Relationship between contextual perceptions and soundscape evaluations based on the structural equation modelling approach

Wei Zhao[1], Jian Kang[2 (*)], Hongpeng Xu[1], Yifei Zhang[1(*)]

1. School of Architecture, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin, 150006, China,

2. Institute for Environmental Design and Engineering, The Bartlett, University College London, London WC1H 0NN, UK

* Corresponding authors

Abstract: Contextual perceptions have a complicated effect on soundscapes in urban open public spaces. The objective of this study was to explore the systematic relationship between urban contextual factors and soundscape evaluations in open public spaces with a recreational function. Six areas in northern China were selected, and a questionnaire survey was conducted to evaluate the satisfaction with contextual factors and soundscapes. The results showed that dominant sound sources of talking and children playing were positively related to soundscape of interest and comfort. Most contextual factors were positively related to soundscape descriptors. Structural equation modelling was conducted using five dimensions: three dimensions of urban contextual perception, namely, urban management, natural and urban conditions, and the physical environment, and two dimensions of soundscape, namely, eventfulness and pleasantness. Urban management showed the most significant positive influence on the soundscape dimension of pleasantness. Physical environment was positively related to the dimension of pleasantness, and natural and urban conditions positively contributed to eventfulness. Moreover, natural and urban conditions and urban management both influenced the physical environment.

Key words: soundscape evaluations, contextual perception, structural equation model (SEM), sound sources

Date Received: 21 Mar 2021
Date Accepted: 16 Jul 2021
Publish online: 21 Jul 2021

1 Introduction

The process of urbanization has led to several environmental problems, and noise pollution is one of these (Yuan et al., 2019). Noise pollution has been shown to have adverse effects on the ecological environment, including adverse effects on biodiversity and physiological and psychological health (Newport et al., 2014; Münzel et al., 2018; Payne, 2013). Early studies on environmentally sustainable acoustics were primarily concerned with the control and management of noise pollution (Yu, 2008). However, noise reduction does not automatically lead to a better acoustic environment and psychological experience (Kang, 2006). Urban renewal offers an opportunity to improve the quality of life and create sustainable cities (Yildiz et al., 2020). The consideration and involvement of soundscape in the process of urban design can provide design strategies for sustainable urban and social development in the urban renewal process.

Soundscape refers to the auditory atmosphere of cities as a part of the holistic experience of urban spaces (Cao & Kang, 2021). It is an acoustic environment in a context as perceived, experienced, or understood by people (ISO 12913-1: 2014). The introduction of a particular context with regard to the soundscape was deemed important because objective indicators did not always significantly correlate with subjective perceptions (Jambrošić et al., 2013). The soundscape paradigm includes complex contexts, including non-acoustic indicators. Some non-acoustic indicators are related to conditions, such as the urban context (Hong and Jeon, 2017b) and physical environment (Jeon et al., 2011), and others are related to social and cultural significance for a community (Yang and Kang, 2005; Kang, 2006; Deng et al., 2020; Tarlao et al., 2021). So far, a limited number of studies have explored the impact of urban-related factors on soundscape evaluations, and the relationships between the factors, in the process of urban renewal.

The factors of urban conditions and management, as non-acoustic indicators in urban open public spaces, influence urban soundscapes. In urban environments, morphological parameters can be useful indicators for examining the soundscape dimension of pleasantness (Hong and Jeon, 2017b). When a soundscape is being characterized, the visual scene is likely to be an important modifying factor in auditory perception (Pheasant et al., 2010), along with natural features and noise levels, which influence tranquillity (Pheasant et al., 2008). As a natural element and a large restorative space, the sea and its presence improve soundscape quality (Puyana, 2016; Hong et al., 2020). In addition, colour coherency and greenery are useful for increasing the soundscape quality (Yu et al., 2014). Crowd density has a parabolic relationship with the subjective parameter of acoustic comfort, which differs from the objective parameter of sound pressure level and subjective loudness (Meng et al., 2017; Zhao et al., 2018). It has been implied that the factors of urban conditions and management affect soundscape evaluation. The abovementioned studies investigated the influence of a single or several descriptors on soundscape. However, the relationship between the factors of urban management and soundscape evaluation has not yet been examined systematically.

The physical environment also influences soundscape evaluations. Daylight dominates soundscape perceptions in urban spaces, in addition to acoustic comfort and visual images, according to social surveys and soundwalks (Jeon et al., 2011a). Thermal and general satisfaction with a place is also considered in this regard (Botteldooren et al., 2013). The visual environment and its congruence with the auditory environment are usually related to acoustic comfort (Ren and Kang, 2015). Soundscape, light scape, and space determined the cognitive persistence of soundscape (Hong et al, 2019). Fragrance was found to decrease the annoyance caused by traffic noise and increased auditory and olfactory satisfaction in urban streets (Ba and Kang, 2019b). The interactions of visual stimuli (Li and Lau, 2020), odour (Jiang et al., 2016; Sanchez et al., 2017; Ba and Kang, 2019a) and sound have been investigated, and found to influence soundscape evaluations. In urban open public spaces, physical environment is not only affected by the weather, but also by the local urban conditions and design, thus affecting the soundscape evaluation. However, the relationships among physical environment assessment, urban management, and soundscape have not yet been explored.

Evaluation models for urban soundscapes have been constructed with influencing factors. A general conceptual model of the environmental experience for soundscapes has been proposed based on interactions between the person and the place, activity, and environmental experience (Herranz-Pascual et al., 2010). Based on the method of artificial neural networks, models for soundscape evaluation with the factors of physical environment, behaviour, society, demographics, and psychology have been constructed at various types of locations (Yu and Kang, 2009). A soundscape quality model for urban waterfronts has been developed through subjective evaluations and objective acoustic and visual parameters (Romero et al., 2016). Furthermore, the influences of urban contexts of functional spaces on sound sources and soundscape evaluations have been explored through a structural equation modelling approach in urban open public spaces (Hong and Jeon, 2015), along with soundscape and visiting experiences in a historical block (Liu et al., 2019b). A model of the influence of contextual factors related to person and social interaction on soundscape evaluations has been developed through structural equation modelling (Tarlao et al., 2021). Extensive research on soundscapes in urban open public places has been conducted in several regions (Guastavino, 2006; Schulte-Fortkamp et al., 2008; Jeon et al., 2014; Aletta et al., 2016a), and has various functions of the public spaces (Nilsson and Berglund, 2006; Schulte-Fortkamp and Fiebig, 2006; Hong and Jeon, 2015;

Gozalo et al., 2018; Pérez-Martínez et al., 2018). However, research on the effect of contextual perceptions of urban factors, such as urban conditions, urban management, and physical environment, on soundscape has yet to be conducted systematically and comprehensively.

As mentioned above, the effects of a single or several indicators influenced on urban soundscape have been explored; however, research on the detailed relationships between urban contextual perceptions and soundscape has been limited in terms of urban-related factors. Therefore, the objective of this study was to explore the relationship between contextual perception of urban factors and soundscape evaluations, and construct a model for the influences of the urban context on soundscape through structural equation modelling (SEM).

2 Method

2.1 Site selection

Six recreational areas were selected as the targeted urban open public spaces, with the aim to include both inland and coastal areas, as shown in Fig. 1. Three inland squares and three coastal areas were selected in the cities of Harbin and Huludao, respectively, which are important, typical, and well-known tourist spots in northeast China. Site 1 was the Flood Control Monument in Harbin. The Flood Control Monument is a famous landmark in Harbin and a popular spot for tourism and leisure. It is situated at the end of the cultural commercial street and is surrounded by open urban parks. Site 2 was a square in Zhaolin Park, which is an urban park located in a commercial centre and surrounded by urban roads in Harbin. There are various spatial forms, greenery, and facilities in the park that attract tourists. Site 3 was St. Alekseyev Church, which is located in a residential community in Harbin. It is the main spot for leisure activities for residents of the surrounding areas, and tourists also visit it. Site 4, site 5, and site 6 were the coastal areas of Longwan, Xingcheng and Dongdaihe, respectively, in the city of Huludao. The six open public spaces are all well-known and conveniently located. Their main function is recreation, providing a place for local residents and tourists to engage in leisure and recreational activities, especially in summer. Various sound sources are present in these areas; for instance, water and wind as natural sounds, footsteps and talking as people sounds, and the sound of traffic as mechanical sounds.

