PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Investigation on the restorative effect of soundscape in parks in high-density cities

——Taking Lu Xun Park, Shenyang, China as an example

Ruining Zhang[1]; Ling Zhu[1]; Yuan Zhang[2*]

[1]School of Architecture and Urban Planning, Shenyang Jianzhu University, China

[2]School of Architecture and Urban Planning, Shenyang Jianzhu University, Eco-Building Physics Technology and Evaluation Provincial Key Lab, China

ABSTRACT

Urban parks, in addition to providing a rest space for urban residents, also provide a restorative environment for relieving stress and relaxing. As the main environmental factor, soundscape affects environmental restorative quality. Small parks in high-density cities have special soundscape characteristics due to their crowded population. This paper selected a small city park in the central area of a city ---- Lu Xun Park （4,3000 ㎡） and conducted soundscape study, including sound pressure level measurement, acoustic event recording, restorative effect evaluation and tourist questionnaire; ArcGIS was used for interpolation analysis and spatial analysis, and a soundscape map was constracted to explore the effects of soundscape on restorative effects.

The results showed that:①L_{Aeq} within the park ranged from: 44.5 dB(A) to 73.8dB(A), and exhibited obvious patterns in time and space;②Sound composition included rich citizen activity sounds, natural sounds and surrounding road traffic sound. There are characteristic differences between these acoustic events in terms of significance and range of transmission, etc;③Sound pressure level, acoustic event composition and landscape features combined affect the soundscape restorative quality of different patches.

Keywords: small parks, soundscape restoration, soundscape map

1. INTRODUCTION

The typical characteristics of today's high-density urban life are excessive stimulation, accelerated rhythm, increased pressure on social competition, and increased adverse emotions, which are likely to cause a variety of mental illnesses such as depression (1). In some environments, it can help people reduce stress and various related negative emotions, reduce mental fatigue and even promote mental and physical health. This environment is called a “restorative environment” (2). The concept of “restorative environment” was first proposed by Kaplan and Talbot (1983), professors of the University of Michigan in the United States. They studied the psychological impact of two weeks of life away from city and found that it had a restorative function for most people. Kaplan proposes the concept of “restorative environment” and defines it as an environment that enables people to better recover from mental fatigue and negative emotions associated with stress (3).

Based on the characters of urban human settlements in China, the national standard “Park Design Specification GB51192” defined a park as: “A park is for public visits, viewing, rest, scientific culture and physical exercise, with completed facilities and green environment" (4). Urban parks dominated by the natural environment, especially those close to people's residences, in addition to the need to assume general functions, also have important significance for the provision of restorative benefits (5).

In 2014, the International Organization for Standardization (ISO) defined Soundscape as acoustic environment as perceived or experienced and/or understood by a person or people, in context (6). The promotion or hindrance of environment restoration quality are called "soundscape restoration

[2*] jzdxzhy@163.com

benefits" (7).

This paper selected Lu Xun Park, a small high-density urban park in Shenyang. The surrounding residential areas are dense, and three sides of it are adjacent to the urban roads. The natural landscape inside the park is abundant, and various acoustic events occur regularly, giving an abundant soundscape. Through the investigation and comparison of L_{Aeq} in different periods, this paper analysed acoustic environment quality, and classified typical acoustic events. Typical acoustic events were selected and their impact area were recorded. These were used to analyse the restorative quality of landscape patches.

2. MATERIALS and METHODS

2.1 Analysis of Space and Environment in Shenyang Lu Xun Park

Lu Xun Park is located at No.6, West Binhe Road, South of Heping District, Shenyang City, Liaoning Province. The park covers an area of 43,000 ㎡ and has a water surface area of 4,390 ㎡. It is a small urban park. The park is surrounded by walls and has an artificial lake, fitness equipments, and a hill. The park is adjacent to the South Canal in the south, the old-fashioned residential quarter in the west, Shenyang Radio and Television University and Luyuan Community in the north, and Luyuan Community in the east, as shown in figure 1.

