Further Research

In light of the limitations of the thesis, further research in the following domains is potentially important.

- Make full use of the advantages of GIS technique

Noise mapping results can be further analyzed using GIS techniques to quantitatively determine the number of people within certain distances of quiet open spaces. It will be useful to find out the number of people are living at different distances of quiet open spaces, the interface with different land uses and the accessibility to nearby residents.

- Additional extensive and intensive interview

It is proposed to replicate the interview at more locations with more people and in different seasons. Furthermore, the questionnaire survey could be augmented by in-depth interviews to probe into interviewees' thoughts, feeling and subjective evaluation on the acoustic quality. Visitors can be encouraged to talk more in detail about their opinions on soundscape design. Interviews can also be conducted with urban planners, park managers and landscape designers. Laboratory simulation experiments could be used as an alternative to gauge the response from these target people.

- Revision of the questionnaire

In order to verify Brown's framework fully, a revision of the questionnaire is highly necessary. A scenario with the presence of unwanted sound only should be introduced and distinguished from that with the presence of wanted sound. To achieve this, visitors need to classify the place according to the dominance of sounds, either with prominent wanted or unwanted sounds, rather than with a mixture of both wanted and unwanted sounds.

- Building prediction models

The OLR prediction model used in this study is by no means for the only way to explore subjective evaluation of the acoustic quality. Many other social and cultural can also influence subjective response. ANN model is a promising candidate given the unique ability of neural network in making associations between dependent parameters and soundscape evaluation.

## 7.5 Concluding Remarks

This research has determined the acoustic characteristics, and visitors' evaluation, of soundscapes in the urban open spaces in Hong Kong. Purported to be an indispensable component of the urban ecosystem, open space is a highly valued resource for modern cities. It brings nature to the city to improve the well-being of people, to ameliorate the microclimate and to provide space for leisure and recreational activities. A properly designed open space offers a sense of peacefulness and tranquility by which one can retreat from the hustle and bustle of the urban life, relief from the urban street and rejuvenate through contemplation. Previous soundscape studies focused on working place, residential buildings and commercial malls, while, urban open spaces have been less touched. Endeavors to improve the acoustic quality in the urban open spaces can contribute to the long-term sustainability of the city.

The soundscape approach adopted in this study departs from the traditional noise control methods of acoustic environment management. Recognizing the acoustic dimension in the planning process makes requires consideration of sound as a resource rather than a waste, which is a paradigm shift. Equally important, the significance of individual sound sources in certain context was highlighted in this study. Previous analysis based on integrative acoustic measures does not differentiate individual sound sources and the embraced information content in a particular context. Brown proposed a two by two framework for soundscape evaluation, in which the acoustic quality is dependent on the overall sound level and the presence of wanted and unwanted sound. The findings from this study have partly validated Brown's framework, highlighting the importance of context, in subjective evaluation of the acoustic quality. These findings have underscored the importance of introducing sounds that is congruent with the context to improve the acoustic environment quality and to enhance visitors' enjoyment of the overall environment.

Although soundscape design has been studied intensively, there have been little attempt to transfer the research findings into practices for soundscape design. Similar to what Kang's group have done (Yu and Kang, 2005b; 2006), the influence of various physical, socio-demographical and psychological factors on soundscape evaluation has been analyzed in this study and different Artificial Neural Network (ANN) Models and Ordinal Logistic Regression (OLR) Models have been constructed for different types of the urban open spaces. If further developed, it can be a useful tool supporting urban planners to predict subjective acoustic quality evaluation in the stage of planning.

The implementation of a successful soundscape design is admittedly a challenging Task. Soundscape design is as yet fraught with complexities arisen from intricate contexts in reality and the juxtaposition of wanted and unwanted sounds. Any attempt to elucidate the relationships should be encouraged and are highly valued. Looking into the future, more efforts should be given to facilitate the transition from noise control to soundscape design, and to weave the soundscape concept with practice in the urban planning process. This is a significant step to make the city more livable and sustainable.