2.2 Questionnaire design

The questionnaire was composed of three parts, and the basic framework was taken from ISO/TS 12913-2 (ISO/TS 12913-2: 2018). The first part of the questionnaire recorded interviewees' basic data regarding demographic and social indicators. This included gender (male or female), age (age groups: below 18, 18–24, 25–34, 35–44, 45–54, above 55), level of education (primary school, middle school, undergraduate or postgraduate), and place of residence (local or nonlocal).

a) Flood Control Monument

b) Square in Zhaolin Park

c) St. Alekseyev Church

d) Coastal place of Longwan

e) Coastal place of Xingcheng

f) Coastal place of Dongdaihe

Fig. 1. Study sites of field investigations.

The second part collected information regarding sound source perceptions. The interviewees were asked to select the sounds they perceived at each investigated site. Sound sources were listed in the questionnaire according to the sound source classification (Jambrošić et al., 2013; Axelsson et al., 2012) and the field conditions of each site. The sound sources included wind, water, and animals among natural sounds; footsteps, talking, children, and sellers/hawkers among people sounds; live music, broadcast, and phones among electronic sounds; and the sound of traffic among mechanical sounds. A five-point Likert scale was used to evaluate the perceived sound sources, using the following ratings: 1 = not at all, 2 = a little, 3 = neutral, 4 = a lot, and 5 = completely.

The third part collected information regarding the urban contextual factors and soundscape evaluations by the interviewees. These factors were also used for developing the research hypothesis of the SEM. The urban context is related to indicators and conditions of urban open spaces with different functions, landscapes (Liu et al., 2019a), visual factors (Hong et al., 2020), and environment (Jeon et al., 2011a). In this study, the urban context was classified into three aspects, that is, urban management, natural and urban conditions, and physical environment. Urban management is mainly related to traffic, crowd, and urban planning (Jiang et al., 2016; Hong and Jeon, 2017b; Meng et al., 2017; Zhao et al., 2018), representing the management results of design and strategies. Natural and urban conditions mainly refer to water, air, colour, and cleanliness (Pheasant et al., 2008; Yu et al., 2014; Puyana, 2016; Hong et al., 2020), representing material and visual elements. Physical environment refers to humidity, temperature, daylight, wind, odour, and sound (Jeon et al., 2011a; Botteldooren et al., 2013; Ren and Kang, 2015; Ba and Kang, 2019b; Hong et al, 2019; Li and Lau, 2020). In total, 13 descriptors of contextual perceptions were selected to evaluate the degree of satisfaction. A five-point Likert scale was used to asses satisfaction, with the following ratings: 1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, and 5 = very satisfied. Additionally, the overall satisfaction of interviewees with the entire survey site was evaluated. Further, five adjective word-pairs of descriptors were used to evaluate the soundscapes. Two adjective word-pairs, uneventful−eventful and unpleasant−pleasant, were selected as the two main dimensions of soundscape evaluation, based on previous studies (Aletta et al., 2016b; Axelsson, 2015). Three adjective word-pairs of soundscape descriptors, uncomfortable−comfortable, agitating−calming, and boring−interesting, were selected as being related to the main factors of relaxation, communication, and interest (Kang and Zhang, 2010), respectively. A five-point Likert scale was employed.

2.3 Field study

The surveys were conducted during the summer season in 2014. A total of 522 interviewees participated in the field questionnaire investigation; they were selected randomly at each investigated site. The information collected from them is presented in detail in Table 1. Men comprised 54.1% of the sample, while women comprised 45.9%. The percentage of interviewees aged 18 to 34 years exceeded those of the other age groups. The questionnaire surveys were conducted during the summer vacation, and therefore, a larger number of young couples with children, families, and students travelling together were present, especially in these well-known tourist attractions. Moreover, because of their convenience and enthusiasm, the proportion of young people and couples filling out the questionnaire was slightly higher. According to their level of education, the sample included mainly middle school and undergraduates. The percentage of nonlocal interviewees exceeded 40%.

2.4 Data analysis and structural equation modelling

The SPSS 24.0 software package was used to analyse statistical parameters according to the information collected via field questionnaire surveys at the six recreational sites. Spearman's rho correlation analysis was used as the main statistical method to identify the relationship between sound source perceptions and contextual and soundscape evaluations. Furthermore, the relationships between contextual factors and soundscape evaluations were investigated via SEM.

Table 1
Main demographic factors of the interviewees.

Demographic information		Percentage (%)
Gender	Male	54.1
	Female	45.9
Age	<18	13.6
	18−24	25.7
	25−34	31.3
	35−44	12.5
	45−54	12.9
	>55	9.5
Level of education	Primary school	6.6
	Middle school	40
	Undergraduate	42.8
	Postgraduate	10.5
Place of residence	Local	58.5
	Nonlocal	41.5

SEM is an extension of multivariate statistics, which integrates factor analysis and path analysis. It is a useful statistical tool for exploring the entire set of relationships among latent constructs. Through SEM, the constructs and their interrelationships can be indirectly measured through a series of observable variables from questionnaire responses. The aim is to test the causal relationships between each category of the conceptual framework and determine the direction of the relationships and their statistical significance (Wu, 2010; Hong and Jeon, 2015; Acun and Yilmazer, 2019; Liu et al., 2019b). During the process of SEM, exploratory and confirmatory factor analysis are carried out (Wu, 2010). Exploratory factor analysis (EFA) is used to extract the principal factors to explore the validity of the investigated data, without a preconceived structure of the outcome. Confirmatory factor analysis (CFA) is used to validate the hypotheses regarding the observed and latent variables, based on a theory or hypothesis (Hair et al., 2009; Wu, 2010; Hong and Jeon, 2015). An SEM for the relationships between urban contextual factors and soundscape evaluations was developed in this study, based on the results of EFA and CFA. SPSS 24.0 was used to perform EFA. AMOS 23.0 was used to conduct CFA and SEM.

3 Results

3.1 Relations between contextual and soundscape descriptors

The percentage of perceived sounds and the mean values of sound sources are presented in Fig. 2. Human sounds of talking and children playing showed high perceived values of 3.67 and 3.35, respectively. The electronic sounds of music and the natural sounds of water and wind corresponded to intermediate levels of perception, with values of 3.08, 3.03 and 2.83, respectively. The mean values for electronic broadcast sounds, human sounds of footsteps and selling, and traffic sound were relatively low, namely, 2.58, 2.53, 2.48, and 2.48, respectively, and those for horn sounds, phones, and mechanics sources were 2.37, 2.07 and 2.02, respectively. Animal sounds corresponded to the lowest perception, with a mean value of 1.61.

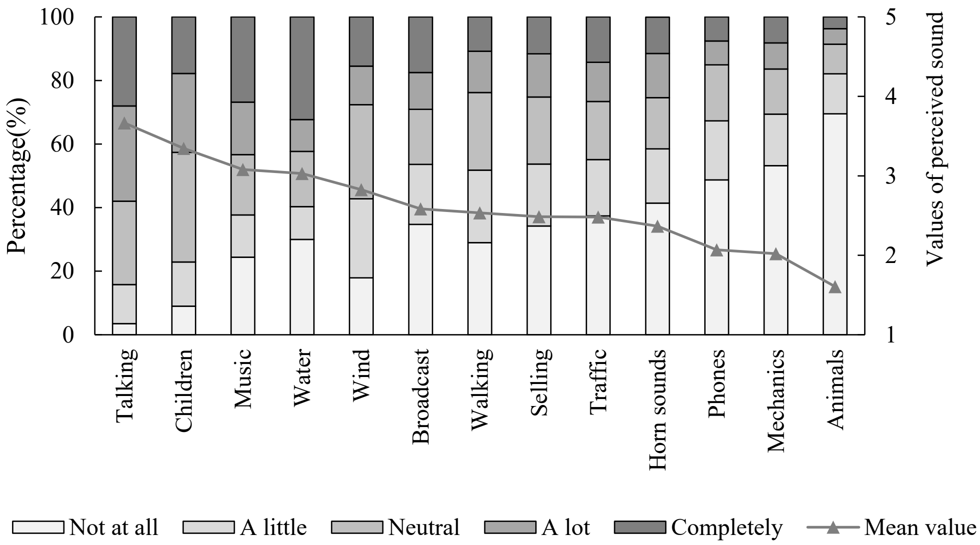

Fig. 2. Percentages of perceived sounds and mean values of sound sources.

