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Investigation and Study on the Influence of High-Density Urban Traffic Noise on the Acoustic Environment of Urban Parks

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ABSTRACT

Urban parks provide residents with space for relaxation, fitness and recreation, while the surrounding traffic noise has a negative impact on their environmental quality. This study conducted a survey of surrounding road conditions in 49 urban parks in the typical high-density city of Shenyang, China. Two parks were selected for traffic condition measurement and noise simulation with Cadna/A; Spatial analysis was also conducted with ArcGIS.

The results showed that: ①49 urban parks were all directly adjacent to urban roads and were mostly adjacent to roads on multiple sides. Adjacent roads were mostly high-level roads; ②Based on the traffic survey of 7 roads of 2 parks, traffic flow was significantly positively correlated with the road level; ③ Based on noise simulation, the L_{Aeq} of the traffic sound on the adjacent roads of the two parks ranged from 59.0-70.9dB(A), and had a certain pattern in time and in whether it was a working day; ④Based on spatial analysis on the significance of traffic sound perception, the proportion of the 2 parks' interior area where traffic sound perception was relatively clear were 36.0% and 51.1% respectively. Going further into the interior, the saliency showed attenuation of different gradients. The attenuation gradients were affected by factors such as spatial characters, landscape features andsound composition.

Keywords: urban park; traffic noise; high-density city;

1. INTRODUCTION

With the continuous improvement of China's economic development and urbanisation level, the demand of urban residents for leisure space is also increasing. As the main public space for citizens' leisure activities, urban parks are the main environment for people to restore their attention and to release stress, and it is also the main place for leisure, fitness and recreation(1).High-density cities are the product of high development. While people enjoy the benefits of high urbanisation, at the same time, negative factors such as tight land use, lack of privacy, life rhythm and pressure are also plagued by high-density cities(2). Taking Shenyang, a typical high-density city, as an example: "the urban parks in Shenyang are insufficient in area, the spatial distribution is uneven, and the contradiction between supply and demand is large... The existing urban parks are 1379.06hm^2, of which the per capita park area is 3.50m^2, only 19.47% of the study area can easily reach a city park on foot"(3). In this city where land is precious, the city park seems to be a gift, people are moving in a space like forced to squeeze, but also enduring the influence of some negative factors, and the negative effects of traffic sounds in urban natural landscapes on environmental recovery benefits have been demonstrated(4,5).In 2014, the International Organization for Standardization (ISO) defined Soundscape as the acoustic environment(6) perceived by individuals or groups in a given scene, and soundscape survey studies have shown that traffic sounds in the interior of the parks is clearly perceived and forms an acoustic landscape with other acoustic events(7).

As an important influencing factor of the acoustic environment of urban parks, background sound has a significant impact on the internal environment of the park. The interference of background noise of urban parks along the street roads is particularly obvious. According to statistics, traffic noise accounts for about 70% of various noise sources (including traffic noise, industrial noise, building construction noise, and

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social life noise) that affect China's urban environment, indicating that traffic noise has become the main noise of current Chinese cities. Source and adverse effects on the human cardiovascular system, nervous system, reproductive system, digestive system and endocrine system(8).

This paper conducted a survey of surrounding road conditions in 49 urban parks in the typical high-density city of Shenyang, China, and selected two parks for a traffic survey. The Cadna/A noise simulation software was used to simulate traffic noise, and SPSS was used to analyse the data. At the same time, the subjective evaluation of traffic sound perception in the two parks was carried out. ArcGIS interpolation analysis was used for visualising the data and the classification and summarisation of the influencing factors of subjective evaluation maps to explore the impact of traffic noise in urban parks.

2. Materials and methods

2.1 Map analysis

Through the method of network map analysis, the traffic conditions of the 49 urban parks in the main urban area of Shenyang were surveyed, including the number of parks, the number of adjacent roads, and the nature of the adjacent roads. The relevant data were statistically compiled to explore whether traffic noise could be a potential possibility that can influence the acoustic environment experience of urban parks.

2.2 Traffic measurement and simulation

Through screening of 49 urban parks, Lu Xun Park and Bayi Park were selected as research samples. Lu Xun Park covers an area of 43,000 m^2 and is a small urban park. Bayi Park covers an area of about 70,000 m^2 and is a medium-sized urban Park(9).

