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Evaluation of Campus Soundscape Construction

Xia Deng[1], Zixuan Liu[1], Mengru Li[1], Jiayi Hao[1]

[1]*College of Architecture and Art Design, Henan Polytechnic University, Jiaozuo, China*

Abstract: *With the vigorous construction of beautiful China and the rise of soundscape research, the application of soundscape in campus environment becomes gradually widespread. The article takes the small garden of the No. 1 teaching building in the North Campus of Henan Polytechnic University as an example, and conducts a study on the soundscape of colleges and universities based on objective sound pressure level measurement and subjective questionnaire research. The objective measurement results show that the average noise value of the garden during daytime is 63dB (A), which is higher than the national standard of 55dB (A). The results of the questionnaire survey indicated that people's overall satisfaction with the soundscape at this location was not highly rated and some degree of soundscape improvement was needed. Accordingly, the article investigates the relationship between sound comfort and sound pressure level, and adopts optimization measures in three aspects: vegetation planning strategy, characteristic soundscape shaping, and environmental material improvement, in order to provide reference for the study of university soundscape.*

Keywords: *Campus soundscape, Sound comfort, Correlation analysis, Soundscape evaluation*

1. Introduction

Along with the improvement of people's awareness of landscape, sound environment has been incorporated into landscape creation, and the evaluation of sound environment quality has become one of the evaluation criteria of campus environment quality. In addition to the indoor acoustic environment of school buildings such as classrooms [1-2], student apartments [3-4], and research laboratories [5], which are of common concern, the outdoor acoustic environment of campuses is also worthy of attention. The outdoor public space of campus is an important place for teachers and students to study, relax and do their daily activities, and the importance of its acoustic environment quality has been widely recognized.

Within the field of campus acoustic landscape evaluation research, Guoqi Li [6] first studied the improvement of the acoustic landscape of a secondary school, but as an early study, he did not evaluate it systematically. Xiaoyun Peng [7] discussed the importance of ecological campus acoustic landscape and creation techniques from the aspects of ecological campus acoustic environment realization technology. Xiaole Wen and Zhengfeng Lin [8] et al. proposed the use of fuzzy matrix to evaluate the quality condition of campus sound environment, which can take into account the uncertainty of campus noise and make the evaluation results more objective and reasonable. Jun Tan and Xianfeng Huang [9] for the first time divided the functional zones of the campus into teaching and living areas for sound environment comfort evaluation research, and divided them into reasonable time periods, and calculated the sound pressure level by weighting. Kang Sun [10], Guanya Zhang [11], Zhuying Li [12], Zhenyan Wang [13] et al. conducted the evaluation of subjective feeling of college campus sound landscape through questionnaire survey. Wanqing Su [14-16] et al. used the qualitative research in "rooting theory", combined with campus soundscape to conduct a study on the evaluation of soundscape based on the construction of innovative growth-oriented campus. Chaomei Jiang [17] ,Yu Lin [18], Wenhang Qiu [19] et al. further used Cadna/A noise simulation software, HS6288B noise spectrum analyzer, numerical model and field deployment monitoring method to evaluate and analyze the campus acoustic environment.

At present, there are more and more studies and evaluation methods about the sound environment of college campus, but most of the published articles are from subjective or objective individual perspectives, and not many of them use the combination of subjective and objective evaluation methods to study the sound landscape of college campus. The article takes the small garden of the No.1 teaching building in the North Campus of Henan Polytechnic University as the research object, uses the combination of physical parameters measurement and subjective questionnaire statistics and other methods of subjective and objective evaluation, makes specific analysis in terms of sound pressure

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level measurement, sound comfort and sound satisfaction evaluation, and proposes corresponding sound environment optimization measures, hoping to provide reference for solving such problems.

2. Study Scope and Data Collection

2.1. Scope of the Study

The North Campus of Henan Polytechnic University is located at No.142 Jiefang Middle Road, Jiefang District, Jiaozuo City, Henan Province, which is in the center of the busy city. The area selected for this study is a small recreational garden next to the No.1 teaching building, which is located in the center of the campus and is the core area for students' frequent daily activities.