The relationships between sound sources and soundscape evaluations are identified by conducting Spearman's rho correlation analysis, as presented in Table 2. The high perceptions of human sounds of talking and children playing both showed significantly positive relationships with soundscape of interesting ($p < 0.05$) and comfortable indicators ($p < 0.01$). The natural sounds of water and wind also had positive effects on interesting ($p < 0.01$) and comfortable ($p < 0.01$) soundscapes, respectively. In addition, sound of animals had positive effect on comfortable ($p < 0.01$) soundscape, despite of less perceived sound source. Calm soundscapes were positively correlated to footstep ($p < 0.05$) phones ($p < 0.05$), and animals ($p < 0.01$) as they were occasional sounds with few perceptions. Traffic and horn sounds were negatively related to the interesting ($p < 0.01$), pleasant ($p < 0.01$) and comfortable ($p < 0.05$) soundscape indicators. Interestingly, live music in the investigated spaces was negatively related to the interesting ($p < 0.01$) and comfortable ($p < 0.01$) indicators. It was related mainly to square dancing at evening time, which was a special characteristic in open public spaces.

Table 2

Correlations between sound sources and soundscape. ** p < 0.01 and * p < 0.05.

Sound sources	Uneventfulness - eventfulness	Agitating - calming	Boring - interesting	Unpleasant - pleasant	Uncomfortable - comfortable
Talking	-0.011	-0.039	0.094*	0.067	0.131**
Children	0.019	-0.040	0.135**	0.000	0.157**
Music	-0.069	-0.019	-0.163**	-0.026	-0.123**
Water	-0.064	-0.063	0.223**	0.070	0.185**
Wind	0.043	0.005	0.162**	-0.078	0.126**
Broadcasts	-0.047	-0.054	-0.006	-0.143**	-0.042
Footsteps	0.056	0.090*	-0.086	-0.053	-0.030
Selling	-0.034	-0.078	-0.042	-0.156**	-0.066
Traffic	-0.007	0.031	-0.077	-0.121**	-0.111*
Horn sounds	0.048	0.066	-0.117**	-0.130**	-0.155**
Phones	0.081	0.089*	0.013	-0.078	-0.070
Mechanics	0.034	0.025	-0.007	-0.079	-0.024
Animals	0.184**	0.212**	0.055	-0.161**	0.139**

The relationships between contextual indicators and soundscape indicators are presented in Table 3. The soundscape of eventfulness (p < 0.05), calming (p < 0.05), interesting (p < 0.01), and comfortable (p < 0.01) were positively related to most of the contextual satisfaction. Pleasant soundscapes had fewer influence indicators (p < 0.05) of contextual perceptions than other soundscape evaluations. Thus, the survey sites were related to functions of recreation, relaxation, and rest. Moreover, the dominant factors that affected the soundscapes were according to the main functions of the place, which is similar to the result of Hong and Jeon (2015).

3.2 SEM of contextual perceptions and soundscape evaluations

Based on SEM, the relationships between soundscape evaluations and the urban contextual factors were examined. As described in Section 2.4, the validity of factor analysis for the investigated data was explored based on EFA. The reliability and validity of the relationships between the observed and latent variables were verified based on CFA. Conceptual and modified structural equation models were constructed.

3.2.1 Step 1: EFA of contextual perceptions and soundscape evaluations

According to the investigated results, EFA was carried out to extract the principal factors for contextual perception and soundscape evaluation for satisfaction. Varimax-rotated principal component analysis was carried out to extract the orthogonal factors.

According to the value of Bartlett's test of sphericity (p = 0.001, p < 0.01) and Kaiser-Meyer-Olkin (KMO=0.889), the possibility of using SEM to model contextual perception and soundscape was confirmed. With the criterion of the corresponding eigenvalue exceeding 1 (Xue, 2017), factors were extracted, as presented in Table 4. Five factors were derived, and they represented 65.3% of the total variance with factor loadings that ranged from 0.4 to 0.9.

Table 3
Correlations between contextual and soundscape descriptors. ** p < 0.01 and * p < 0.05.

Contextual perceptions	Uneventfulness - eventfulness	Agitating - calming	Boring - interesting	Unpleasant - pleasant	Uncomfortable - comfortable
Traffic	0.093*	0.144**	0.198**	0.085	0.384**
Crowd	0.197**	0.222**	0.238**	0.083	0.465**
Urban planning	0.143**	0.164**	0.267**	0.091*	0.457**
Odour	0.114**	0.160**	0.201**	0.059	0.418**
Water	0.122**	0.127**	0.217**	-0.016	0.305**
Air	0.233**	0.237**	0.281**	0.084	0.376**
Colour	0.155**	0.196**	0.178**	-0.006	0.298**
Cleanliness	0.216**	0.222**	0.134**	-0.001	0.314**
Humidity	0.085	0.119**	0.272**	0.107*	0.434**
Temperature	0.099*	0.137**	0.254**	0.125**	0.389**
Daylight	0.132**	0.167**	0.211**	0.028	0.391**
Wind	0.095*	0.099*	0.219**	0.076	0.381**
Sound satisfaction	0.207**	0.252**	0.319**	0.147**	0.496**
Overall satisfaction	0.166**	0.180**	0.343**	0.264**	0.807**

Contextual perceptions could be interpreted based on Factors 1, 2 and 3, which explained 53.4% of the variance in total. Factor 1 was associated with urban management, which included traffic, crowd, urban planning, and odour, and explained 36.7% of the variance. Factor 2 was associated with natural and urban conditions, which included water, air, colour, and cleanliness, and explained 9.3% of the variance. Factor 3 represented the physical environment, such as the humidity, temperature, daylight, and wind, and explained 7.4% of the variance.

Soundscape evaluations were interpreted based on Factors 4 and 5, which explained 11.9% of the variance in total. Factor 4 was associated with the eventful-factor of the soundscape, which included uneventfulness–eventfulness, agitating–calming, and boring–interesting, and explained 6.4% of the variance. Factor 5 was associated with the pleasant-factor of the soundscape, which included unpleasant–pleasant, overall satisfaction, uncomfortable–comfortable, and sound environment satisfaction, and explained 5.4% of the variance. Thus, the five principal factors derived via EFA formed the main factors of the SEM for contextual perceptions and soundscape evaluation.

Table 4
Principal factors in the contextual perceptions and soundscape evaluation that were extracted via EFA.