Figure 1 – Lu Xun Park Plan Analysis

2.2 Soundscape survey and soundscape map

The on-site investigation was divided into two parts, namely L_{Aeq} measurement and acoustic event recording. The park was divided into 15m*15m grids. A convenient measurement point was selected as a measuring point at the centre of each grid, with a total of 139 effective measuring points. On a typical working day (May 6, 2019), data were collected in the morning, midday and evening. The surrounding road traffic conditions and crowd characteristics in the park are shown in Table 1. 8 pre-trained surveyors started simultaneous measurement from the starting grid at each same time period according to a preset walking route, and ensured that all the grids in the responsible area were measured within 30 minutes. The measurement content at each grid point includes ①1min L_{Aeq} data (Secondary Sound Level Meter); ②geographic coordinates of the measurement point (Omap APP); ③the measurement point acoustic event significant order (acoustic event significant quantity table).ArcGIS interpolation analysis(9) was used to analyse the collected data and to construct a soundscape map.

Table 1 - Analysis of measurement period characteristics

Period	Time	Traffic conditions	Crowd characteristics	Activity characteristics
Morning	7:30-8:00	Early peak	Mainly middle-aged	Abundant exercise
Midday	11:30-12:00	platykurtic	Mainly middle-aged and a few young children	Many recreational activities
Evening	18:00-18:30	Late peak	Mainly middle-aged and a few children	More fitness activities

2.3 Soundscape walk and subjective evaluation

The soundscape walk is a way for the listener to feel the soundscape positively and comprehensively, namely, listen to the soundscape of each area slowly along an established route [8]. According to the landscape features, the park was divided into 7 landscape patches. 8 surveyors with a background in relevant professions (Architecture: 4, Landscape: 4) (Shenyang Jianzhu University, China) were divided into 4 groups each with one male and one female to avoid gender bias. 4 groups of surveyors took a soundscape walk in the park and performed a soundscape experience and restorative evaluation. In order to avoid sequence effect, the four groups of surveyors used different walking routes, two of which started from the south gate, and the other two groups started from the north of the park, and from each gate circled the park clockwise and anticlockwise.

Within each patch, each surveyor recorded the subjective perception of the soundscape, including "relaxing feeling", "beautiful experience", "exploratory of connotation" and "immersion". The specific semantic description is shown in Table 2 (8). All the above indicators used the 5-level semantic difference scale, and the average score of the four dimensions had been used as an indicator to characterise the restoration quality of the patch.

Table 2 - Soundscape Restoration Rating Scale

Restorative feeling of soundscape	Semantic description	Rating level
Relaxing feeling	Relaxed - nervous, gentle - stimulating	very strong, strong, average, weak, very weak
Beautiful experience	Beautiful - ugly, like - hate	
Exploratory of connotation	Interesting - boring, positive - negative	
Immersion	Pleasure - trouble, comfort - uncomfortable	

3. RESULTS

3.1 L_{Aeq}, acoustic events distribution and soundscape map

3.1.1 L_{Aeq} and distribution

The latitude and longitude of the 139 measuring points and the L_{Aeq} of the three periods were imported into ArcGIS, and the typical working day L_{Aeq} distribution mapping was obtained by Inverse Distance Way (9), as shown in figure 2.

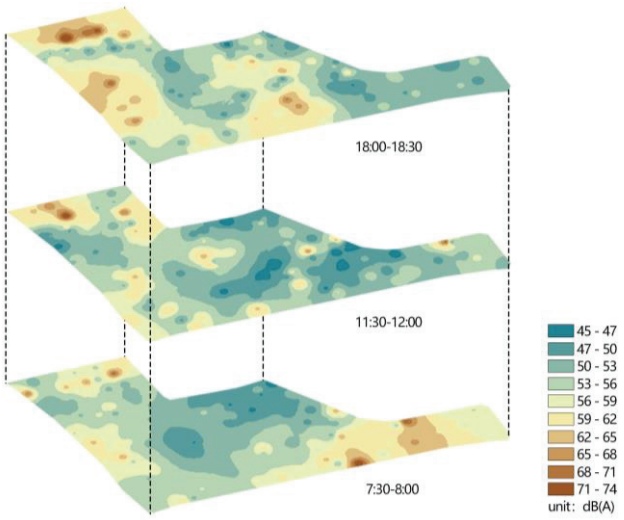

Figure 2 – Typical working day L_{Aeq} distribution

It can be seen from the figure that the overall L_{Aeq} in the park is large and the sound environment is noisy. It is 45.3-73.7dB(A), 45.3-72.8 dB(A) and 45.9-73.8 dB (A) in the morning, midday and evening respectively; through variance analysis, the L_{Aeq} difference between morning and midday was deemed significant ($0.01<P=0.021<0.05$), and the difference in L_{Aeq} between morning and evening was also significant ($0.01<P=0.034<0.05$).There are also differences in the distribution of L_{Aeq} at different spatial locations in the same period.