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**Appendix A: Questionnaire (English)**

**Questionnaire Used in the Survey of the Acoustic Quality in Urban Hong Kong Open Spaces**

| | |
|---|---|
| Number: | |
| Date: | |
| Time: | |
| Venue: | |
| Surveyor: | |

Part One: Visiting habit

| | | | |
|---|---|---|---|
| place of residence | | | |
| ☐ | nearby | ☐ | other districts (please specify) |
| ☐ | local district | | |
| transportation | | | |
| ☐ | walking | ☐ | bike |
| ☐ | public transport | ☐ | private car |
| ☐ | other (please specify) | | |
| frequency: how often do you come for a visit | | | |
| ☐ | everyday | ☐ | several times a week |
| ☐ | weekend | ☐ | occasionally |
| ☐ | once a week | ☐ | other (please specify) |
| time: when do you come in general | | | |
| ☐ | before 10 am | ☐ | from 10 am to 4 pm |
| ☐ | after 4 pm | ☐ | randomly |
| ☐ | other (please specify) | | |

Purpose of visiting (multiple choice, please order)

| | | | |
|---|---|---|---|
| ☐ | accompany children/family | ☐ | rest |
| ☐ | walking | ☐ | photo taking |
| ☐ | doing sports | ☐ | having lunch |
| ☐ | playing chess | ☐ | having class |
| ☐ | meeting friends | ☐ | working |
| ☐ | escape from domestic environment | ☐ | visiting |
| ☐ | stay close to the nature | ☐ | shopping |
| ☐ | pass by and rest | ☐ | fishing |
| ☐ | reading | ☐ | others |

Part Two: Acoustic Environment Evaluation

| How do you feel like the whole environment? | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| Very bad | Bad | Moderate | Good | Very good |
| | | | | |

| How do you feel like the acoustic environment here? | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| Very bad | Bad | Moderate | Good | Very good |
| | | | | |

Could you please describe the surrounding acoustic environment?

________________________________________________

________________________________________________

What is your general opinion about the acoustic environment?

| | 1<br>Very much | 2<br>Some-what | 3<br>Neither | 4<br>Some-what | 5<br>Very much | |
|---|---|---|---|---|---|---|
| noisy | | | | | | quiet |
| artificial | | | | | | natural |
| annoying | | | | | | favorable |

What sounds have you heard here? Please use the number between 1 and 5 to indicate how strongly you like it or dislike it. (1 for strongly dislike and 5 for strongly like it)

| Sound source | 1<br>Dislike most | 2<br>Dislike | 3<br>Neutral | 4<br>Like | 5<br>Like most |
|---|---|---|---|---|---|
| a. | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. | ☐ | ☐ | ☐ | ☐ | ☐ |
| d. | ☐ | ☐ | ☐ | ☐ | ☐ |
| e. | ☐ | ☐ | ☐ | ☐ | ☐ |
| f. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | | | | | |

Among the sounds you mentioned above,

a) The most favorable sounds:____________________
b) The most unfavorable sounds:____________________

Besides the sounds you heard, being within the area, what are you

c) Most willing to hear:____________________
d) Most unwilling to hear:____________________

What if you heard the following sounds in this place?

| | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | | Dislike most | Dislike | Neutral | Like | Like most |
| ☐ | bird | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | insect | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | wind blowing trees | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | sound of running water | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | church bell | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | construction sound | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | traffic noise | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | surrounding speech | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | children's shouting | ☐ | ☐ | ☐ | ☐ | ☐ |

Part Three: Personal information

| | | | |
|---|---|---|---|
| age: | | | |
| ☐ | below eighteen | ☐ | eighteen to twenty-four |
| ☐ | twenty five to thirty | ☐ | thirty one to forty |
| ☐ | forty one to sixty | ☐ | above sixty |
| gender | | | |
| ☐ | male | ☐ | female |
| occupation | | | |
| ☐ | manager and administrator | ☐ | service worker |
| ☐ | professionals | ☐ | sales worker |
| ☐ | clerk | ☐ | housewife |
| ☐ | skilled labor | ☐ | retired |
| ☐ | student | ☐ | others |
| education | | | |
| ☐ | primary school or below | ☐ | secondary school (s1-s7) |
| ☐ | college | ☐ | university or above |

Part Four: Feedback from the interviewer

Please list the sounds you have heard according to the Principle of Primary Sequence

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| | | | | | |

Evaluation of the acoustic quality:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very bad | Bad | Moderate | Good | Very good |
| | | | | |

Please express your general impressions of the surrounding acoustic environment?

______________________________________________

______________________________________________

Your appraisal about the interviewee:

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | Very bad | Bad | Moderate | Good | Very good |
| Comprehension | | | | | |
| Expression | | | | | |
| Reliability | | | | | |

What is your general impression about the interviewee?