Contextual perception and soundscape	Factor loading	Explained variance (%)
Factor 1: Urban management		36.7
Traffic	0.769	
Crowd	0.722	
Urban planning	0.642	
Odour	0.635	
Factor 2: Natural and urban conditions		9.3
Water	0.781	
Air	0.675	
Colour	0.645	
Cleanliness	0.613	
Factor 3: Physical environment		7.4
Humidity	0.847	
Temperature	0.843	
Daylight	0.631	
Wind	0.555	
Factor 4: Eventful-factor		6.4
Uneventfulness–eventfulness	0.863	
Agitating–calming	0.829	
Boring–interesting	0.612	
Factor 5: Pleasant-factor		5.4
Unpleasant–pleasant	0.740	
Overall satisfaction	0.684	
Uncomfortable–comfortable	0.676	
Sound satisfaction	0.395	

3.2.2 Step 2: CFA for the contextual perceptions and soundscape evaluations

The reliability and validity of the contextual perceptions and soundscape evaluations for the SEM were examined by CFA, with the observed and latent variables. Based on the results of Cronbach's alpha calculation, the reliability of five latent factors was verified. The Cronbach's alpha values were all higher than 0.7, indicating satisfactory reliability (Wu, 2010). Convergent and discriminant validity of the factors, which composed their construct validity, were examined. In terms of the convergent validity, various indicators such as factor loading, average variance extracted (AVE), and construct reliability (CR) were evaluated. The standardized factor loadings refer to the influence of latent variables on observed variables, where values higher than 0.5 are required to confirm satisfactory convergent validity. CR refers to the reliability coefficient of the latent variable of the model in SEM analysis. AVE indicates what extent of the variation explained by the latent constructs was due to measurement error. Additionally, a CR higher than 0.7 and AVE higher than 0.5 are required to suggest adequate convergent validity (Wu, 2010; Liu et al., 2019). Discriminant validity is the degree to which a latent variable is distinct from other latent variables (Hong and Jeon, 2015), using AVE to compare with the squared value of the correlation coefficients between latent constructs. In terms of the discriminant validity, the values of the maximum shared variance (MSV) and average shared variance (ASV) are required to be less than the values of AVE to show satisfactory discriminant validity (Hair, 2009; Wu, 2010; Hong and Jeon, 2015; Liu and Wang, 2016).

As presented in Table 5, the results of CFA for the contextual perceptions and soundscape evaluations regarding the reliability and construct validity were calculated. Cronbach's alpha values of the five latent variables were all more than 0.7, thereby indicating satisfactory reliability and showing reasonably satisfactory convergent validity. The standardized factor loadings were all more than 0.5, the values of CR all more than 0.7, and the values of AVE nearly more than 0.5. The constructs showed satisfactory discriminant validity. The values of MSV and ASV were both lower than that of AVE. During the process of CFA, the standard factor loading of the unpleasant–pleasant descriptor was less than 0.5, which indicated a weak relationship. It was removed from the latent variables of the soundscape for pleasantness, in order to increase the reliability (Wu, 2010).

Table 5
Results of CFA for the observed and latent variables.

Latent variables (Observed variables)	Cronbach's alpha	Std. factor loading	CR	AVE	MSV	ASV
Urban management	0.799		0.80	0.50	0.49	0.37
Traffic		0.669				
Crowd		0.699				
Urban planning		0.760				
Odour		0.688				
Natural and urban conditions	0.786		0.79	0.50	0.49	0.33
Water		0.630				
Air		0.665				
Colour		0.750				
Cleanliness		0.733				
Physical environment	0.808		0.82	0.54	0.41	0.27
Humidity		0.876				
Temperature		0.844				
Daylight		0.620				
Wind		0.560				
Eventful-factor	0.737		0.76	0.51	0.16	0.11
Uneventfulness–eventfulness		0.828				
Agitating–calming		0.767				
Boring–interesting		0.525				
Pleasant-factor	0.808		0.83	0.63	0.48	0.30
Overall satisfaction		0.898				
Uncomfortable–comfortable		0.878				
Sound satisfaction		0.568				

3.2.3 Step 3: Conceptual SEM for contextual perceptions and soundscape evaluations

Previous studies have illustrated that urban contextual factors have an influence on soundscape evaluation (ISO 12913-1: 2014). Further, urban management related to urban planning and morphological parameters is correlated to soundscape evaluations (Hong and Jeon, 2017b; Margaritis et al., 2020). Natural elements and coherency in urban management can improve the soundscape quality (Pheasant et al., 2008; Yu et al., 2014; Puyana, 2016). Physical environment also influences soundscapes (Jeon et al., 2011a; Botteldooren et al., 2013). In addition to this, urban management, natural and urban conditions, and physical environment influence each other. A conceptual model of urban contextual perceptions and soundscape evaluations was obtained for interpreting the relationships among the latent variables, as shown in Fig. 3. There were five latent variables in total: three latent variables of urban contextual perception were 'urban management', 'natural and urban conditions', and 'physical environment'; two latent variables of soundscape evaluation were 'eventful-factor' and 'pleasant-factor'. According to previous studies and former results, three main hypotheses (Ma, Mb, and Mc) and ten specific secondary hypotheses (Ma1 to Ma6; Mb1 to Mb3; and Mc1) were proposed:

Ma. Contextual perceptions influence soundscape evaluation.

Ma1. Urban management is positively correlated to eventful-factor.

Ma2. Natural and urban conditions are positively correlated to eventful-factor.

Ma3. Physical environment is positively correlated to eventful-factor.

Ma4. Urban management is positively correlated to pleasant-factor.

Ma5. Natural and urban conditions are positively correlated to pleasant-factor.

Ma6. Physical environment is positively correlated to pleasant-factor.

Mb. Indicators of contextual perceptions influence each other.

Mb1. Natural and urban conditions are positively correlated to the physical environment.

Mb2. Natural and urban conditions are positively correlated to urban management.

Mb3. Urban management is positively correlated to the physical environment.

Mc. The pleasant-factor of soundscapes influences the eventful-factor.

Mc1. The pleasant-factor of soundscapes is correlated to the eventful-factor.

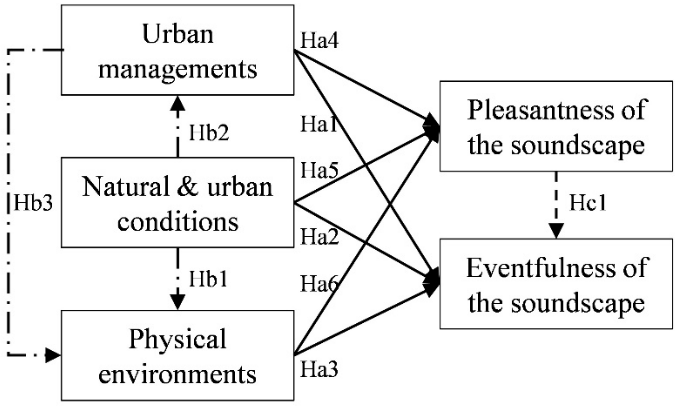

Fig. 3. A conceptual SEM of urban contextual perceptions and soundscape.

3.2.4 Step 4: Modified SEM for contextual perceptions and soundscape

AMOS 23.0 software was used to create the model for SEM. The goodness-of-fit indices were estimated for the conceptual model of contextual perceptions and soundscape evaluations by the maximum likelihood method. The Goodness of Fit Index (GFI) calculates the proportion of variance that is accounted for by the estimated population covariance (Wu, 2010). Comparative Fit Index (CFI) analyses the model fit by examining the discrepancy between the data and the hypothesised model. A GFI and CFI value more than 0.9 was considered acceptable (Wu, 2010; Chan et al., 2021). Root Mean Square Error of Approximation (RMSEA) is a measure of approximate fit in the population, and is therefore concerned with the discrepancy due to approximation (Chan et al., 2017). An RMSEA value less than 0.08 was an adequate fit (McDonald and Ho, 2002; Wu, 2010; Li et al., 2021). The obtained and recommended values to assess the validity of the SEM are presented in Table 7. It is found that the values GFI, CFI, and RMSEA for the conceptual model did not fit well according to the recommended values. Therefore, the modification paths with higher Modification Indices (MI) in AMOS and reasonable hypothesis were added to the model. Three paths of six observed variables were added to the conceptual model to fit the recommended values as follows; the values of goodness-of-fit indices for the modified model are presented in Table 6.

Mn1. The traffic condition is positively correlated to the crowd condition.

Mn2. Air conditions are positively correlated to the wind environment.

Mn3. The daylight environment is positively correlated to the sound environment.

The modified model is illustrated in Fig. 4, and the results of the hypotheses and standardized path loadings of the SEM for contextual perceptions and soundscape evaluations are presented in Table 7. Ten paths out of thirteen research hypotheses (three main hypotheses of Ma, Mb, and Mc and modified research hypotheses of Mn1, Mn2, and Mn3), were statistically significant, except for Ma1, Ma3, and Ma5.

