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Effect of temporary open-air markets on the sound environment and acoustic perception based on the crowd density characteristics

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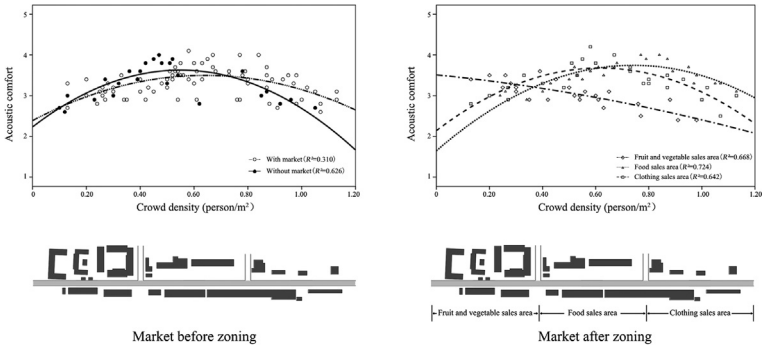
HIGHLIGHTS

- Sound environment can be changed by temporary open-air markets planning.
- Acoustic perception can be affected by temporary open-air markets zoning.
- Acoustic comfort can be improved by temporary open-air markets zoning.

GRAPHICAL ABSTRACT



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ABSTRACT

The sound environment and acoustic perception of open-air markets, which are very common in high-density urban open spaces, play important roles in terms of the urban soundscape. Based on objective and subjective measurements of a typical temporary open-air market in Harbin city, China, the effects of the temporary open-air market on the sound environment and acoustic perception were studied, considering different crowd densities. It was observed that a temporary open-air market without zoning increases the sound pressure level and subjective loudness by 2.4 dBA and 0.21 dBA, respectively, compared to the absence of a temporary market. Different from the sound pressure level and subjective loudness, the relationship between crowd density and the perceived acoustic comfort is parabolic. Regarding the effect of a temporary open-air market with different zones on the sound environment and acoustic perception, when the crowd densities were the same, subjective loudness in the fruit and vegetable sales area was always higher than in the food sales area and the clothing sales area. In terms of acoustic comfort, with an increase in crowd density, acoustic comfort in the fruit and vegetable sales area decreased, and acoustic comfort in the food sales area and the clothing sales area exhibited a parabolic change trend of increase followed by decrease. Overall, acoustic comfort can be effectively improved by better planning temporary open-air markets in high-density urban open spaces.

1. Introduction

"Temporary open-air markets" refers to a business type that is present in public spaces, such as streets, squares, or specific buildings, during a certain time period under effective control (Tangires, 2008). Such

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markets have a long history in time. Their earliest recorded appearance can be traced back to the sixth century BC (Hsieh and Chang, 2006). In high-density cities in Asian countries such as China and Japan, temporary open-air markets are common: nearly every 10 blocks has (or once had) a temporary open-air market (Suminski et al., 2008). Studies indicate that 75% of all residents in these countries visit a temporary open-air market weekly (Susskind and Chan, 2000). Temporary open-air markets are also places where tourists can experience a local area's characteristic cultural life (Zakariya, 2010, 2011a, 2011b). However, because of negligent management, the perception by nearby residents of the sound environment of temporary open-air markets is not ideal (Carles et al., 1999; Guéguen et al., 2007). Therefore, how to improve the sound environment in temporary open-air markets has become an issue that must be addressed by urban planners and the government.

The sound environment and acoustic perception in urban open spaces exhibit typical and variant features. For example, studies have demonstrated that the chirping of birds, church bells, the sound of running water, and the joyful shouts of children are sounds that people enjoy hearing in squares with recreational functions. In squares with commercial functions, the sound of music being played outdoors and inside shops is appreciated (Kang, 2007). Bruce and Davies (2011) demonstrated that the function of the soundscapes of religious spaces, commercial spaces, distribution spaces, and traffic spaces in historical districts exhibits clear differences. In commercial spaces, the design of the sound environment plays an important role in the creation of a commercial atmosphere (So and Kimura, 1998; Hao et al., 2015). In addition, background music in shopping spaces effectively increases the acoustic comfort of shoppers. In contrast, the sound of hawkers promoting their wares decreases acoustic comfort (Song et al., 2011). Meng and Kang (2015) found that human acoustic comfort is associated with the type of sound source. The acoustic comfort created by natural sounds is the most preferable, whereas the acoustic comfort of traffic sounds and mechanical sounds is the least preferable. Several researchers have begun to utilise the typicality and variance of sound sources in soundscape design (Song and Ma, 2012; Song et al., 2012). Different from general urban open spaces, temporary open-air markets are characterised by temporariness (Pottiesherman, 2013) and cannot exist independently. They are the product of human behavioural activity (Zakariya, 2010, 2011a, 2011b; Mohamad et al., 2015). Therefore, studies on the sound environment of open spaces should consider such activities.

