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

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

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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 m²) 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 constructed to explore the effects of soundscape on restorative effects.

The results showed that: ¹LAeq 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
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 $\text{m}^2$ and has a water surface area of 4,390 $\text{m}^2$. 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.

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 $1\text{min}$ $L_{Aeq}$ data (Secondary Sound Level Meter); geographic coordinates of the measurement point (Omap APP); the 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>
<thead>
<tr>
<th>Period</th>
<th>Time</th>
<th>Traffic conditions</th>
<th>Crowd characteristics</th>
<th>Activity characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>7:30-8:00</td>
<td>Early peak</td>
<td>Mainly middle-aged</td>
<td>Abundant exercise</td>
</tr>
<tr>
<td>Midday</td>
<td>11:30-12:00</td>
<td>platykurtic</td>
<td>Mainly middle-aged and a few young children</td>
<td>Many recreational activities</td>
</tr>
<tr>
<td>Evening</td>
<td>18:00-18:30</td>
<td>Late peak</td>
<td>Mainly middle-aged and a few children</td>
<td>More fitness activities</td>
</tr>
</tbody>
</table>

Figure 1 – Lu Xun Park Plan Analysis
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>
<thead>
<tr>
<th>Restorative feeling of soundscape</th>
<th>Semantic description</th>
<th>Rating level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relaxing feeling</td>
<td>Relaxed - nervous, gentle - stimulating</td>
<td>very strong, strong, average, weak, very weak</td>
</tr>
<tr>
<td>Beautiful experience</td>
<td>Beautiful - ugly, like - hate</td>
<td></td>
</tr>
<tr>
<td>Exploratory of connotation</td>
<td>Interesting - boring, positive - negative</td>
<td></td>
</tr>
<tr>
<td>Immersion</td>
<td>Pleasure - trouble, comfort - uncomfortable</td>
<td></td>
</tr>
</tbody>
</table>

3. RESULTS

3.1 LAeq, acoustic events distribution and soundscape map

3.1.1 LAeq and distribution

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

![Figure 2 – Typical working day LAeq distribution](image)

It can be seen from the figure that the overall LAeq 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 LAeq difference between morning and midday was deemed significant \( (0.01<P=0.021<0.05) \), and the difference in LAeq between morning and evening was also significant \( (0.01<P=0.034<0.05) \). There are also differences in the distribution of LAeq 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) 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>
<thead>
<tr>
<th>Sound category</th>
<th>Specific acoustic event sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural sound</td>
<td>Birdcall, wind blowing leaves, wind</td>
</tr>
<tr>
<td>Traffic sound</td>
<td>External traffic, bicycle ringtone</td>
</tr>
<tr>
<td>Instrument sound</td>
<td>saxophone, erhu, flute</td>
</tr>
<tr>
<td>Active sound</td>
<td>Equipment sound</td>
</tr>
<tr>
<td></td>
<td>Table tennis, bounce ball, radio, square dance, fan dance</td>
</tr>
<tr>
<td></td>
<td>human sound</td>
</tr>
<tr>
<td></td>
<td>Conversation, children's play, exercise, fit walking, chorus</td>
</tr>
</tbody>
</table>

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).
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>
<thead>
<tr>
<th>Significant level classification</th>
<th>Acoustic event</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 level</td>
<td>External traffic, conversation, flute, saxophone, square dance, fan dance</td>
</tr>
<tr>
<td>4 level</td>
<td>Birdcall, chorus, Erhu</td>
</tr>
<tr>
<td>3 level</td>
<td>Bicycle ringtone, radio sound, children's play</td>
</tr>
<tr>
<td>2 level</td>
<td>Table tennis, wind, and bounce ball</td>
</tr>
<tr>
<td>1 level</td>
<td>Fit walking, wind blowing leaves</td>
</tr>
</tbody>
</table>
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 LAeq](image)

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; ② concentrated sounding and narrow transmission range, such as fan dance, table tennis, chorus; ③ scattered sounds but widespread such as square dance, exercise; ④ scattered sounds and spread a narrow range, such as children’s play.

Playing the flute occurred 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 occurred 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](image)

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

<table>
<thead>
<tr>
<th>Patch</th>
<th>Under forest</th>
<th>Artificial lake</th>
<th>Leisure and recreation</th>
<th>Hill</th>
<th>Entrance square</th>
<th>Fitness square</th>
<th>Activity square</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean $L_{Aeq}$ (dB(A))</td>
<td>50.9</td>
<td>53.2</td>
<td>50.5</td>
<td>52</td>
<td>53.3</td>
<td>53.6</td>
<td>60.4</td>
</tr>
<tr>
<td>Variance</td>
<td>77.6</td>
<td>11.5</td>
<td>5.9</td>
<td>13.9</td>
<td>70.4</td>
<td>7.5</td>
<td>96.5</td>
</tr>
</tbody>
</table>

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
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.

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