The seven streets adjacent to Bayi Park and Lu Xun Park were simultaneously measured at ten time points on weekdays and rest days. The measurement team used the camera to shoot the volume and speed of traffic at each time. The shooting time of each street was 10 minutes per time, and the traffic flow was counted. The relationship between the two parks and the roads is shown in Figures 1 and 2.

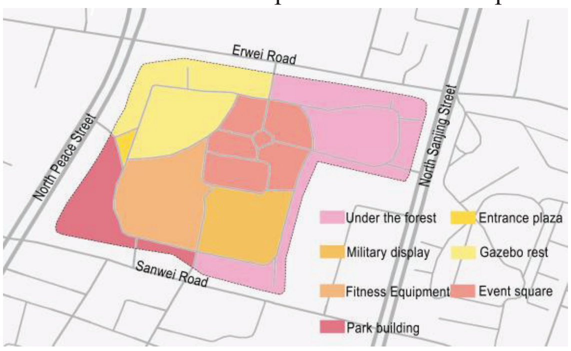

Figure 1 – Bayi Park Division and Road Relations

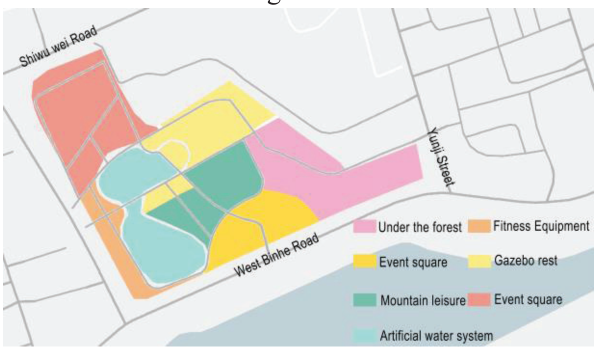

Figure 2 – Lu Xun Park District and Road Relations

The Cadna/A Noise Simulation System is a Software of noise simulation that is based on the ISO9613 standard method. As the noise prediction software(10) recommended by China's State Environmental Protection Administration Environmental Assessment Center, it has been widely used in the evaluation of industrial facilities, roads and railways, airports and other noise equipment, and has been widely recognised by many scholars. Based on the traffic noise analysis function of Cadna/A, this paper simulated the road traffic flow around Bayi Park and Lu Xun Park, calculated the traffic noise simulation map of seven roads adjacent to the two parks, and explored the impact external traffic noise had on the two parks.

2.3 Traffic sound significance evaluation

According to the grid of 15m×15m and 20m×20m, Lu Xun Park and Bayi Park were divided into 139 and 174 grids. Each park was allocated 8 groups of students (trained Shenyang JianZhu University students). On a working day, the crowds had fewer activities and the traffic was more crowded. Between 11:30-12:15 students used mobile phones to collect audio and video for each grid. The duration was the 60s, and the traffic flow was counted and sound pressure level measurement was performed on the adjacent roads of the two parks in the same time period. Four university students with good health and audition ability were selected to evaluate the traffic sound perception of the audio and video collected in the grid points. The evaluation index used the 5-level Richter scale (very weak, relatively weak, intermediate, obvious, very obvious) to quantify the saliency. The average score was taken. Traffic noise simulations were carried out on the traffic conditions of the two parks during the measurement period and compared with the measured values.

2.4 Spatial significance analysis

At present, noise maps have been widely used in urban planning design and noise control(11). Spatial data visualisation and spatial analysis based on visualization technology are the keys to technologies of Geographic Information System (GIS)(12). Geographic information system refers to the technical system that collects, stores, manages, calculates, analyzes, displays and describes the geographical distribution data of all or part of the Earth's surface space under the support of computer hardware and software systems.

According to the data of the subjective evaluation table of the traffic noise perception in the two parks, the two park's space coordinate elements are assigned to the corresponding attributes by means of the GIS platform, which is converted into raster data by the Kriging interpolation method and superimposed with the geographic data, draw a map of the traffic noise perception saliency evaluation of the two parks to explore the distribution of traffic noise on the two parks.

3. Results

3.1 Park and road adjacent conditions in the main urban area

According to the boundary shape of the 49 parks in the main urban area of Shenyang, the two main axes were simplified, and the adjacent roads in each direction of each park were counted and the adjacent road levels were counted. The results are shown in Table 1.