Morning is the noisiest period of the day. L_{Aeq} in more than 52.5% area exceeded the 55 dB(A) (10) specified by the acoustic environmental quality standard. At this time, the park was greatly affected by the early peak traffic of the external roads and, morning exercise. There were many types of activities in the park and the active population was dense, which made the L_{Aeq} in the morning park high. The areas with higher L_{Aeq} were mainly distributed on the north and southeast sides of the park. The squares on the north side of the park were larger, and the activities of the crowds were more abundant, such as fan dance and square dance. Although the vegetation on the southeast side was dense, there was a typical acoustic event, playing the flute, which had strong penetrating power and a large influence range, giving rise to a relatively high L_{Aeq}.

The overall L_{Aeq} in the midday was low, and the area with L_{Aeq} exceeding 55 dB(A) accounted for 36% of the total area. During this period, there were fewer traffic outside the park, and the traffic noise inside the park was not obvious. Natural sound perception was more obvious. At this time, the number of people in the park was the lowest. The crowd activities were mainly leisure and recreational, but there were also a small number of other activities, such as playing saxophone, chorus, etc. The areas with higher L_{Aeq} were mainly distributed in the hard square on the north side of the park, where crowds were more concentrated.

The overall L_{Aeq} in the evening was slightly higher than that in the midday, slightly lower than the morning, and the area with the L_{Aeq} exceeding 55 dB(A) was 43.9%. Due to the late peak, the traffic was loud and the natural sound was reduced. At this time, the park mainly focused on fitness and leisure activities, such as square dance. The areas with higher L_{Aeq} are mainly distributed on the north, west and south sides of the park with a large square. The L_{Aeq} of the activity square on the north side was the highest in the whole day, which peaked at 73.8 dB(A).

From the spatial distribution difference of the park L_{Aeq}, it can be seen that there are large differences in different spaces. There is a large square on the north side of the park, which is the main activity area for tourists, and the crowd activities were concentrated, so the L_{Aeq} is larger; the west side square has more fitness equipment, the crowd is mostly fitness activities, L_{Aeq} is lower than the square; The south side of the park is adjacent to the city's secondary trunk road, which was seriously affected by traffic noise, and the L_{Aeq} is larger.; the east side of the park is abundant in vegetation, with not much open space, the crowds have less concentrated activities, and the L_{Aeq} is lower.

3.1.2 Acoustic events and distribution

A total of 18 acoustic events were recorded in the three periods, which were classified according to the type of sound source, as shown in Table 3. Among them, natural sounds included birdcall, wind blowing leaves, and wind; traffic sounds included external traffic, bicycle ringtone, the two together constituted the park background sound; the active sounds are from abundant citizens' leisure and fitness activities and included acoustic instruments sound, equipment sound, and human sound constitute the foreground sound of the park.

Table – 3 classification of park sound events

Sound category		Specific acoustic event sound
Natural sound		Birdcall, wind blowing leaves, wind
Traffic sound		External traffic, bicycle ringtone
	Instrument sound	saxophone, erhu, flute
Active sound	Equipment sound	Table tennis, bounce ball, radio, square dance, fan dance
	human sound	Conversation, children's play, exercise, fit walking, chorus

According to the saliency degree of the acoustic events recorded by the surveyor, the traffic sound, natural sound, and the active sound are assigned 5-0 respectively, wherein 5, 4, 3, 2, 1 and 0 are very significant, relatively significant, general, relatively slight respectively, very slight and almost inaudible.

Using ArcGIS, soundscape map was constructed by the method of Kriging interpolation, as shown in Figure 3. The traffic sound, active sound, and natural sound are represented by red, yellow and blue. After superimposition different colors appear, which can express the different types of sound composition and its significance in the park (11).