______________________________________________

______________________________________________

Notes:

______________________________________________

______________________________________________

**Appendix B: Questionnaire (Chinese)**

香港市區公共空間聲音環境質素問卷調查

| | |
|---|---|
| 編號 | |
| 日期 | |
| 時間 | |
| 地點 | |
| 訪問員 | |

第一部分：使用模式

| 居住地區 | | | |
|---|---|---|---|
| ☐ | 附近 | ☐ | 其他地區，(請註明)： |
| ☐ | 本區 | | |
| **交通工具** | | | |
| ☐ | 步行 | ☐ | 單車 |
| ☐ | 公共交通工具 | ☐ | 私家車 |
| ☐ | 其他（請註明） | | |
| **多久時間來此一次** | | | |
| ☐ | 每日 | ☐ | 一星期內多次 |
| ☐ | 週末 | ☐ | 偶爾，無固定 |
| ☐ | 每週一次 | ☐ | 其他（請註明） |
| **通常什麼時候到此** | | | |
| ☐ | 上午 10 時之前 | ☐ | 上午 10 時至下午 4 時 |
| ☐ | 下午 4 時以後 | ☐ | 無固定 |
| ☐ | 其他（請註明） | | |

來這裡的目的（可選多項，依次排序）

| | | | |
|---|---|---|---|
| ☐ | 陪家人/小朋友 | ☐ | 離開室內環境 |
| ☐ | 散步 | ☐ | 接觸大自然 |
| ☐ | 運動 | ☐ | 路過休息 |
| ☐ | 下棋 | ☐ | 看書/閱報 |
| ☐ | 找朋友 | ☐ | 休息 |
| ☐ | 拍照 | ☐ | 食飯 |
| ☐ | 上課 | ☐ | 工作 |
| ☐ | 參觀 | ☐ | 其他(請註明)： |

環境質素評價

| 您覺得這裡的整體環境質素如何？ | | | | |
|---|---|---|---|---|
| 很差<br>1 | 不好<br>2 | 一般<br>3 | 還好<br>4 | 很好<br>5 |
| | | | | |

## 第二部分：景音情況評估

聲音環境質素評價

| 您覺得這裡的整體聲音環境質素如何？ | | | | |
|---|---|---|---|---|
| 很差<br>1 | 不好<br>2 | 一般<br>3 | 還好<br>4 | 很好<br>5 |
| | | | | |

請您描述一下周圍的聲音環境：

________________________________________

________________________________________

________________________________________

________________________________________

請形容對這裡聲音環境的感覺

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 嘈吵 | | | | | | 寧靜 |
| 人爲 | | | | | | 自然 |
| 煩厭 | | | | | | 喜愛 |

（1）在這裡可以聽到哪些聲音?（2）請用 1 至 5 形容，你對聽到的聲音的感覺，1 代表不喜歡，5 代表喜歡。

| 聲音源 | 不喜歡 ◄·····► 1 | 2 | 3 | 4 | 喜歡 5 |
|---|---|---|---|---|---|
| a. | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. | ☐ | ☐ | ☐ | ☐ | ☐ |
| d. | ☐ | ☐ | ☐ | ☐ | ☐ |
| e. | ☐ | ☐ | ☐ | ☐ | ☐ |
| f. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | | | | | |

在您剛才提及的聲音中，

a) 感覺最舒服的是 ____________________

b) 感覺最不好的是 ____________________

不在您剛才提及的聲音中，有哪些是您在此環境中

c) 最希望聽到的聲音是 ____________________

d) 最不希望聽到的聲音是 ____________________

請表示如果在此環境中聽到下列聲音，您的感覺如何

| 聲音源 | | 不喜歡 ◄······► 喜歡 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| ☐ | 雀鳥聲 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 昆蟲聲 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 風吹樹葉的聲音 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 流水聲 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 噴泉聲 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 教堂鐘聲 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 施工聲音 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 交通噪音 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 說話聲 | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ | 小孩聲 | ☐ | ☐ | ☐ | ☐ | ☐ |