Table 1 – Status of roads around the park in 49

		Highest adjacent road level				
		highway	Main road	Secondary road	Branch road	total
Number of sides adjacent to roads	4	4.1%	6.1%	4.1%	2.0%	16.3%
	3	6.1%	6.1%	12.3%	0%	24.5%
	2	2.0%	18.4%	16.4%	6.1%	42.9%
	1	4.1%	4.1%	6.1%	2.0%	16.3%
	total	16.3%	34.7%	38.9%	10.1%	100%

The results showed that all the 49 parks in the main urban area of Shenyang were directly adjacent to an urban road on one side, indicating the potential for traffic noise in the parks in the main urban area of Shenyang. Urban parks with directly adjacent roads on two or more sides accounted for 83.7% of all parks, and the parks with the highest adjacent road level higher than secondary roads accounted for 89.9%, of which 4.1% of the urban parks are adjacent to roads on all four sides and with highest-level adjacent road being a highway. Parks adjacent to road on only one side and only to branch road accounted for only 2.0%. From this point of view, the urban parks in the main urban area of Shenyang were affected by the severe traffic noise. This is related to the dense urban population and restricted land use.

3.2 Measurement and simulation of traffic conditions during daytime

3.2.1 Traffic conditions measured

The traffic flow of seven adjacent roads in the two parks was measured. The statistics of the adjacent roads of the two parks are shown in Table 2. The traffic flow statistics of the seven adjacent roads are shown in Figures 3 and 4.

Table 2 – The adjacent roads of the two parks

Side	Lu Xun Park			Bayi Park		
	Adjacent road	Road level	Number of lanes	Adjacent road	Road level	Number of lanes
East	Yunji Street	Branch road	One-way two lanes	North Sanjing Street	Secondary road	Two-way four-lane
West	Residential area	——	——	North Heping Street	Main road	Two-way ten lane
South	West binhe Road	Secondary road	Two-way four-lane	Sanwei Road	Branch road	Two-way two-lane
North	Shiwu Wei Road	Branch road	Two-way two-lane	Erwei Road	Branch road	Two-way two-lane