Table 6
The values of goodness-of-fit indices for the proposed and modified models.

Model fit index	x^2/df	GFI	CFI	RMSEA
Obtained values	4.458	0.895	0.898	0.081
Modified values	3.688	0.912	0.923	0.072
Recommended values	<5	>0.9	>0.9	<0.08

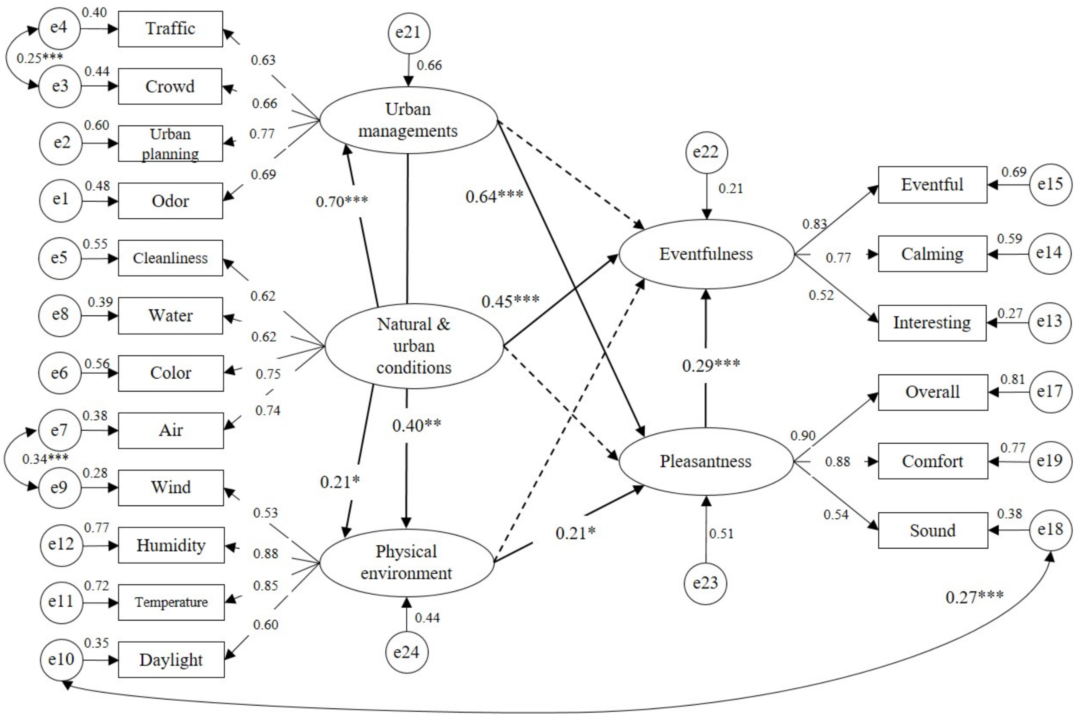

Fig. 4. Modified model for contextual perceptions and soundscape.

In terms of hypothesis Ma, contextual perceptions showed correlations to soundscape evaluations for three out of six specific hypotheses. As presented in Table 7, urban management and the physical environment had no effect on the soundscape of eventfulness ($p > 0.05$). Natural and urban conditions had no effect on the soundscape of pleasantness ($p > 0.05$), whereas they showed a significantly positive effect on the soundscape dimension of eventfulness ($p < 0.001$), with a standardized regression coefficient of 0.45. Urban management ($p < 0.001$) and the physical environment ($p < 0.05$) positively correlated to the soundscape dimension of pleasantness; the effects showed standardized regression coefficients of 0.64 and 0.21, respectively.

Regarding hypothesis Mb, as presented in Table 8, natural and urban conditions ($p < 0.05$) and urban management ($p < 0.01$) both showed significantly positive effects on physical environments, with standardized regression coefficients of 0.21 and 0.4, respectively. Natural and urban conditions showed the most significant positive influences on urban management ($p < 0.001$), with a standardized regression coefficient of 0.7.

Table 7
Results of 13 research hypotheses and standardized path loadings for the modified model of contextual perceptions and soundscape evaluations.

Hypotheses		*β*	C.R.	*p*-value
Ma1	Urban management → eventful-factor	-0.18	-1.154	0.248
Ma2	Natural and urban conditions → eventful-factor	0.45	3.553	0.000
Ma3	Physical environment → eventful-factor	-0.09	-1.213	0.225
Ma4	Urban management → pleasant-factor	0.64	11.319	0.000
Ma5	Natural and urban conditions → pleasant-factor	-0.04	-0.590	0.555
Ma6	Physical environment → pleasant-factor	0.21	2.379	0.017
Mb1	Natural and urban conditions → physical environment	0.21	2.100	0.049
Mb2	Natural and urban conditions → urban management	0.70	9.213	0.000
Mb3	Urban management → physical environment	0.40	3.168	0.002
Mc1	Pleasant-factor → eventful-factor	0.29	3.400	0.000
Mn1	Traffic condition → crowd condition	0.25	4.515	0.000
Mn2	Air condition → wind environment	0.34	6.494	0.000
Mn3	Daylight environment → sound environment	0.27	5.569	0.000

Regarding hypothesis Mc, the soundscape dimension of pleasantness showed a significantly positive effect on the dimension of eventfulness ($p < 0.001$), with a standardized regression coefficient of 0.29. It has been shown that a soundscape has two main dimensions, namely, pleasantness and eventfulness (Jeon and Hong, 2015; Axelsson et al., 2010), especially for open public spaces, which are correlated with each other.

In terms of the modified research hypotheses Mn1, Mn2 and Mn3, the traffic conditions and crowd conditions for urban management showed a positive correlation ($\beta = 0.25$, $p < 0.001$), thereby demonstrating both the relationships and the importance of facilitating traffic and reducing crowding in recreational areas. The relationship between air conditions and wind environment also showed a positive effect ($\beta = 0.34$, $p < 0.001$), thereby highlighting satisfaction with the physical environment, especially in open public spaces when people stay outside for longer durations in summer. Additionally, a statistically significant relationship was identified between the daylight environment and sound environment ($\beta = 0.27$, $p < 0.001$). The soundscape was positively correlated with characteristics of the physical environment, such as daylight and temperature. This result is similar to those of previous studies (Jeon et al., 2011a; Jeon et al., 2011b), stating that non-auditory factors, such as the daylight quality of the physical environment, are among the main contextual factors that affect soundscape evaluation.

4 Discussions

4.1 Effects of contextual factors on soundscape

Perceptions of urban contextual factors positively contributed to soundscape evaluations. Urban management showed the most significantly positive influence on the soundscape dimension of pleasantness. Similar to previous studies, the soundscape was related to the types, functions, neighbouring contexts of the landscape (Hong and Jeon, 2017a), and traffic (Puyana et al., 2016) which are related to various urban management policies. Natural and urban conditions positively influenced eventfulness, which is related to the material and visual design of the waterscape and the colour and cleanliness. Watts et al. (2011) discussed the influences of dirt and flowers on the reduction and improvement of tranquillity. Herranz-Pascual et al. (2017) explored waterscape influenced soundscape evaluation. These elements were both related to natural and urban conditions. Meanwhile, natural and urban conditions and urban management influenced the physical environment. Therefore, construction of a favourable physical environment is recommended, including urban planning, spatial layout, and visual qualities, similar to previous studies (Galal et al., 2020; Ng, 2009; Hao et al., 2015; La Malva et al., 2011). The physical environment, including daylight and temperature, which is one of the main non-auditory contextual factors was positively correlated with soundscape evaluation. This result corresponds to those of previous studies (Jeon et al., 2011a; Jeon et al., 2011b; Brown et al., 2011). Various components of contextual perceptions were related to sound sources; these findings can be used to improve soundscape evaluations, and develop strategies for pleasant soundscape evaluation.