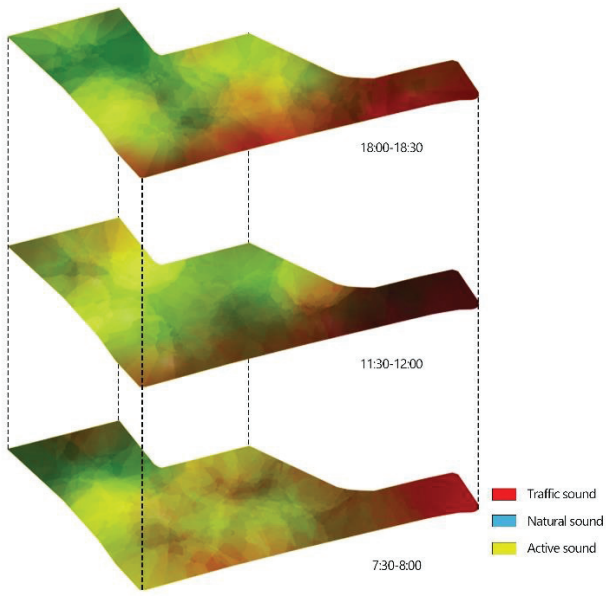

Figure 3 – Acoustic event distribution map

It can be seen from the figure that there is a large difference in the distribution of sounds in different time periods at the same space; the distribution of sounds between different spaces at the same period also had a large difference. From the distribution in time it can be seen that, the morning period was the early traffic peak and crowd fitness period. The sound of the park was mainly active sound. Traffic sound was more significant, mainly distributed in the southeast side of the park adjacent to the urban road, and the natural sound was mainly distributed in the north side of the park, occupying less area; in the midday the park was quieter, active sounds becomes weaker, while natural sound was strengthened and mainly distributed in the dense vegetation area on the east side of the park. At this time, the traffic sound of the park was mainly distributed in the south side of the park adjacent to the urban road. In the evening, there was a late traffic peak, and the active sound was higher than that in the midday. The traffic sound was more prominent, and it is distributed on the south side of the park near the urban road.

From the spatial distribution it can be seen that the park was abundant in activities throughout the day, and the active sound was more obvious, distributed throughout the park; the number of birds in the park was large, and natural sound was mainly concentrated in plant-intensive places, such as the east side of the park; There were urban roads adjacent to three sides of the park, but there were walls surrounding the park, making traffic sound not as obvious, mainly distributed on the south side of the park, close to the urban roads.

3.2 Typical acoustic event perception saliency and impact surface analysis

3.2.1 Significance analysis of acoustic event perception

There are abundant active sounds in the park, as well as natural sounds and traffic sounds. The three types of sounds together constitute the acoustic environment of the park. The 18 acoustic events recorded by the surveyors are classified into 5-1 grades according to sound saliency, as shown in Table 4.

Table 4 – Significant analysis of acoustic events

Significant level classification	Acoustic event
5 level	External traffic, conversation, flute, saxophone, square dance, fan dance
4 level	Birdcall, chorus, Erhu
3 level	Bicycle ringtone, radio sound, children's play
2 level	Table tennis, wind, and bounce ball
1 level	Fit walking, wind blowing leaves

3.2.2 Typical acoustic event impact surface analysis

Different sounds have different salience and range of influence, and different impact surfaces. According to the saliency ordering of acoustic events, the acoustic events with strong saliency, wide transmission range, and clear vocalisation points were selected as typical acoustic events, and impact surface analysis was performed, as shown in Figure 4.

Figure 4 – Typical acoustic event influence surface and sound source point L_{Aeq}

It can be seen from the figure that the typical acoustic event is divided into 4 categories: ① concentrated sounds but widespread, such as playing the flute and the saxophone; ②concentrated sounding and narrow transmission range, such as fan dance, table tennis, chorus; ③scattered sounds but widespread such as square dance, exercise; ④scattered sounds and spread a narrow range, such as children's play.

Playing the flute occured in the south side of the woods in the early morning period. Although there were more trees in the surrounding area, due to less activity under the forest and the flute sound being sharper, the propagation range was wider, and the L_{Aeq} of the sound source point was 66 dB(A). Playing the saxophone occurs near the pavilion in the middle of the park. The surrounding activities were less, the environment was wider, the sound spread was wider, and the L_{Aeq} of the sound source point was 60.5 dB(A).

Fan dance occured on the west side of the artificial lake. The area is relatively open, and the water surface absorbs sound strongly. Therefore, the sound had obvious debilitation in the direction of the artificial lake on the east side of the sound source point. The L_{Aeq} of the sound source point is 57.8 dB(A). The table tennis activity took place in the square on the west side of the park. Due to the enclosure of the west side wall, the sound weakness was less obvious on the west side of the sound source point, and it was more obvious because of the water surface on the east side. The L_{Aeq} of the sound source point was 54.8 dB(A). On the west side of the chorus was a small mountain with a height of five metres. The east side was a park wall and the south side was the entrance square. The sound shows a relatively weak performance in the direction of the wall. The L_{Aeq} of the sound source point was 71.9 dB(A).