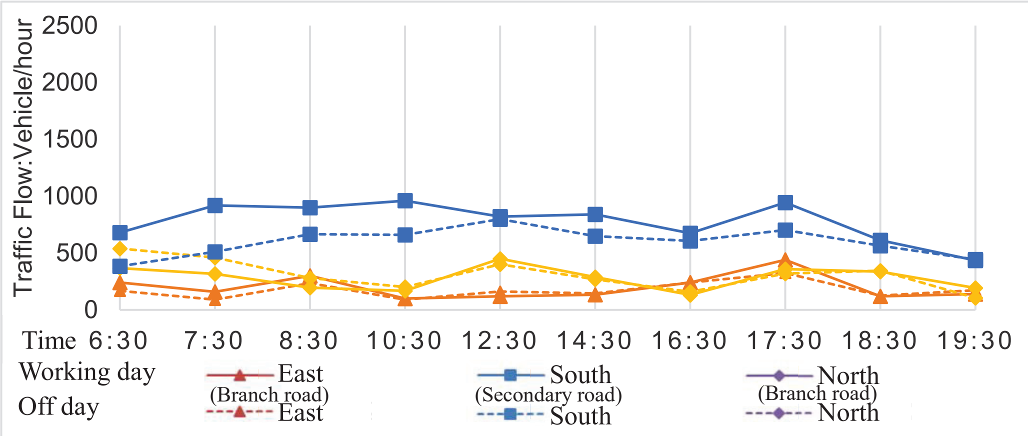

Figure 3 – Lu Xun Park traffic flow statistics

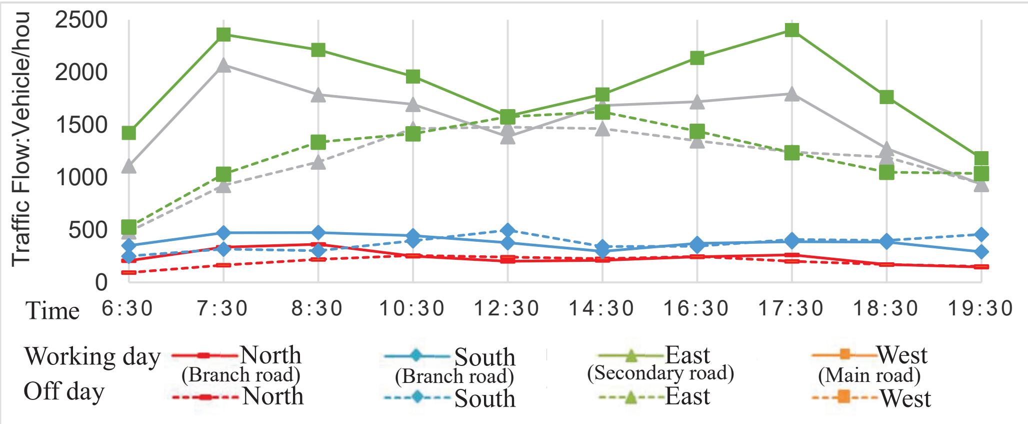

Figure 4 – Bayi Park Traffic Statistics

As can be seen from the figure, overall, the traffic volume of Bayi Park was higher than that of Lu Xun Park in one day. The two roads with the most traffic flow are the Peace North Street and the North Third Street near Bayi Park. The most frequent moments appeared at Peace North Street between 17:00 and 18:00, reaching 2,402 vehicles/hour. From the variation in one day it can be seen that, the traffic volume of each road in the working day was higher at the morning time and the evening time. This is because the morning and evening hours are at the peak of the commute. In contrast, on the rest day, this situation is more moderate than the working day.

From the level of the adjacent roads of the two parks, the traffic on the North Avenue, which is a main road, is significantly higher than that of other roads on both weekday and rest day. The secondary roads of the North Third Street and the West Binhe Road were relatively more peaceful than North Street. The traffic volume was small. The traffic on the branch roads, the Erwei road, the Sanwei Road and the Shiwuwei road was less and the variation was small throughout the day.

Correlation between road grade and traffic flow in seven urban roads adjacent to the two parks: Pearson correlation coefficient test was performed by SPSS24, giving $p=0<0.01$, $r=0.794$, which proved that road level and traffic flow were significantly positively correlated at 0.01 level, that is, the higher the road level, the greater the traffic volume.

3.2.2 Traffic sound simulation results

The traffic flow, vehicle type and road speed limit of the seven urban roads adjacent to Lu Xun Park and Bayi Park were put into Cadna/A noise simulation's software according to working days and rest days, and the German RLS-90 standard was selected for simulation to obtain The sound pressure level results of traffic noise at different time periods for the seven roads on the working day and rest day, as shown in Figures 5 and 6.

The noise simulation showed that the traffic sound L_{Aeq} of the adjacent roads of the two parks was distributed at 59.0-70.9dB(A), and the maximum value of 70.9dB(A) appeared in the Xibinhe Road adjacent to Lu Xun Park at 12:30, the minimum value of 59.0dB (A) appeared at 19:30 time of the working day on the Shiwuwei Road adjacent to Lu Xun Park. This showed that the two parks were affected by traffic noise from the adjacent urban roads to different extent.

Overall, the traffic simulation results were close to the traffic flow statistics, indicating that the traffic flow was the main cause of traffic noise, but there was no significant difference between the sound pressure levels of the main roads and the secondary roads in the adjacent roads of the two parks. This could be because that the width of the main road and the North Street were wide, which played a positive role in the attenuation of traffic noise. Different vehicle type composition and the road speed limit also affect the traffic noise simulation results.

It can be seen from Figure 5 that the sound pressure level of adjacent road traffic in Lu Xun Park fluctuated greatly during the day, and the overall sound pressure level was higher in the morning and evening peak periods, and the sound pressure level was lower in the rest of the day. The traffic sound during the peak period had a great impact on Lu Xun Park, and the during rest of the time period had a lower impact.