Based on the proposed model of the relationships between perception of urban contextual factors and soundscape evaluations, which was obtained via SEM, soundscape design strategies for applications should be investigated. The process of soundscape planning and design should be integrated in urban design and renewal. Urban construction and urban management can be improved with the utilization of facilities and conditions, including the physical environment and visual qualities, thereby improving the soundscape in urban recreational public spaces. Moreover, natural resources in recreational areas should be conserved to enhance the ecological environment and soundscape with natural sounds.

Users can be guided and managed through designing urban spaces and providing an improved interesting and comfortable soundscape atmosphere. Sounds of human beings talking and children playing are also positively correlated with soundscape evaluations.

Therefore, an appropriate number of people can create a comfortable and lively atmosphere in a public space, especially in a recreational area with leisure and entertainment functions. Proper spatial design of an open square, such as functional zoning, positions of exit, open and closed organization, and separation of spaces can provide a rich spatial form and spatial experience. At the same time, a variety of activities can be created, such as Tai Chi, dancing, skateboarding, and so on. Various groups of people can be formed according to the type of activities they want to indulge in, to avoid a large crowd in the same place. Facilities such as seats, performances, lights, and aromatic plants would also affect people's choice of where to stay in the squares. Appropriate sound sources (such as fountains) can be added to form a masking noise and construct a pleasant and comfortable atmosphere. Thus, the vitality of open public spaces can be improved in terms of location, microclimate, and other facilities (Chen et al., 2015; Chen et al., 2020). The soundscape is an important approach to increase such attractiveness and vitality.

4.2 Effects of sound sources on contextual factors and soundscape

The sound sources differed based on the types of main activities and functions of the investigated sites. According to a previous study (Hong and Jeon, 2015), user activities, birds, and wind were the main sound sources in urban recreational spaces. Human and natural sounds in these spaces could overcome the negative effects of noise that was generated by the surroundings and influence soundscape evaluations (Szeremeta and Zannin, 2009). Therefore, human and natural sounds should be conserved suitably to create and maintain a comfortable and interesting atmosphere, especially in recreational spaces. The sounds of people talking and children playing positively related to the soundscape dimensions of interest and comfort, which is similar to a previous study of human behaviour in response to soundscape evaluation (Jo and Jeon, 2020). Human sounds, especially the sounds of other people's activities, can contribute to the social soundscape and stimulate interactions among users in a public space (Cao and Kang, 2021). According to previous studies, human sounds corresponded to a dynamic experience and increased liveliness in urban parks.

The presence of music in public spaces led to differences in soundscape evaluations, based on the adaptability of the type of spatial function, the demographic information of visitors, and stay time in the site. In this study, music related to square dancing was negatively correlated to interest and comfort in urban open public spaces. This result is similar to that of Liu et al. (2019b) who conducted their study in a historical block. It also corresponds to the result of a previous soundscape evaluation study of square dancing in a Chinese urban park (Ba et al., 2017), namely that, when there was a square dance, the acoustic comfort and pleasure would gradually decrease as the duration increased. This may be likely due to the differences in the visiting purposes of visitors and interviewees in open squares, urban parks, and renovated historical blocks. Additionally, the effect of music is related to the type and form of performance. Live music is popular in open public spaces and the type of music is less important. However, if the music is played from a loudspeaker, the influence of the type, melody, and beat of music on subjective evaluations must be considered (Yang and Kang, 2005, Suhanek et al., 2020). For example, Chinese folk songs are helpful for improving the pleasure and suppressing annoyance among the elderly (Qin et al., 2020), while young people prefer music from stores and passing cars (Yang and Kang, 2005).

Sound sources have impacts on the soundscape evaluation, and some sources are regulated by urban conditions, urban design, and management. Reasonable planning and design would preserve or create natural and ecological environment, and then produce rich sounds of natural sounds. The design of waterscape adds interactive perception of vision and hearing. In urban management, electronic sound source is also recommended to be control. For urban design and management, it affects the perception of some sound sources, and soundscape evaluation.

5 Conclusions

In this study, the relationships between contextual perceptions of urban factors and soundscape evaluations were examined, and a structural equation model of the influences of urban contextual factors on soundscape evaluation was developed, in six urban open public spaces in northern China. The following conclusions were obtained.

First, the correlations between urban contextual perceptions and soundscape evaluations were examined. Eventful, calming, interesting, and comfortable soundscapes were positively correlated to satisfaction of most urban factors in urban public spaces. Pleasantness of the soundscape had less influence on the urban contextual descriptors than other soundscape indicators.

Second, a structural equation model of the influence of urban contextual factors on soundscape evaluations was explored. Urban management and the physical environment were positively related to soundscape pleasantness. Natural and urban conditions showed positive effects on soundscape eventfulness. This study illustrated systematic factors regarding urban factors as non-acoustic indicators. It provides a better understanding of the complex roles of urban management, natural and urban conditions, and the physical environment in soundscape evaluation.

The findings demonstrated the relationships between contextual perceptions and soundscape evaluation in detail, and a structural equation model was constructed systematically. The main limitations of the measured data are the social aspects of the survey, namely that, contextual perceptions and soundscape evaluations should be considered in other cities and countries as well, based on the corresponding cultures. Additionally, the SEM model of the relationship is based on the main functions of recreation and leisure for soundscape evaluations and contextual perceptions. In other types of open public spaces with different functions, such as residential, business, and commercial areas, the main activities and purposes are different. Thus, the detailed relationships between soundscape evaluations and contextual perceptions should be verified in these contexts as well.

Acknowledgements

The research was funded by Natural Science Foundation of China (51778169), Heilongjiang Province Postdoctoral Science Foundation in China (LBH-Z17078), and European Research Council (ERC) Advanced Grant (740696). The authors are also grateful to Kristian Jambrošić for useful discussions.

References

Acun, V., & Yilmazer, S. (2019). Combining grounded theory (GT) and structural equation modelling (SEM) to analyze indoor soundscape in historical spaces. *Applied Acoustics*, *155*, 515-524. https://doi.org/10.1016/j.apacoust.2019.06.017.

Aletta, F., Kang, J., Astolfi, A., & Fuda, S. (2016a). Differences in soundscape appreciation of walking sounds from different footpath materials in urban parks. *Sustainable Cities and Society*, *27*, 367-376. https://doi.org/10.1016/j.scs.2019.101706.

Aletta, F., Kang, J., & Axelsson, Ö. (2016b). Soundscape descriptors and a conceptual framework for developing predictive soundscape models. *Landscape and Urban Planning*, *149*, 65-74. https://doi.org/10.1016/j.landurbplan.2016.02.001.

Axelsson, A., Nilsson, M. E., & Berglund, B. (2012). The Swedish soundscape-quality protocol. *Journal of the Acoustical Society of America*, *131*, 3476. https://doi.org/10.1121/1.4709112.

Axelsson, Ö. (2015). How to measure soundscape quality. In *Proceedings of the Euronoise 2015 conference*.

Axelsson, Ö., Nilsson, M.E., & Berglund, B. (2010). A principal components model of soundscape perception. *Journal of the Acoustical Society of America*, *128*, 2836-2846. https://doi.org/10.1121/1.3493436.

Ba, M., & Kang, J. (2019a). A laboratory study of the sound-odour interaction in urban environments. *Building and Environment*, *147*, 314-326. https://doi.org/10.1016/j.buildenv.2018.10.019.

Ba, M., & Kang, J. (2019b). Effect of a fragrant tree on the perception of traffic noise. *Building and Environment*, *156*, 147-155. https://doi.org/10.1016/j.buildenv.2019.04.022.

Ba, M., Zhang, X., & Kang, J. (2017). On the influence of square dance in the park on the evaluation of soundscape. *Urban Architecture*, *7*, 9-12. (In Chinese)

Botteldooren, D., Andringa, T., Aspuru, I., Brown, L., Dubois, D., Guastavino, C., Lavandier, C., Nilsson, M., & Preis, A. (2013). Soundscape for European cities and landscape: understanding and exchanging. In *COST TD0804 Final conference: Soundscape of European cities and landscapes*.

