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A soundscape approach to analyze traffic noise in the city of Taipei, Taiwan

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ABSTRACT

Traffic noise has been a serious issue in urbanized areas and caused annoyance and health problems. It is thus essential to monitor and reduce traffic noise Traditional approaches focus on the measurement of amplitude or frequency of noise. Nonetheless, these measurements hardly help researchers distinguish unique features of dominant noise at different types of land use. This study adopts the theoretical framework of urban soundscape to examine noise patterns. Amplitude, frequency and time, are three key parameters for the analysis of soundscape. Sound recordings are made at four urban sites (downtown, one commercial, and two residential areas) in the City of Taipei, Taiwan, during three time periods (8 am, 3 pm, and 8:30 pm). Sound data is processed by *seewave* and *XLSTAT* software for the representation of spatiotemporal patterns of urban soundscape. Principal Component Analysis (PCA) approach is introduced to analyze the dominant sources of noise under various types of land use. The analytical results intuitively explain how various types of vehicles play vital roles under different types of land use. For instance, cars or taxis are the dominant sources of noise in residential and commercial areas in the afternoon and evening. The results also specify the dominance of public transport such as buses in the downtown areas during daytime. In summary, the adoption of the descriptive soundscape pattern and computer-based statistical analysis in this study helps researchers not only understand the relation between traffic noise and urban landscape but also develop a conceptual framework to reduce impacts of noise and improve the quality of life in cities.

1. Introduction

With rapid urbanization and development of transportation vehicles, traffic noise has become a critical issue in modern societies. Brainard, Jones, Bateman, and Lovett (2004), for instance, measure noise on a population-weighted average and discover many concentrated residential clusters in Birmingham, UK, have up to 23% higher exposure to noise than in suburbs. Ma, Tian, Ju, and Ren (2006) conduct longitudinal study by analyzing traffic noise data from 1989 to 2003 and find a trend that the time period noise exceeding China's national permissible noise pollution thresholds has been significantly increasing during the 14-year period. Similar studies have also been done to analyze how traffic noise affects human environment in various urban areas (e.g. Balaÿ, 1998; Berger, 2003; Dursun, Ozdemir, Karabork, & Kocak, 2006; Iannone, Guarnaccia, & Quartieri, 2011; Obaidat, 2011). In these studies, individual parameters such as amplitude, frequency, or time, are often selected to measure noise and quantify the effects of noise in urban environment. For instance, a heat map created by GIS-based interpolation is drawn to represent spatial patterns of noise and help decision makers take actions to reduce noise pollution (Obaidat, 2011).

However, the measurement of noise only reflects degree of noise but hardly helps researchers specify types of noise and how they affect the environment. For instance, people agree that traffic noise is the key source in urban noise pollution, but Barot (1999) and Krause (1993) examine the effects of outdoor urban noise pollution in their study areas and discover the major source of noise is from birds and small animals rather than low rumbling sounds of traffic and other urban-originated noise. Although the measurement of noise is important in urban studies, the description of noise and its perceptible effects with noise quantity and its impact on space should also be considered (Balay, 2004). Schafer (1994) posits the soundscape approach that identifies frequencies and amplitude of several types of noises on a two-dimension spectrum to describe various features of noise. This descriptive approach is notably congruent to help humans perceive noise because it manifests a visual pattern of noise and adopted to explore types of noise in cities (Hall, Irwin, Edmondson-Jones, Phillips, & Poxon, 2013; Kang, 2010; Licitra, 2012). Nonetheless, a general lack in noise studies and specifically in the soundscape approach is the spatial-temporal visualization of noise patterns through the conversion from analog signals to a digital form. Currently a prevailing approach is the use of measurement-based noise maps to elaborate spatial impacts of noise (e.g. Ausejo, Recuero, Asensio, Pavón, & López, 2010; Heinonen-Guzejev et al., 2000; Ko, Chang, & Lee, 2011). Another approach is to conducts a questionnaire survey to qualitatively investigate urban soundscape and sound quality or urban environments (Guastavino, 2006; Sommerhoff,

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Recuero, & Suárez, 2004). These static manners only emphasize on the degree of noise but are not able to distinguish types and sources of noise. It is also challenging to adopt these approaches to analyze spatial-temporal dynamics of sounds due to constant changes of intensity over time and different land use types (Balay, 2004; Pijanowski et al., 2011; Villanueva-Rivera, Pijanowski, Doucette, & Pekin, 2011).

As a result, this research focuses on two key objectives: 1) to integrate three key parameters of noise, amplitude, frequency, and time, to implement spatial-temporal representation of urban soundscape, and 2) to explore dominant traffic noise under various urban land use types through computer-based analytical approaches. After a brief introduction of urban noise, the importance of the description of noise is emphasized in Section 2. Methods for spatial-temporal representation and sound analyses in the City of Taipei, Taiwan, are highlighted in Section 3. Section 4 examines types and patterns of traffic noise under different time periods and discusses the analytical results. The benefit of adopting computational statistics into soundscape patterns to examine traffic noise is concluded in Section 5.