In the field research of the small garden, it was found that the garden was used more frequently by the student group and the garden landscape had a greater impact on the students' life and study, so multiple measurement points were set in the garden by analyzing the life and study patterns of the student group (Figure 1). The small garden was evenly divided horizontally and vertically, forming a rectangular grid of 7×6 cells, each cell being 3.3m×4.9m. Each cell was a measurement point, and the data from the measurement points were analyzed to investigate the quality and improvement direction of the campus sound landscape.

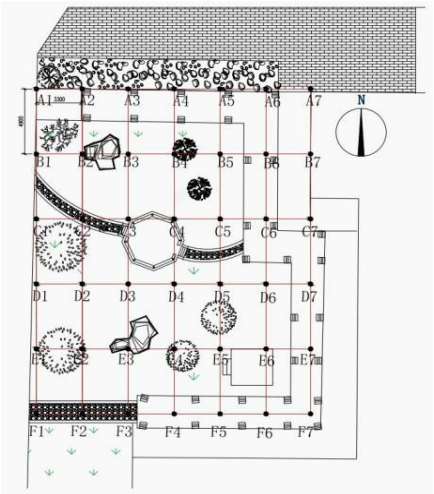

Figure 1: Distribution of measurement points in the small garden.

2.2. Classification of Soundscape Elements

Based on the existing three types of sound elements, namely artificial sound, natural sound and mechanical sound, and combined with the actual condition of the small garden of the North Campus of Henan Polytechnic University, the sound elements were classified (Table 1).

Table 1: Classification of sound elements.

Sound source type	Sound element name
Artificial sound	The sound of conversation, footsteps, and memorization
Natural Sound	The sound of wind, birds and insects
mechanical sound	Traffic sound, broadcasting sound, mechanical noise

2.3. Data Acquisition

According to the monitoring requirements in the implemented "Sound Environmental Quality Standards", this sound pressure level data collection experiment was selected on a sunny day with a light breeze, using TES-1352 series sound level meter from 6:00 a.m. to 23:00 p.m. every three hours for 42 measurement points in the same order. The data were measured and recorded at the same time as the main source of sound.

The sound landscape subjective data survey was conducted in the form of an online questionnaire, and the initial questions of the questionnaire were repeatedly modified according to the results of the

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preliminary screening survey to determine the sound landscape evaluation scale, which finally formed a reasonable questionnaire. The content of the questionnaire mainly consists of evaluation questions on the comfort, coordination and overall satisfaction of the acoustic landscape, and the evaluation questions are all on a 5-level scale (Table 2). A total of 200 questionnaires were distributed during the whole survey, and after removing the invalid questionnaires, 187 valid questionnaires were finally recovered and screened, with an efficiency rate of 93.5%.

Table 2: Scale of questions for questionnaire evaluation.

Evaluation Scale	Score
Very comfortable / very coordinated / very satisfied	2 points
Comfortable/coordinated/satisfactory	1 point
No feeling / no feeling / indifferent	0 points
Uncomfortable/uncoordinated/unsatisfactory	-1 point
Very uncomfortable/very uncoordinated/very unsatisfactory	-2 points

3. Soundscape Status Research Analysis

3.1. Sound Pressure Level Mapping and Analysis

The average values of the sound pressure levels at different times of the day were obtained for 42 measurement points in the small garden. Different colors were used to distinguish the sound pressure levels in each range, with redder colors representing higher sound pressure levels and bluer colors representing lower sound pressure levels, and the sound pressure level maps were drawn for each time of day (Figure 2, 3, 4, 5). The sound pressure level values inside the small garden differed with the time of day they were located and the factors that influenced them, creating a differentiated sound environment.

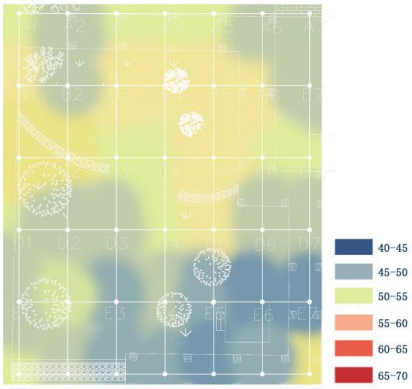

Figure 2: Sound pressure level distribution in the garden from 6:00 to 9:00.