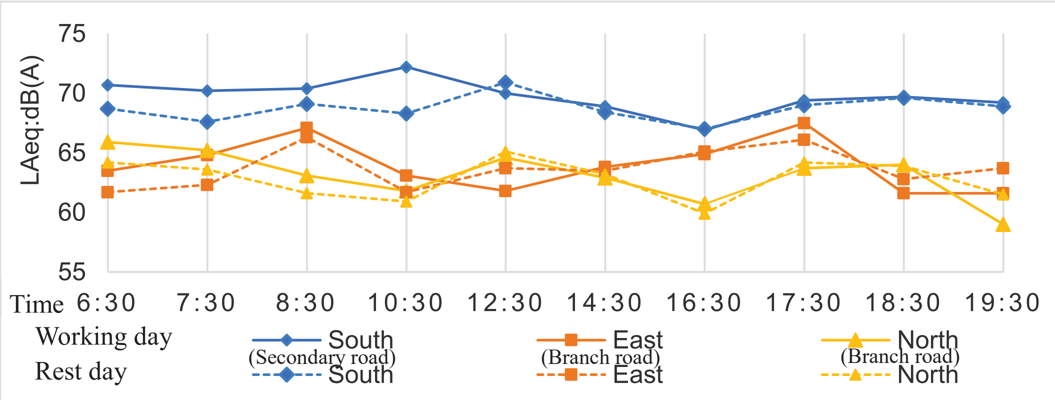

Figure 5 – Traffic simulation of adjacent roads in Lu Xun Park

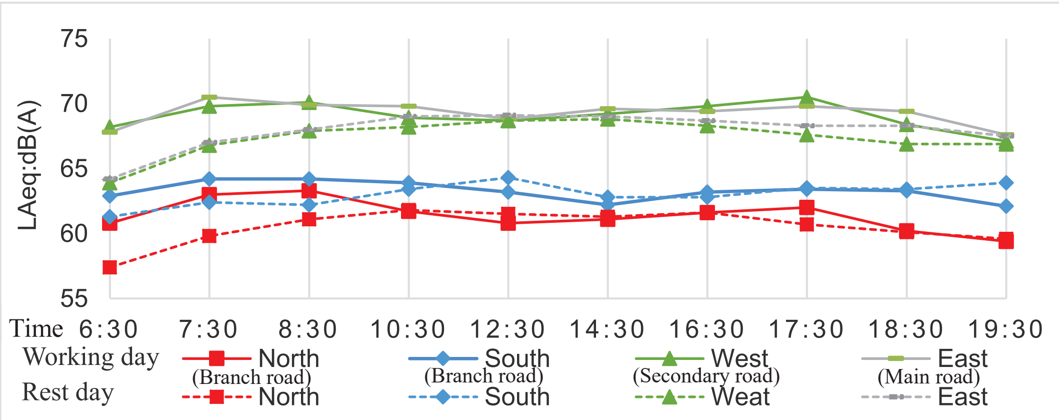

Figure 6 – Traffic simulation of adjacent roads in Lu Xun Park

From Figure 6 it can be seen that the sound pressure level of the traffic on the adjacent roads of Bayi Park was relatively flat during the day, and the sound pressure level was higher but not obviously during the morning and evening peak hours, indicating that the Bayi Park was affected by the traffic sound in one day consistently.

Considering traffic volume and traffic sound comprehensively, it is not difficult to find that for roads such as North Heping Street, North Sanjing Street , West binhe Road, the traffic volume was high, which lead to the higher sound pressure level of the simulated traffic. Sanwei Road, Yunji Street, and Shiwu Wei Road had lower traffic flow, which resulted in a lower sound pressure levels of simulated traffic. The higher the road level, the higher the number of lanes, the greater the traffic flow. The traffic sound pressure level was also higher.

The simulated values of the seven road traffic noises showed a clear difference between the working days and the rest days. Overall, the sound pressure levels of traffic noises on the seven roads were higher than the rest days on the working day. This was most obviously seen at 6:30-8:30. In addition, variance test obtained by the single-factor analysis of SPSS revealed that P=0.715,F=5.363, significance P=0.026<0.05. This means that at the time of 6:30-8:30 traffic noise sound pressure level had significant difference in working days and rest days on the seven roads. The reason for that is that this time segment is in the morning rush hour on weekdays, and its traffic volume is larger than that during the rest of the day. From the perspective of the park being affected, this time period is the morning exercise time. There are more crowd activities in the park, which is highly disturbed by traffic noise during the working day. Analysis of other time periods, in the same way, did not reveal significant differences.

3.2.3 Traffic noise measurement and simulation comparison

The traffic noise of the adjacent seven roads measured at the typical time of the two parks was put into Cadna/A for traffic noise simulation, and the traffic sound pressure level was obtained. The simulation and measured data of seven road traffic noises are shown in Table 3.