2. From measurement to description

Most of the sound that people hear in the urban environment is accidental and unpleasant. As such, studies have suggested that such sound is not only a nuisance, but also causes a wide range of health problems from hypertension to adversely affecting children's cognition and general health (Bodin et al., 2009; Ouis, 2001; Stansfeld et al., 2005). It is particularly worrying that urban dwellers attempt to sedate themselves from the physically unhealthy environmental noise by plugging in earphones or headphones, which in turn affects one's mental state; essentially shifting the impact of noise from a relatively physiological effect to a more psychological and mental one. This problem is intensified as the world becomes increasingly urbanized and people in urban areas experience an indiscriminate spread of 'more and larger sounds' (Schafer, 1994, p. 3). This increase is generally observed in many noise studies (Chowdhury, Debsarkar, & Chakrabarty, 2012; Georgiadou, Kourtidis, & Ziomas, 2004; Jahandar, Hosseinpour, & Sahraei, 2012; Nejadkoorki, Yousefi, & Naseri, 2010; Parris & Schneider, 2009; Yang & Kang, 2005), and there is a growing need to understand how the increase in amount and variety of sounds will influence the urban soundscape.

Some studies explore the effects of using spectrum-approach studies of noise in hospital wards, which prove to be very effective as newer medical technology and more innovative layout planning mitigates the effects of noise on patients (Bentley, Murphy, & Dudley, 1977; Hodge & Thompson, 1990). The methodology in these studies has the potential for spectral analysis in an outdoor environment and helps researchers shift the focus back on the description of sounds and raise sonic awareness in noise research. Traditionally, sound is measured by noise level, for instance, normal conversations at 50 dB, rock concert at 105 dB, and gunshots at 140 dB. There is, however, no systematic approach to describe unique features of various sound patterns. A key value to understand types of sounds is to help decision makers customize a noise pollution plan based on different notions of comfort levels and acoustic factors. Balaÿ (1998) shows that three streets in Lyon, France (Rue Romarin, Rue Major Martin, and Rue du Garet) have identical noise levels but entirely different soundscapes, and recommended the city council to observe the soundscapes over measuring its quantity. This holistic approach to the problem could result in a new way in presenting dimensions of urban sounds through qualitative means.

Traffic noise has become a large component in an urban soundscape since the industrial revolution. The societal shift from a manual to automatic, slow to fast, and more recently, mono-centric to poly-centric manner has allowed humans to be subjected to more sounds, such that the environment's capacity to convey information is hampered (e.g. birdsong and rustling leaves hint at the autumn season). As more vehicles use the road, traffic noise logarithmically increases (Iannone et al., 2011) and similar-sounding information (e.g. birds, chatter, trains) in the soundscape 'mutates' into anti-information, which humans deem as noise. Because this group of noises grow yearly, eventually humans will polarize sounds into loud and quiet (Wrightson, 2000), and block out noise somewhat parallels how music increases in volume and range after each century (Fig. 1), for instance. On a larger scale, the homogenous sounds of vehicles have dominated over all the other sounds such that traffic sounds the same in almost every city, and the city life has been associated to most people as filled with incessant noise and activities (Newman & Lonsdale, 1996). As urban planners revitalize urban cores to include recreational and residential activities to remain relevant and competitive (Wong, 2004), it is vital to consider the aurally crowded urban soundscape that affects human audibility spatially and temporally.

Recent research has already discussed the influence of traffic noise in cities (Jahandar et al., 2012; Ma et al., 2006). Yet a qualitative analysis of traffic noise and how traffic noise fits inside the larger domain of sound ranges is rarely discussed. It is thus essential to adopt soundscape, coined by Schafer (1994), to describe the array of always-present noises and identify the dominant sound patterns under different types of land use (Fig. 1). This approach delineates sound patterns based on two variables: amplitude (or volume) and frequency. It blends both the use of spectrograms and numerical data derived from traditional analog signals. It not only identifies traffic dominance and visualizes spatiotemporal patterns in the soundscape by tabulating absolute values from spectrograms but also provides many affordances in noise description and analysis. Truax (2001) adopts similar theories and conceptualizes sound as a key mediating agent between an individual and his or her immediate environment. Essentially, both scholars are trying to suggest that humans interact with the environment by listening to it like a musical composition, and that humans also own the responsibility for it (Schafer, 1977). To have a better understanding of soundscape, two types of sound environment should be further discussed. Low-Fidelity (Lo-Fi) environments are acoustically overcrowded places that have unfavourable signal-to-noise ratio, as opposed to High-Fidelity (Hi-Fi) environments which carry more natural sounds that do not overlap, and vary throughout the year as different creatures form dominant sounds (Schafer, 1977). Homogenized Lo-Fi environments arise, as earlier mentioned, from mass and rapid urbanization.

3. Methodology

3.1. Selection of sites

City of Taipei was chosen as the study area due to the high rate of noise driven by rapid urbanization and recent grand plans to revitalize the urban core and facilitate gentrification (Fang & Ling, 2003; Huang, Wang, & Budd, 2009). To analyze the relation between dominant types of traffic noise and urban forms, four sites with different types of land use were selected: central business district (CBD), commercial, residential, and a mixture of commercial and residential sites (Fig. 2). In terms of the types of land use, the soundscape of these sites might vary in weekdays and weekends. For the consistency of sound recording, this study only examined the soundscape at different types of land use during weekdays.

3.2. Procedures of sound recording

A pair of identical sound level meters (Model: Extech Instruments 407736, ±1.5 dB accuracy) were used to record urban noise at the four sites. The sound level meters were positioned on each side of the street for redundancy and a stereophonic pair of recordings. The main concern for the establishment of the stereophonic pair was to better distinguish sound types by ear. Each device was placed at the edge of the road at 2 m above the ground to avoid ground reflections while maintaining an acceptable height for a human (Fig. 3). Ground reflection