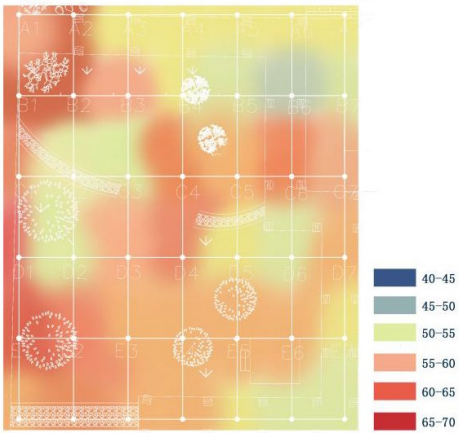

Figure 3: Sound pressure level distribution in the garden from 11:30 to 14:30.

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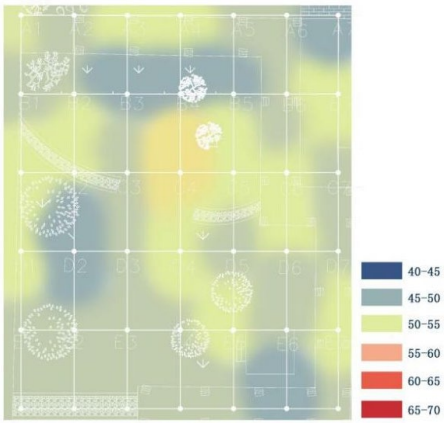

Figure 4: Sound pressure level distribution in the garden from 16:00 to 19:00.

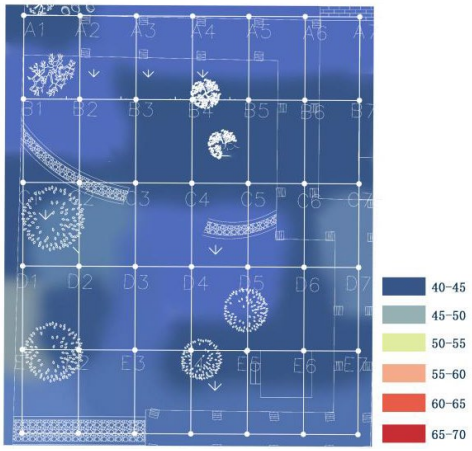

Figure 5: Distribution of sound pressure level in the garden from 20:00 to 23:00.

According to the national standard of the People's Republic of China "Sound Environment Quality Standard" GB3096-2008, the limit value of school environmental noise is 55dB (A) in daytime and 45dB(A) in nighttime.

It was found that from 6:00 a.m. to 9:00 a.m., the main factors influencing the soundscape of the small garden were the sound of memorization, conversation and birdsong. The overall sound pressure level values are in the range of 49-57dB (A), partly exceeding the environmental noise limit. From the north-south direction, the overall sound pressure level values in the north and middle of the small garden are higher than those in the south, and this difference mainly comes from the sound of students' memorization and conversation in the north and middle pavilions. In addition, because the north and west sides of the small garden are close to the main road of the campus, they are susceptible to traffic and conversation sounds, so the sound pressure level values of the north and west sides are in the range of 51-57dB(A), which is significantly higher than the east and south sides of the small garden.

From 11:30-14:30, the soundscape impact factors in the small garden were footsteps and conversations. The overall sound pressure level values are in the range of 51-68dB(A), and the sound pressure level at most locations has exceeded the ambient noise limit and the comfort level is low. In the east-west direction, the sound pressure level is higher in the west and middle of the garden, mostly in the range of 59-68dB(A), mainly because the road on the west side of the garden is the main road connecting the teaching area and the living area of the campus, and the time is the time when school ends at noon, so the road is crowded with people and noisy, which has a negative impact on the sound landscape of the garden.

From 16:00 to 19:00 in the afternoon, the influencing factors of the soundscape of the small garden were conversations and birdsong. The sound pressure level values at most locations were within the range of 47-55dB(A), which met the requirements of environmental noise limits. Among them, the sound pressure level is relatively high because the central location of the garden is a resting space with good environmental landscape and people stay there for a long time.