第三部分：個人資料

| 年齡: | | | |
|---|---|---|---|
| ☐ | 18 歲以下 | ☐ | 18-24 歲 |
| ☐ | 24-30 歲 | ☐ | 31-40 歲 |
| ☐ | 41-60 歲 | ☐ | 60 歲以上 |
| 性別 | | | |
| ☐ | 男 | ☐ | 女 |
| 職業 | | | |
| ☐ | 經理及行政級人員 | ☐ | 服務人員 |
| ☐ | 專業人員 | ☐ | 銷售人員 |
| ☐ | 文員 | ☐ | 主婦 |
| ☐ | 技術工人 | ☐ | 退休人士 |
| ☐ | 學生 | ☐ | 其他 |
| 教育程度 | | | |
| ☐ | 小學或以下 | ☐ | 中學(中一至中七) |
| ☐ | 大專(非學位課程) | ☐ | 大學或以上 |

第四部分：訪問員意見

請按主次順序列出在此環境中，主要的聲音

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| | | | | | |

聲音環境質素評價

| 這裡的整體聲音環境質素如何？ | | | | |
|---|---|---|---|---|
| 很差 1 | 不好 2 | 一般 3 | 還好 4 | 很好 5 |
| | | | | |

請描述一下周圍的聲音環境：

________________________________________

________________________________________

________________________________________

________________________________________

對被訪者的評價：

| | 非常 low ◄·····················► 非常 high<br>1　　2　　3　　4<br>5 | | | | |
|---|---|---|---|---|---|
| 理解問題的能力 | | | | | |
| 表達意見的能力 | | | | | |
| 答案的可靠性 | | | | | |

整體而言，你對被訪者的感覺是：

________________________________________

________________________________________

________________________________________

________________________________________

附注：

________________________________________

________________________________________

________________________________________

________________________________________

**Appendix C: Summary of successful interviews in different time of the day and different functional zones**

| Study Site | Functional Zone | Sub-total | Time | Account |
|---|---|---|---|---|
| Sha Tin Park (219) | Get-together place | 93 | Morning | 38 |
| | | | Noon | 33 |
| | | | Afternoon | 22 |
| | Sightseeing area | 54 | Morning | 13 |
| | | | Noon | 19 |
| | | | Afternoon | 22 |
| | Quiet relaxing place | 72 | Morning | 11 |
| | | | Noon | 14 |
| | | | Afternoon | 47 |
| Hong Kong Park (70) | Sightseeing area | 56 | Morning | 12 |
| | | | Noon | 19 |
| | | | Afternoon | 25 |
| | Sports field | 14 | Morning | 4 |
| | | | Noon | 1 |
| | | | Afternoon | 9 |
| Victoria Park (167) | Quiet relaxing place | 39 | Morning | 9 |
| | | | Noon | 15 |
| | | | Afternoon | 15 |
| | Sports field | 41 | Morning | 1 |
| | | | Noon | 9 |
| | | | Afternoon | 31 |
| | Sightseeing area | 16 | Morning | 6 |
| | | | Noon | 4 |
| | | | Afternoon | 6 |
| | Children playground | 33 | Morning | 6 |
| | | | Noon | 6 |
| | | | Afternoon | 21 |
| | Get-together place | 38 | Morning | 15 |
| | | | Noon | 7 |
| | | | Afternoon | 16 |
| Kowloon Park (206) | Sightseeing area | 83 | Morning | 8 |
| | | | Noon | 14 |
| | | | Afternoon | 61 |
| | Chatting and resting area | 69 | Morning | 9 |
| | | | Noon | 6 |
| | | | Afternoon | 54 |
| | Quiet relaxing place | 31 | Morning | 13 |
| | | | Noon | 13 |
| | | | Afternoon | 5 |
| | Children playground | 9 | Morning | 1 |
| | | | Noon | 6 |
| | | | Afternoon | 2 |
| | Get-together place | 14 | Morning | 2 |
| | | | Noon | 3 |
| | | | Afternoon | 9 |