Brown, A. L., Kang, J., & Gjestland, T. (2011). Towards standardization in soundscape preference assessment. *Applied Acoustics*, *72*, 387-392. https://doi.org/10.1016/j.apacoust.2011.01.001.

Cao, J., & Kang, J. (2021). The influence of companion factors on soundscape evaluations in urban public spaces. *Sustainable Cities and Society*, *69*, 102860. https://doi.org/10.1016/j.scs.2021.102860.

Chan, S. Y., Chau, C. K., & Leung, T. M. (2017). On the study of thermal comfort and perceptions of environmental features in urban parks: A structural equation modeling approach. *Building and Environment*, *122*, 171-183. http://dx.doi.org/10.1016/j.buildenv.2017.06.014.

Chan, Y. N., Choy, Y. S., To, W. M., & Lai, T. M. (2021). Influence of classroom soundscape on learning attitude. *International Journal of Instruction*, *14*(3), 341-358.

Chen, F., Lin, J., & Zhu, X. (2015). Landscape activity evaluation of elders in winter city base on the methods of EAPRS and NGST. *Chinese Landscape Architecture*, *31*, 100-104. (In Chinese)

Chen, F., Zhu, X., & Zhang, A. (2020). The construction and comparative analysis of landscape vitality evaluation model of different public space in winter city. *Chinese Landscape Architecture, 36*, 92-96. (In Chinese)

Deng, L., Kang, J., Zhao, W., & Jambrošić, K. (2020). Cross-national comparison of soundscape in urban public open spaces between China and Croatia. *Applied Sciences*, *10*, 960. https://doi.org/10.3390/app10030960.

Galal, O. M., Sailor, D. J., & Mahmoud, H. (2020). The impact of urban form on outdoor thermal comfort in hot arid environments during daylight hours, case study: New Aswan. *Building and Environment*, *184*, 107222. https://doi.org/10.1016/j.buildenv.2020.107222.

Gozalo, G. R., Morillas, J. M. B., González, D. M., & Moraga, P. A. (2018). Relationships among satisfaction, noise perception, and use of urban green spaces. *Science of the Total Environment*, *624*, 438-450. https://doi.org/10.1016/j.scitotenv.2017.12.148.

Guastavino, C. (2006). The ideal urban soundscape: investigating the sound quality of French cities. *Acta Acustica United with Acustica*, *92*, 945-951.

Hair, J., Black, W., Babin, B. J., & Anderson, R. (2009). *Multivariate Data Analysis* (7th ed.). Englewood Cliffs: Prentice Hall.

Hao, Y. Y., Kang, J., & Krijnders, J. D. (2015). Integrated effects of urban morphology on birdsong loudness and visibility of green areas. *Landscape and Urban Planning*, *137*, 149-162. https://doi.org/10.1016/j.landurbplan.2015.01.006.

Herranz-Pascual, K., Aspuru, I., & García, I. (2010). Proposed conceptual model of environmental experience as framework to study the soundscape. In *Proceedings of INTERNOISE 2010*.

Herranz-Pascual, K., García, I., Diez, I., & Santander, A. (2017). Analysis of field data to describe the effect of context (acoustic and non-acoustic factors) on urban soundscapes. *Applied Sciences*, *7*(2), 173. https://doi.org/10.3390/app7020173.

Hong, J. Y., & Jeon, J. Y. (2015). Influence of urban contexts on soundscape perceptions: A structural equation modeling approach. *Landscape and Urban Planning*, *141*, 78-87. https://doi.org/10.1016/j.landurbplan.2015.05.004.

Hong, J. Y., & Jeon, J. Y. (2017a). Exploring spatial relationships among soundscape variables in urban areas: A spatial statistical modelling approach. *Landscape and Urban Planning*, *157*, 352-364. https://doi.org/10.1016/j.landurbplan.2016.08.006.

Hong, J. Y., & Jeon, J. Y. (2017b). Relationship between spatiotemporal variability of soundscape and urban morphology in a multifunctional urban area: A case study in Seoul, Korea. *Building and Environment*, *126*, 382-395. https://doi.org/10.1016/j.buildenv.2017.10.021.

Hong, J. Y., Lam., B, Ong, Z. T., Ooi, K., Gan, W. S., Kang, J., Yeong, S., Lee, I., & Tan, S. T.

(2020). Effects of contexts in urban residential areas on the pleasantness and appropriateness of natural sounds. *Sustainable Cities and Society*, *63*, 102475. https://doi.org/10.1016/j.scs.2020.102475.

Hong, X., Wang, G., Liu, J., & Lan, S. (2019). Cognitive persistence of soundscape in urban parks. *Sustainable Cities and Society*, *51*, 101706. https://doi.org/10.1016/j.scs.2019.101706.

International Organization for Standardization. (2014). *ISO 12913-1:2014 acoustics - soundscape - part 1: definition and conceptual framework*. Geneve: ISO.

International Organization for Standardization. (2018). *ISO/TS 12913-2:2018 acoustics -soundscape - part 2: data collection and reporting requirement*. Geneve: ISO.

Jambrošić, K., Horvat, M., & Domitrović, H. (2013). Assessment of urban soundscapes with the focus on an architectural installation with musical features. *Journal of the Acoustical Society of America*, *134*, 869-879. https://doi.org/10.1121/1.4807805.

Jeon, J. Y., & Hong, J. Y. (2015). Classification of urban park soundscapes through perceptions of the acoustical environments. *Landscape and Urban Planning*, *141*, 100-111. https://doi.org/10.1016/j.landurbplan.2015.05.005.

Jeon, J. Y., Hwang, I. H., & Hong, J. Y. (2014). Soundscape evaluation in a Catholic cathedral and Buddhist temple precincts through social surveys and soundwalks. *Journal of the Acoustical Society of America*, *135*, 1863-1874. https://doi.org/10.1121/1.4866239.

Jeon, J. Y., Lee, P. J., & Hong, J. Y. (2011a). Effects of contexts on perception of urban soundscape. *Journal of the Acoustical Society of America*, *129*, 2570. https://doi.org/10.1121/1.3588481.

Jeon, J. Y., Lee, P. J., Hong, J. Y., & Cabrera, D. (2011b). Non-auditory factors affecting urban soundscape evaluation. *Journal of the Acoustical Society of America*, *130*, 3761. https://doi.org/10.1121/1.3652902.

Jiang, L., Masullo, M., & Maffei, L. (2016). Effect of odour on multisensory environmental evaluations of road traffic. *Environmental Impact Assessment Review*, *60*, 126-133. https://doi.org/10.1016/j.eiar.2016.03.002.

Jo, H. I., & Jeon, J. Y. (2020). The influence of human behavioral characteristics on soundscape perception in urban parks: Subjective and observational approaches. *Landscape and Urban Planning*, *203,* 103890. https://doi.org/10.1016/j.landurbplan.2020.103890.

Kang, J. (2006). *Urban Sound Environment*. London: CRC Press.

Kang, J., & Zhang, M. (2010). Semantic differential analysis of the soundscape in urban open public spaces. *Building and Environment*, *45*, 150-157. https://doi.org/10.1016/j.buildenv.2009.05.014.

La Malva, F., Astolfi, A., Bottalico, P., & Valerio, R. M. (2011). City's quality of life based on livingscape approach (urban blight, soundscape, light-scape, thermic-scape, subjective replies of users) to improve an urban historical place. In *Proceedings of Forum Acusticum 2011 conference*.

Li, H., & Lau, S. K. (2020). A review of audio-visual interaction on soundscape assessment in urban built environments. *Applied Acoustics*, *166*, 107372. https://doi.org/10.1016/j.apacoust.2020.107372.

Li, Z., Han, X., Lin, X., & Lu, X. (2021). Quantitative analysis of landscape efficacy based on structural equation modelling: Empirical evidence from new Chinese style commercial streets. *Alexandria Engineering Journal*, *60*, 261-271. https://doi.org/10.1016/j.aej.2020.08.005.