Square dance was mainly distributed in the square on the north side and the south side. The active music sounds loud, the range of propagation and interference was large, and the influence surface was large. The L_{Aeq} of the three sound source points was 73.8/63/60.5 dB(A) respectively. The exercise activities were mainly distributed in the squares on the north side and the west side. The sound spread narrow and rapidly attenuated to the periphery. The L_{Aeq} of the two sound source points was 69.5/56.7 dB(A) respectively.

Children's playing sounds had multiple sound source points, mainly distributed in the squares and the artificial lake around the north. The L_{Aeq} of the two sound source points were 48.7/48.4 dB(A) respectively.

3.3 Landscape patch soundscape recovery experience

The scores of the subjective perceptual experience of the soundscapes were tested by Kendall's Harmony Coefficient. The Kendall's harmony coefficient W^a=0.317, X^2 = 68.472, and the significance

test for X^2 is 0.00<0.001. It reached a very significant level, and this shows that the 8 reviewers had a high level of consistency, so the average of the 8 reviewers' scores can be used as the score for the restoration quality of each landscape patch; the scores of the subjective perception of the soundscape were then sorted, and the total mean of the restoration quality of each landscape patch was obtained, as shown in Figure 5. The L_{Aeq} mean and variance of each landscape patch in the corresponding period of subjective evaluation were calculated, as shown in Table 5.

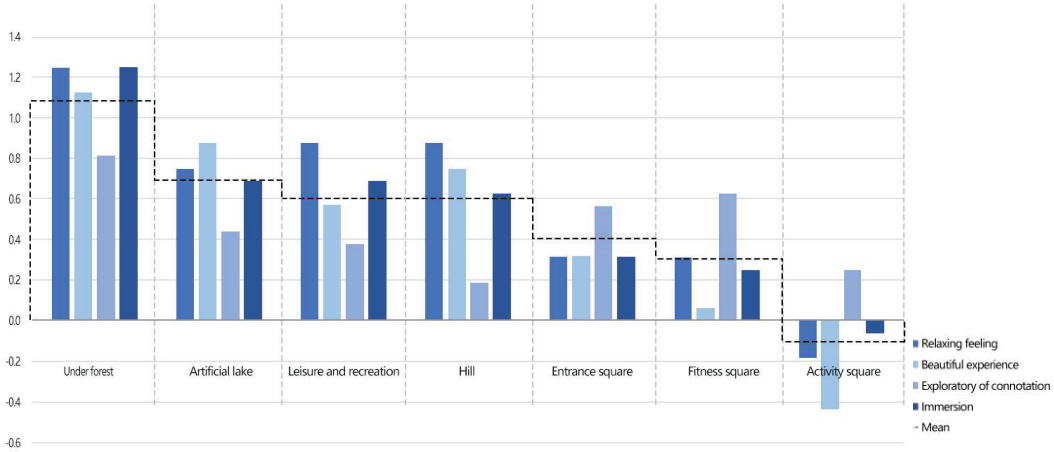

Figure 5 – Soundscape Restoration Quality Score and Total Mean

Table 5 – L_{Aeq} mean and variance of each plaque

Patch	Under forest	Artificial lake	Leisure and recreation	Hill	Entrance square	Fitness square	Activity square
mean L_{Aeq} (dB(A))	50.9	53.2	50.5	52	53.3	53.6	60.4
Variance	77.6	11.5	5.9	13.9	70.4	7.5	96.5

It can be seen from the figure that the total mean of the soundscape restorative quality in the patch of under forest is the highest, the total mean of the artificial water patch, the leisure and recreation area and the hill area is higher, the entrance square and the fitness square, which were in turn higher than that of the activity square is the lowest.

The under forest area was densely vegetated, with beautiful scenery, abundant natural sounds, a small number of square, and a few crowded activities. The two dimensions of “relaxing feeling” and “immersion” were higher. Although the L_{Aeq} mean was low and the overall environment was quiet, the patch had typical acoustic events concentrated in the source points, such as the flute, so the L_{Aeq} distribution was not uniform and the variance was large.