The differences between the activities that occur in different zones also affect the sound environment and acoustic perception (Meng and Kang, 2016). Some previous studies revealed that the perception of traffic noise differs substantially from that of musical sounds (Wells et al., 2016; Quintero and Ferrer, 2015). In addition, music-related human activities may increase the sound pressure level by 10.8–16.4 dBA, while non-music-related human activities may increase the sound pressure level by 9.6–12.8 dBA (Meng and Kang, 2016). Studies on urban park soundscapes indicate that recreational areas and quiet areas are characterised by low-frequency sounds. However, in more active areas, intermediate-frequency sounds are more evident (Joo et al., 2011; Li et al., 2014). Adding temporary water landscape experiences to urban open spaces effectively increases their acoustic comfort (You et al., 2010; Jin et al., 2012). Several studies also indicate that a variety of temporary activities in parks could alter the visual and auditory attention of tourists (Pirotta et al., 2014). The cited studies indicate that different functional zones in temporary open-air markets may differently affect the sound environment and acoustic perception.

A crowd is a special type of sound source (Crisler, 1976). In addition, a crowd also has a sound-absorption effect (Long, 2006). Therefore, crowd density may also affect the sound environment of urban open spaces (Meng and Kang, 2015). A number of studies indicate that the crowd density and the sound level of urban open spaces are strongly associated (Hayne et al., 2006; Hayne et al., 2011). In certain typical urban open spaces, crowd density can affect not only objective acoustic indicators, such as speech articulation and reverberation time (Zhang, 2011), but also subjective acoustic perception (Meng and Kang, 2015; Li and Meng, 2015). Previous studies indicate that the crowd density in temporary markets can vary substantially (Sun et al., 2017). Therefore, in the study of the sound environment and acoustic perception of temporary open-air markets, crowd density should be considered an important indicator.

The aim of this paper was to study the effect of temporary open-air markets on the sound environment and acoustic perception under different crowd densities. Using a typical temporary open-air market as an example, the effect of temporary open-air markets on the sound environment and acoustic perception under different crowd densities was studied using a questionnaire and objective measurements. First, the effect of the temporary open-air market before zoning on the sound level, subjective loudness, and acoustic comfort was analysed. Then, the effects of the temporary open-air market with the different zones on the perception of sound sources, sound levels, subjective loudness, and comfort were analysed.

2. Method

The study methods included selection of a survey site, crowd density measurement, a questionnaire-based survey, and sound-level measurement.

2.1. Survey site

A typical temporary open-air market on Wenxing Street in Harbin, China, was selected as the survey site (Fig. 1). The decision to study this location was based on the following 3 reasons. First, the mean height-to-width ratio of the street on which the market was located is 3:1; which is typical for high-density cities (Shan, 2008; Ng et al., 2011). Next, the temporary open-air market had a large scale and a long history. Therefore, a large number of local residents as well as domestic and international tourists visit the market. Thus, the market provides convenient conditions in which to study the sound environment and acoustic perception under different crowd densities. Finally, the market's business model (i.e., its scale and format) resembles that of markets encountered in Europe and Japan (Zakariya, 2010) and thus has typicality. Booths in this market are distributed on both sides of the road. The market operates Saturday to Wednesday from 17:00–22:00. The market's width is approximately 10 m, and its total length is approximately 600 m. Previous studies indicate that any area of a market within 25–35 m of a road might be affected by traffic noise (Meng and Kang, 2015). In addition, areas close (i.e., 10–15 m) to the end of the road on which the market is located experience highly unstable crowd-flow changes (Raimbault and Dubois, 2005; Yu and Kang, 2006). Therefore, both ends of the road on which the study object was located, which were 35 m from road traffic, were not included in the measurement range.

Prior to August 2016, this temporary open-air market primarily sold fruits and vegetables, other food, and clothing. The other food items primarily consisted of specialty snacks and drinks as well as groceries (Fig. 1a). These 3 categories accounted for 96% of the market's business (Sun et al., 2017). The booth types were randomly distributed throughout the market. However, in August 2016, to facilitate improved management, the market management authority divided the market into 3 independent zones (Fig. 1b): a fruit and vegetable sales area, a food sales area, and a clothing sales area. The booth distribution was not changed with zoning and is shown in Fig. 1c. Therefore, to study the effects of the temporary open-air market on the sound environment and sound-source perception, measurements were performed twice: once before and once after the market was zoned.

Studies indicate that environmental changes, such as changes in temperature and humidity, influence subjective acoustic perception (Thwaites et al., 2005; Val et al., 2006). To avoid the effects of these environmental factors, measurements were performed in July and