Liu, J., Wang, Y., Zimmer, C., Kang, J., & Yu, T. (2019a). Factors associated with soundscape experiences in urban green spaces: A case study in Rostock, Germany. *Urban Forestry and Urban Planning*, *37*, 135-146. https://doi.org/10.1016/j.ufug.2017.11.003.

Liu, J., Yang, L., Xiong, Y., & Yang, Y. (2019b). Effects of soundscape perception on visiting experience in a renovated historical block. *Building and Environment*, *165*, 106375.

https://doi.org/10.1016/j.buildenv.2019.106375.

Liu, X., & Wang, Y. (2016). Reliability and validity of the individual authenticity measure at work for Chinese employees. *Chinese Journal of Clinical Psychology*, *124*, 454-458. (In Chinese)

Margaritis, E., Kang, J., Aletta, F., & Axelsson, Ö. (2020). On the relationship between land use and sound sources in the urban environment. *Journal of Urban Design*, *25*, 629-645. https://doi.org/10.1080/13574809.2020.1730691.

Meng, Q., Sun, Y., & Kang, J. (2017). Effect of temporary open-air markets on the sound environment and acoustic perception based on the crowd density characteristics. *Science of the Total Environment*, *601*, 1488-1495. https://doi.org/10.1016/j.scitotenv.2017.06.017.

McDonald, R. P., & Ho, M. R. (2002). Principles and practice in reporting structural equation analysis. *Psychological Methods*, *7*, 64-82.

Münzel, T., Sørensen, M., Schmidt, F., Schmidt, E., Steven, S., Kröller-Schön, S., & Daiber, A. (2018). The adverse effects of environmental noise exposure on oxidative stress and cardiovascular risk. *Antioxidants and Redox Signaling*, *28*(9), 873-908. https://doi.org/10.1089/ars.2017.7118.

Newport, J., Shorthouse, D. J., & Manning, A. D. (2014). The effects of light and noise from urban development on biodiversity: Implications for protected areas in Australia. *Ecological Management and Restoration*, *15*(3), 204-214. https://doi.org/10.1111/emr.12120.

Ng, E. (2009). Policies and technical guidelines for urban planning of high-density cities-air ventilation assessment (AVA) of Hong Kong. *Building and Environment*, *44*, 1478-1488. https://doi.org/10.1016/j.buildenv.2008.06.013.

Nilsson, M. E., & Berglund, B. (2006). Soundscape quality in suburban green areas and city parks. *Acta Acustica United with Acustica*, 92, 903-911.

Payne, S. R. (2013). The production of a perceived restorativeness soundscape scale. *Applied Acoustics*, *74*, 255-263. https://doi.org/10.1016/j.apacoust.2011.11.005.

Pérez-Martínez, G., Torija, A. J., & Ruiz, D. P. (2018). Soundscape assessment of a monumental place: A methodology based on the perception of dominant sounds. *Landscape and Urban Planning*, *169*, 12-21. https://doi.org/10.1016/j.landurbplan.2017.07.022.

Pheasant, R., Horoshenkov, K., & Watts, G. (2008). The acoustic and visual factors influencing the construction of tranquil space in urban and rural environments tranquil spaces-quiet places?. *Journal of the Acoustical Society of America*, *123*, 1446-1457. https://doi.org/10.1121/1.2831735.

Pheasant, R. J., Fisher, M. N., Watts, G. R., Whitaker, D. J., & Horoshenkov, K. V. (2010). The importance of auditory-visual interaction in the construction of 'tranquil space'. *Journal of Environmental Psychology*, *30*, 501-509. https://doi.org/10.1016/j.jenvp.2010.03.006.

Puyana Romero, V., Maffei, L., Brambilla, G., & Ciaburro, G. (2016). Modelling the soundscape quality of urban waterfronts by artificial neural networks. *Applied Acoustics*, *111*, 121-128. https://doi.org/10.1016/j.apacoust.2016.04.019.

Qin, Y., Zhao, W., & Kang, J. (2020). Effects of background sound sources types on emotion and activities in activity spaces of elderly care facilities. *Journal of Human Settlements in West China*, *35*, 43-49. (In Chinese)

Ren, X., & Kang, J. (2015). Effects of the visual landscape factors of an ecological waterscape on acoustic comfort. *Applied Acoustics*, *96*, 171-179. https://doi.org/10.1016/j.apacoust.2015.03.007.

Sanchez, G. M. E., Van Renterghem, T., Sun, K., De Coensel, B., & Botteldooren, D. (2017). Using virtual reality for assessing the role of noise in the audio-visual design of an urban public space. *Landscape and Urban Planning*, *167*, 98-107. https://doi.org/10.1016/j.landurbplan.2017.05.018.

Schulte-Fortkamp, B., & Fiebig, A. (2006). Soundscape analysis in a residential area: An evaluation of noise and people's mind. *Acta Acustica United with Acustica*, *92*, 875-880.

Schulte-Fortkamp, B., Volz, R., & Jakob, A. (2008). Using the soundscape approach to develop a public space in Berlin - perception and evaluation. *Journal of the Acoustical Society of America*, *123*, 3808. https://doi.org/10.1121/1.2935519.

Suhanek, M., Djurek, I., Grubea, S., & Petosi, A. (2020). Classification of music artwork using the subjective emotional criterion for implementation in soundscape synthesis. In *Proceedings of the Forum Acusticum 2020*.

Szeremeta, B., & Zannin, P. H. T. (2009). Analysis and evaluation of soundscapes in public parks through interviews and measurement of noise. *Science of the Total Environment*, *407*, 6143-6149. https://doi.org/10.1016/j.scitotenv.2009.08.039.

Tarlao, C., Steffens, J., & Guastavino, C. (2021). Investigating contextual influences on urban soundscape evaluations with structural equation modeling. *Building and Environment*, *188*, 107490. https://doi.org/10.1016/j.buildenv.2020.107490.

Watts, G. R., Pheasant, R. J., & Horoshenkov, K. V. (2011). Predicting perceived tranquillity in urban parks and open spaces. *Environment and Planning B: Planning and Design*, *38*, 585-594. https://doi.org/10.1068/b36131.

Wu, M. (2010). *Structural equation model: Operation and application of AMOS* (2nd ed). Chongqing: Chongqing University Press.

Xue, W. (2017). *Statistical analysis and application of SPSS* (5th ed). Beijing: China People's University Press.

Yang, W., & Kang, J. (2005). Soundscape and sound preferences in urban squares: a case study in Sheffield. *Journal of Urban Design*, *10*, 61-80. https://doi.org/10.1080/13574800500062395.

Yildiz, S., Kivrak, S., Gültekin, A. B., & Arslan, G. (2020). Built environment design-social sustainability relation in urban renewal. *Sustainable Cities and Society*, *60*, 102173. https://doi.org/10.1016/j.scs.2020.102173.

Yu, C. J. (2008). *Environmentally sustainable acoustics in urban residential areas*. Sheffield: University of Sheffield.

Yu, L., & Kang, J. (2009). Modeling subjective evaluation of soundscape quality in urban open spaces: An artificial neural network approach. *Journal of the Acoustical Society of America*, *126*, 1163-1174. https://doi.org/10.1121/1.3183377.

Yu, L., Kang, J., & Liu, H. (2014). A Study on the influence of urban design elements on soundscape: A case of Shenzhen Dongmen culture. *New Architecture*, (10), 65-67. (In Chinese)

Yuan, M., Yin, C., Sun, Y., & Chen, W. (2019). Examining the associations between urban built environment and noise pollution in high-density high-rise urban areas: A case study in Wuhan, China. *Sustainable Cities and Society*, *50*, 101678. https://doi.org/10.1016/j.scs.2019.101678.

Zhao, X., Zhang, S., Meng, Q., & Kang, J. (2018). Influence of contextual factors on soundscape in urban open spaces. *Applied Sciences*, *8*, 2524. https://doi.org/10.3390/app8122524.