| | | | | |
|---|---|---|---|---|
| Wan Chai Park (59) | Children playground | 7 | Morning | 4 |
| | | | Noon | / |
| | | | Afternoon | 3 |
| | Sightseeing area | 33 | Morning | 9 |
| | | | Noon | 7 |
| | | | Afternoon | 17 |
| | Sports field | 19 | Morning | 3 |
| | | | Noon | 6 |
| | | | Afternoon | 10 |
| Tai Po Waterfront Park (57) | Sightseeing area | 57 | Morning | 16 |
| | | | Noon | 20 |
| | | | Afternoon | 21 |
| Sham Shui Po Park I (139) | Chatting and resting area | 46 | Morning | 5 |
| | | | Noon | 25 |
| | | | Afternoon | 16 |
| | Sightseeing area | 35 | Morning | 12 |
| | | | Noon | 16 |
| | | | Afternoon | 7 |
| | Quiet relaxing place | 58 | Morning | 25 |
| | | | Noon | 13 |
| | | | Afternoon | 20 |
| Sham Shui Po Park II (32) | Quiet relaxing place | 11 | Morning | 7 |
| | | | Noon | 4 |
| | | | Afternoon | / |
| | Chatting and resting area | 21 | Morning | 9 |
| | | | Noon | 6 |
| | | | Afternoon | 6 |
| Shek Kip Mei Park (15) | Quiet relaxing place | 15 | Morning | 4 |
| | | | Noon | 10 |
| | | | Afternoon | 1 |
| Charter Garden (89) | Sightseeing area | 10 | Morning | 3 |
| | | | Noon | 7 |
| | | | Afternoon | / |
| | Quiet relaxing place | 44 | Morning | 14 |
| | | | Noon | 10 |
| | | | Afternoon | 20 |
| | Chatting and resting area | 35 | Morning | 25 |
| | | | Noon | 10 |
| | | | Afternoon | / |
| Harcourt Garden (30) | Quiet relaxing place | 15 | Morning | 6 |
| | | | Noon | / |
| | | | Afternoon | 9 |
| | Chatting and resting area | 15 | Morning | 6 |
| | | | Noon | 2 |
| | | | Afternoon | 7 |

| | | | | |
|---|---|---|---|---|
| TLW Garden (32) | Quiet relaxing place | 23 | Morning | 8 |
| | | | Noon | 5 |
| | | | Afternoon | 10 |
| | Children playground | 9 | Morning | / |
| | | | Noon | 5 |
| | | | Afternoon | 4 |
| Sai Yee Street Garden (28) | Chatting and resting area | 10 | Morning | / |
| | | | Noon | 3 |
| | | | Afternoon | 7 |
| | Children playground | 18 | Morning | / |
| | | | Noon | 8 |
| | | | Afternoon | 10 |
| Tai Po Central Town Plaza (79) | Sightseeing area | 49 | Morning | 6 |
| | | | Noon | 22 |
| | | | Afternoon | 21 |
| | Children playground | 30 | Morning | / |
| | | | Noon | 13 |
| | | | Afternoon | 17 |
| Status Square (43) | Sightseeing area | 21 | Morning | 13 |
| | | | Noon | 4 |
| | | | Afternoon | 4 |
| | Chatting and resting area | 22 | Morning | 10 |
| | | | Noon | / |
| | | | Afternoon | 12 |
| Cenotaph Plaza (78) | Sightseeing area | 13 | Morning | 5 |
| | | | Noon | / |
| | | | Afternoon | 8 |
| | Chatting and resting area | 65 | Morning | 32 |
| | | | Noon | 23 |
| | | | Afternoon | 10 |
| Avenue of Stars (139) | Sightseeing area | 60 | Morning | 20 |
| | | | Noon | 12 |
| | | | Afternoon | 28 |
| | Chatting and resting area | 79 | Morning | 53 |
| | | | Noon | 17 |
| | | | Afternoon | 9 |
| Mong Kok Road Playground (32) | Children playground | 15 | Morning | 13 |
| | | | Noon | 2 |
| | | | Afternoon | / |
| | Chatting and resting area | 17 | Morning | 2 |
| | | | Noon | 8 |
| | | | Afternoon | 7 |
| Wan Tau Kok Playground (14) | Sports field | 7 | Morning | 7 |
| | | | Noon | / |
| | | | Afternoon | / |
| | Chatting and resting area | 7 | Morning | / |
| | | | Noon | 4 |
| | | | Afternoon | 3 |

| | | | | |
|---|---|---|---|---|
| Tai Po Tau Playground (31) | Children playground | 21 | Morning | / |
| | | | Noon | 6 |
| | | | Afternoon | 15 |
| | Chatting and resting area | 10 | Morning | / |
| | | | Noon | 2 |
| | | | Afternoon | 8 |
| Shek Kip Mei Sports ground (24) | Sports field | 24 | Morning | 5 |
| | | | Noon | 7 |
| | | | Afternoon | 12 |
| Macpherson Playground (27) | Sports field | 27 | Morning | 6 |
| | | | Noon | 5 |
| | | | Afternoon | 16 |