It can be seen from the table that the simulated values of road traffic noise in seven cities were higher than the measured values, but the overall sound pressure level error was between 1.1dB(A) and 4.7dB(A), which was within the acceptable range. High levels represented road traffic noise levels. The simulated traffic noise sound pressure level L_{Aeq} was 65.2dB(A)-73.7dB(A) for the seven roads during the working day at 11:30-12:30, which had various level of impact on the two parks during this time period. By comparing and analysing the traffic conditions and traffic data of Lu Xun Park and Bayi Park, it can be seen that:

Table 3 – Seven road traffic noise simulation and actual measurement

	North Heping Street	North Sanjing Street	Erwei road	Sanwei Road	West Binhe Road	Shiwu Wei Road	Yunji Street
Traffic flow, vehicles/hour	2154	2478	678	390	780	234	138
Heavy truck ratio, %	3.6	2.7	6	0.9	10.8	0.9	10.9
Road speed limit (small and medium car /large car, km/h)	60/55	50/45	35/30	30/30	50/45	30/25	40/30
Analog sound pressure level, dB(A)	72.4	73.7	67.7	65.2	69.9	65.8	65.9
Measured sound pressure level, dB(A)	70.1	69.8	65.5	64.1	65.2	63.8	64.7

As a small urban park, Lu Xun Park had a secondary road and two sub-districts. The park was adjacent to the road with a large length but the speed limit of the road was low. Bayi Park was a medium-sized city park with two adjacent main roads and two secondary roads, and the speed limits were higher. According to the sound pressure level of Cadna/A software, it can be found that the traffic sound pressure level generated by the streets around Bayi Park was significantly higher than that of Lu Xun Park.

3.3 Traffic noise perception significance evaluation analysis results

The Kendall Harmony Coefficient Test is a correlation measure for calculating the degree of correlation between multiple rank variables, and it can objectively reflect the reliability relationship among different scorers. The Kendall Harmony Coefficient Test was carried out for the four groups of traffic noise perception significant scores of the two parks. The number of video samples in the two parks was 313, and the Kendall Harmony Coefficient W^a=0.802, X^2=1000.892, X^2=0.000<0.01, so the four groups of scores are significant at the 0.01 level, that is, they have extremely significant consistency. It is therefore possible to conduct traffic noise significance map analysis.

3.3.1 Traffic noise significance map analysis

The average number of subjective evaluations of traffic noise in the four groups of Bayi Park and Lu Xun Park was averaged, and the geographic coordinates and other data were put into ArcGIS. The spatial distribution of the traffic noise saliency of the two parks using Kriging interpolation. It is shown in figure 7 and 8

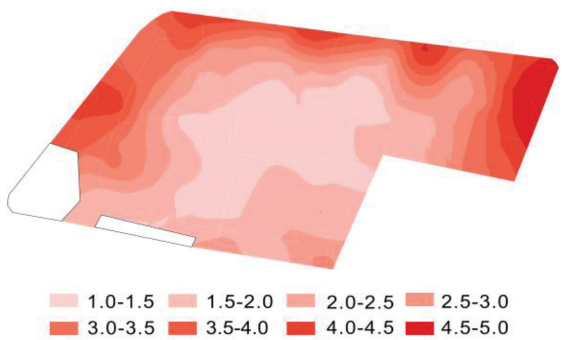

Figure 7–Evaluation of traffic noise saliency in Bayi Park

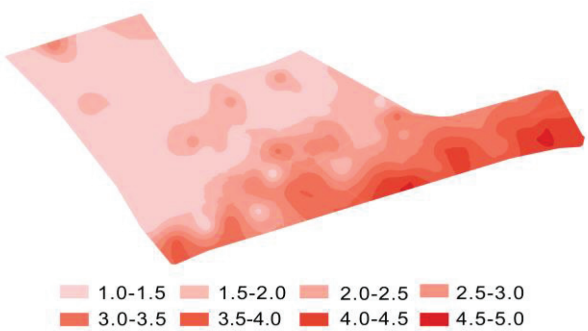

Figure 8–Evaluation of traffic noise saliency in Lu Xun Park

It can be seen from the figures that the two parks were affected by different degrees of traffic noise. The overall impact on Bayi Park was higher than that on Lu Xun Park, and the distribution patterns of the two parks were significantly different.

According to lunchtime traffic noise significance map of the two parks, it can be found that the influence of traffic sound as background sound on the two parks was different. Among them, area in Lu Xun Park that was affected by traffic sounds to a level of 2 (relatively weak) accounted for 36.0% of the total park area; Bayi Park was significantly affected by traffic sounds with level of 2 or above accounting for 51.1% of the total area.