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From 20:00 to 23:00 at night, the impact factors of the small garden soundscape are mechanical sound and traffic sound. There is almost no one staying in the garden during this time, and the overall sound pressure level values are within the range of 41-51dB(A), with only a few locations exceeding the nighttime ambient noise limits. For example, the local location on the east side of the garden is susceptible to mechanical noise, and the sound pressure level value is high, which has a greater impact on the sound landscape.

3.2. Questionnaire Research Evaluation Analysis

3.2.1. Acoustic Comfort Evaluation

The comparison of the comfort evaluation of different types of sounds revealed (Figure 6) that most students chose to feel nothing for man-made sounds such as traffic sounds, footsteps and conversations. Most students chose to feel comfortable for sounds generated by natural factors such as birdsong, insects and wind, and most people chose to feel uncomfortable for radio and mechanical noises. It can be concluded that due to long-term social activities, people are more likely to ignore man-made sounds and feel more comfortable with natural sounds, while some mechanical noises will affect people's mood and thus make them feel uncomfortable.

A comparison of the sound comfort ratings for different times and different partitions revealed (Figure 7) that the students' overall comfort level for the garden was high during the hours of 6:00-9:00 in the morning and 20:00-23:00 in the evening, while the overall comfort level was slightly lower during 11:30-14:30 in the noon and 16:00-19:00 in the afternoon. And during the same time period, students generally rated the sound comfort level of the front and middle porches and pavilions higher than that of the grass and paths. It can be concluded that there may be some connection between people's evaluation of sound comfort and their activity behavior, etc. For example, pavilions and corridors can provide people with resting space, and their sound comfort ratings will increase accordingly, while the ratings of grass and paths will decrease accordingly.