The artificial lake had less greening, less natural sound, more open water surface and no waterside activity, so it had lower exploratory. However, due to the hydrophilicity of humans, the score was higher in the dimension of “beautiful experience”. The L_{Aeq} mean was higher and the variance was lower, indicating that the patch was relatively open, lack of occlusion of sound propagation, and L_{Aeq} distribution was uniform. The leisure recreation had a high vegetation coverage rate, and the natural sound was more obvious. It mainly included activities such as fit walking with less interference, and the area was far away from the street, and was less affected by traffic sounds. The “relaxation feeling” dimension was higher. The L_{Aeq} mean and variance were both low, indicating that the L_{Aeq} was overall low and evenly distributed. There was a large height difference in the hill, and there was a large occlusion in the sound transmission. However, the view of the top of the hill was wide and the scenery is beautiful. The entire park can be seen. The “relaxation feeling” dimension was high, the L_{Aeq} mean and the variance was low, indicating that the patch was relatively quiet.

The entrance square had low vegetation coverage, low natural sound, and there were large squares in the patch, which carried more crowd activities, such as fitness, square dance, crowd conversations. The patch was located near urban roads. The traffic sound was loud and the L_{Aeq} mean was high, but the activity of the patch was more concentrated, and there was an entrance wall, so the variance was

large. The fitness square has few plants, and there are many fitness activities, which gave people a positive feeling. Therefore, the "exploratory of connotation" was higher, but the sports equipment was densely distributed, the crowd activities were concentrated, and the patch lacked occlusion. Therefore, the L_{Aeq} mean was higher and the variance was smaller.

There was little greening in the activity square area, the plant absorbed soundless, so the natural sound was lower, the patch had a large square, public activities were more abundant, the sound was noisier, and the was affected by surrounding traffic sound. The L_{Aeq} mean and variance were the largest. It showed that due to the concentrated activities in the region, the sound attenuation to the periphery was weak, and a variety of sounds intertwined.

4. CONCLUSION

According to the statistical results of the data, it can be seen that the L_{Aeq} of the park has different distributions in time and space. Different acoustic events have different influence surfaces. L_{Aeq}, acoustic events and landscape features affect the restoration quality of the soundscape:

① The L_{Aeq} distribution in the park was 44.5-73.8dB(A), in which L_{Aeq} was the highest in the morning, lowest midday, and medium in the evening, and was higher on the north side of the park. The L_{Aeq} of the central east part was significantly lower than rest of the park. L_{Aeq} distribution in the park was not uniform;

② The sound composition of the park included abundant citizen's activities, natural sounds and surrounding road traffic sounds. The analysis of typical acoustic events revealed that different acoustic events had characteristic differences in significance and influence surface;

③ According to the restoration quality scores of the landscape patches the L_{Aeq} mean, and L_{Aeq}, acoustic event composition and landscape features of the seven patches were different, which affected the soundscape restorative quality.

ACKNOWLEDGEMENTS

Thanks for the financial support from the Liaoning Province Archives Science and Technology Project Funding, China (Contract No. L-2018-X-11)

REFERENCES

1. Kaplan R, Kaplan S. Tl1e Experience of Nature: A Psycholog1cal Perspective. New York: Cambridge University Press, 1989.
2. Kaplan S. The Urban Forest as a Source of Psychological Well-Being. In: Bradley GA(ed.). Urban Forest Landscapes: Integrating Mult1d1sc1pl1nary Perspectives. Seattle: University of Washington Press, 1995. p.100-108.
3. Kaplan S. A Model of Person-Environment Compatibility. Environment and Behavior, 1983(1): p. 311-332.
4. GB51192-2016, Park Design Specification.
5. Wilkie S, Clouston L. Environment preference and environment type congruence: Effects on perceived restoration potential and restoration outcomes. Urban Forestry & Urban Greening, 2015, 14(2): p.368-376.
6. International organization for standardization.(2014).ISO 12913-1: acoustics soundscape part1: definition and conceptual framework.
7. Analysis of City Park Soundscape on the Time Dimension. Architecture and Culture, 2016(9).
8. Zhang Yuan. Study on the recovery benefit of soundscape and the improvement of acoustic environment quality in urban open space. New Architecture,2014(5): p.18-21.
9. Tomlinson R. Thinking About GIS: Geographic Information System Planning for Managers. Esri Press, 2003.
10. GB3096-2008.Acoustic environmental quality standard.
11. Liu Jiang, Kang Jian, Holger, Behm, Luo Tao. A Study of the Relationship between Soundscape Perception and Urban Landscape in Urban Open Space. New Architecture2014(5): p. 40-43.