The distribution of traffic sounds in Lu Xun Park was mainly concentrated in the south part of the Xibinhe Road area, the eastern Yunji Street and the northern part of the Shiwu Wei road, and it is rapidly decaying to the inside. There are areas in the park where most of the traffic sounds were less affected. The traffic sound distribution inside Bayi Park was concentrated on the other three roads and borders except for Sanwei Road in the south, especially in the North Heping Street and North Sanjing Street, and the degree of internal traffic attenuation was slower than that of Lu Xun Park. There were only a few areas within the park that were weakly affected by traffic sounds.

3.3.2 Effect of spatial features on the attenuation of traffic noise

Combining the spatial layout of the two parks themselves with the setting of the landscape environment and the impact of traffic sounds, it can be found that:

Park's shape influence: Lu Xun Park had irregular polygons, only three sides were directly adjacent to surrounding roads, and there are fewer parks and roads nearby; Bayi Park is rectangular, and all four sides are directly adjacent to the surrounding roads and the park interior and roads There are more neighboring areas and are more susceptible to traffic sounds.

The role of landscape features: Lu Xun Park has a 2.2 metre high wall surrounding it and multiple natural features such as forests that can hinder the transmission of noise inside the park. The area where such natural landscape exists in Lu Xun Park was obviously affected by the traffic sound. less. In addition, there was a water system inside Lu Xun Park, and there were less paved grounds, more exposed natural ground, which had a certain absorption effect on the sound, while the trees inside Bayi Park were sparse and failed to form a forest. The garden was mostly hard stone bricks. With paved ground, sound was more likely reflected, which is not conducive to the attenuation of traffic noise.

Impact of the spatial morphology: There was a small mountain inside of Lu Xun Park. The terrain with a high difference had a certain role in promoting the attenuation of external traffic. The interior of Bayi Park was relatively flat, and the landscape in the park was mostly sculpture and various types of metal weaponry, which lacked the ability to absorb noise.

3.3.3 Shielding effects of dominant sound on other acoustic events

Partial correlation analysis of traffic sound, natural sound and human voice in the subjective perception evaluation of the two parks was carried out and the results are shown in Tables 4.

Table 4 – Partial Correlation Analysis of Subjective Perception Evaluation in Two Parks

Park name	Control variable	Analytical variable	Correlation coefficient	P value
Bayi Park	Human activity sound	Traffic sound Natural sound	-0.085	0.266
	Traffic sound	Human activity sound Natural sound	-0.335	0.000**
	Natural sound	Human activity sound Natural sound	-0.723	0.000**
Lu Xun Park	Human activity sound	Traffic sound Natural sound	0.006	0.946
	Traffic sound	Human activity sound Natural sound	-0.395	0.000**
	Natural sound	Human activity sound Natural sound	-0.581	0.000**

**, $P<0.01$

It can be seen from the table that the subjective perceptual evaluation analysis of the two parks followed the same pattern, that is, when the two variables of traffic sound and natural sound were separately controlled, the vocal and natural sounds, vocals and traffic sounds were both significantly negatively correlated at the level of 0.01. This means that when controlling the third variable, the human voice and the natural sound, the human voice and the traffic sound would be mutually concealed. When controlling the vocal variable, the traffic sound and the natural sound did not show a significant correlation, indicating that the human voice in the acoustic events perceived inside the two parks was the most important functional sound in the park, occupying a dominant position. And play a higher shielding effect on the other two acoustic events.

4. Conclusions

1. Taking Shenyang, a typical high-density city, as an example, 49 urban parks in the main urban area were affected by different degrees of traffic noise, mainly represented by multi-faceted direct adjacent roads and the high-level nature of the adjacent roads. These are the typical features of the roads adjacent to urban parks. The road level is significantly positively correlated with traffic volume at the 0.01 level for all roads adjacent to the two parks, that is, the higher the road level, the greater the traffic volume.

2. The traffic noise simulation of two typical urban parks showed that the traffic sound of adjacent roads L_{Aeq} was 59.0-70.9dB(A), and the traffic volume of different levels of roads was different from that of simulated traffic. The sound pressure levels of the adjacent roads in the two parks varied in different days, and there was a certain distribution pattern in the period and the working day. The traffic noise on the working day was generally higher than the rest day, with significant difference between6:30 and 8:30.

3. The proportion of areas with relatively clear traffic noise perception in the two parks were 36.0% and 51.1%, respectively, and had different degrees of attenuation going deep inside. The influence factors of attenuation gradient were: ①morphological features ②landscape features within the park ③spatial morphological features ④shielding effects of dominant sound on other acoustic events.

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