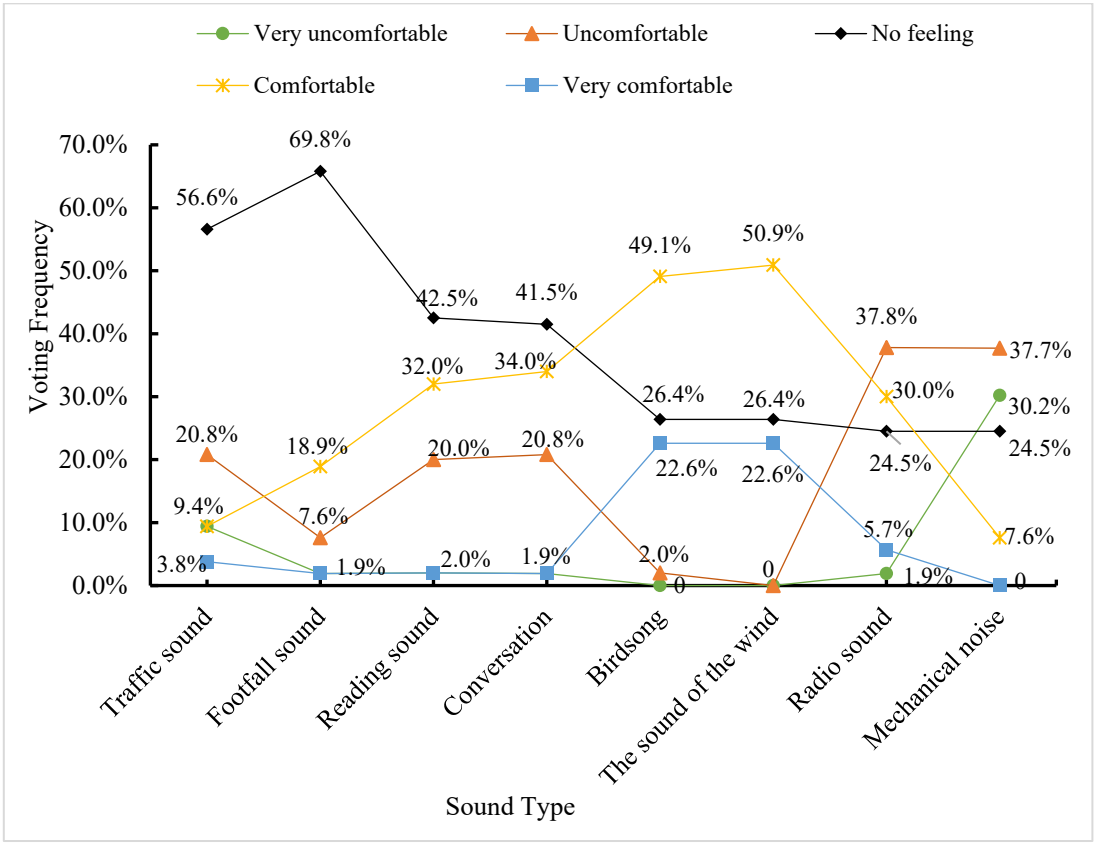

Figure 6: Evaluation of various sound comfort levels in the garden.

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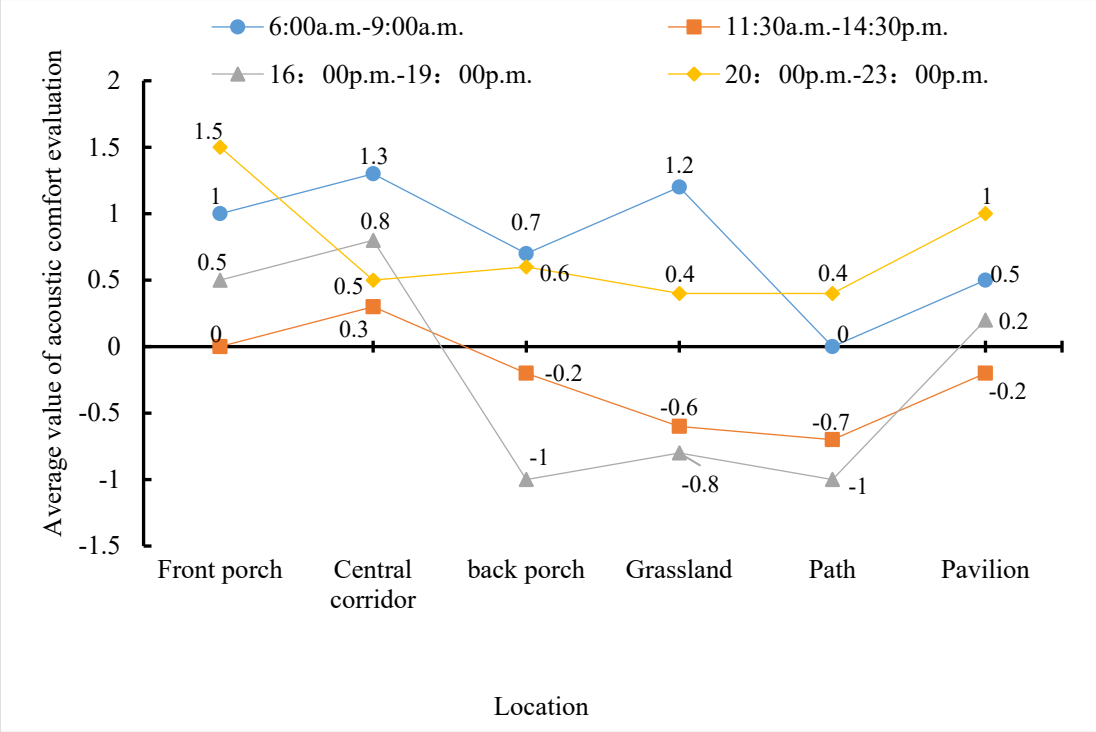

Figure 7: Evaluation of sound comfort in different areas.

3.2.2. Sound Satisfaction and Coordination Evaluation

By compiling the results of 187 questionnaires (Figure 8), it was found that more than 30% were dissatisfied and 14% were very dissatisfied in terms of overall satisfaction with the sound in the small garden, and in total only about 30% were satisfied or very satisfied with the overall environment of the small garden, so from the overall voting results, the soundscape of the small garden needs some degree of improvement.

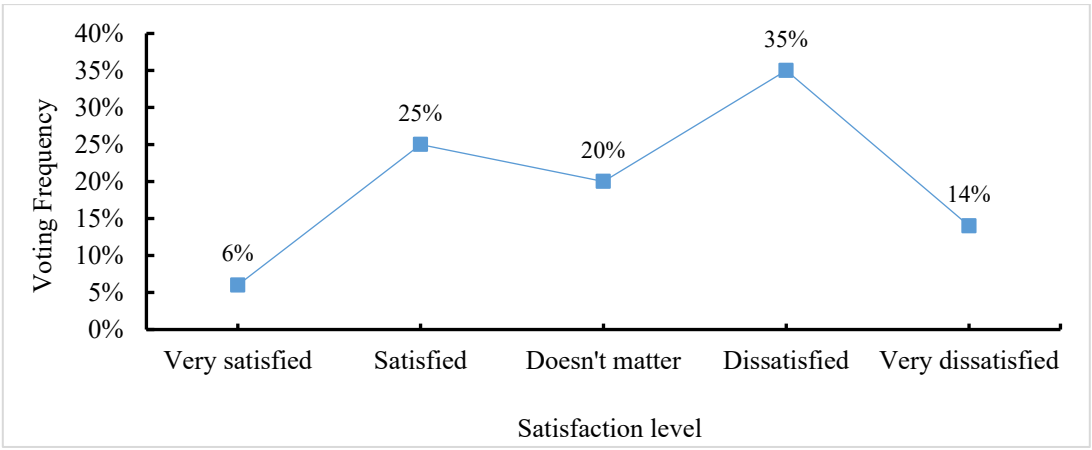

Figure 8: Satisfaction rating of the overall environment in the garden.

In addition, with regard to the evaluation of the coordination of various sounds within the garden, there were large differences in people's subjective perceptions of different sounds within the small garden (Figure 9). The statistical results show that people voted more frequently on the evaluation of the coordination of wind, birdsong, and insects in the small school garden. In contrast, people rated the incoordination of mechanical noise and conversation sounds from the external air-conditioning units inside the garden higher, believing that they damaged the overall sound environment of the small garden and appeared to be incoordinated with the creation of the overall sound landscape of the garden.

Therefore, more attention should be paid to the shaping of natural sound in the creation of sound landscape, and increasing the sound of nature in small gardens can better meet the needs of the public and create a more comfortable campus sound landscape.

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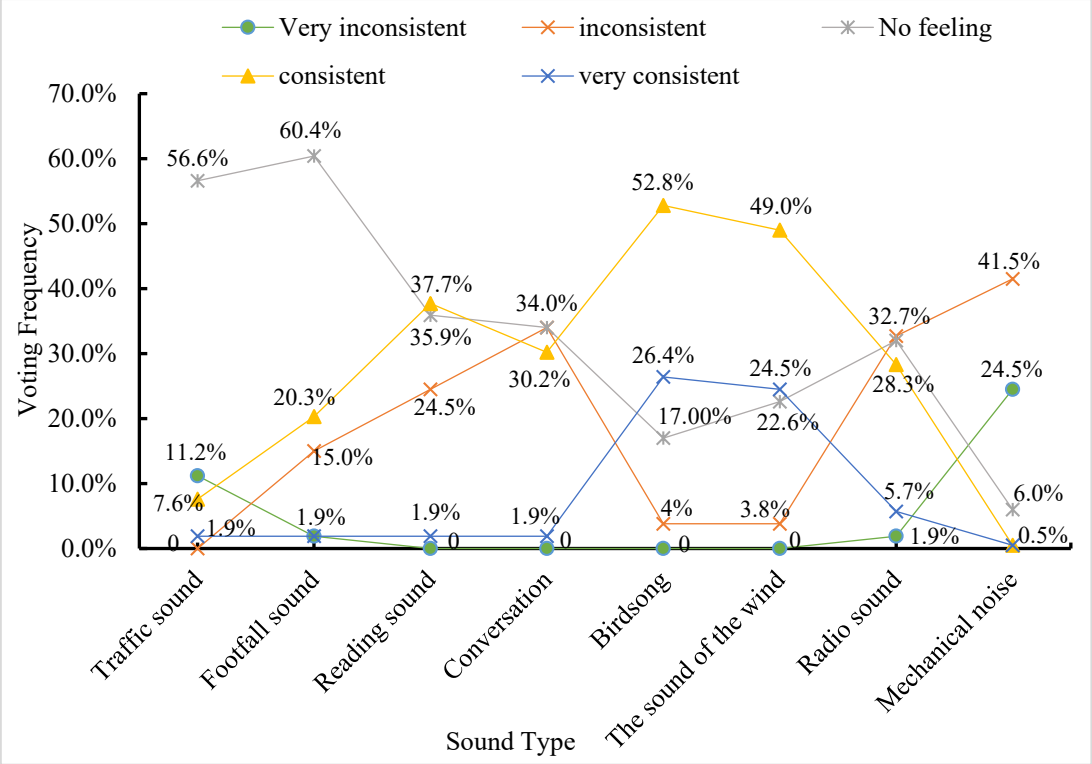

Figure 9: Evaluation of the coordination of various sounds in the garden.

3.3. Comprehensive Evaluation of Soundscape Subjectivity and Objectivity

3.3.1. SPSS Correlation Analysis of Sound Comfort and Sound Pressure Level

Combined with the questionnaire research results, SPSS statistical software was applied to explore the correlation between subjective sound comfort evaluation results and objective sound pressure level experimental data in the same place at the same time through Spearman's correlation analysis (Table 3). The results show that there is a negative correlation between sound comfort and sound pressure level, the larger the sound pressure level, the lower the sound comfort, and reducing the sound pressure level can ensure the subjective sound comfort is improved to a certain extent, which provides a direction for how to improve the comfort of campus acoustic landscape.

Table 3: Spearman correlation analysis of sound pressure level and sound comfort.

		Sound pressure level	Subjective comfort
Sound pressure level	Correlation coefficient	1.000	-0.417
	Sig. (bobtail)	0.000	0.006
Subjective comfort	Correlation coefficient	-0.417	1.000
	Sig. (bobtail)	0.006	0.000

3.3.2. Comprehensive Evaluation of Soundscape

Through the experimental data collection and analysis, it was found that the sound pressure levels in different areas of the small garden varied at different times of the day, and there were more influencing factors. Among them, the sound pressure level ranges from 6:00-9:00 in the morning and 16:00-19:00 in the afternoon are similar, while 11:30-14:30 at noon and 20:00-23:00 at night are the periods of the day with the highest and lowest sound pressure level values, respectively. Some time periods and most areas do not meet the national standards on noise limits, in which the north and west sides of the garden adjacent to the road are susceptible to the sound of traffic and footsteps, and the east side is susceptible to mechanical noise at local locations, and the sound environment quality is poor and should be improved.

Through the analysis of subjective questionnaire research, it is found that people's evaluation of mechanical noise is relatively low, while the evaluation of natural sound is relatively high. Therefore, when improving the sound environment, we can consider reasonably increasing the sound of nature to

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neutralize or even offset the interference brought by noise.

4. Soundscape Optimization Suggestions

4.1. Zoning Planning

Regarding the sound landscape renovation, the vegetation planting methods of vertical zoning and horizontal zoning can be mainly adopted.

Vertical zoning is to improve the effect of noise isolation mainly by planting plants in different layers of high, medium and low. The first layer is the lawn layer. The second layer is the flowering shrub layer, whose height can isolate part of the conversation sound, traffic sound, etc. The third and fourth layers are the tree layer. When the sound reaches near the plants, part of the sound is filtered out by the small holes on the surface of the green plants, so that the sound can be cut down.

Horizontal zoning refers to planting different kinds of plants in areas with different sound pressure levels in the horizontal direction, while also changing the plant density according to the distance from the sound source and flexibly adjusting the impact of other sounds on the sound landscape in the small garden. The combination of the two landscape zoning methods can enrich the diversity of plants as well as the landscape features of the site, creating a richer garden soundscape environment for teachers and students.

4.2. Introduction of Natural Sounds

According to the experimental results, it can be seen that people have a higher evaluation of the sound of wind, birdsong and insects, which can not only increase the vitality of the sound landscape, but also bring positive psychological feelings to people.

In addition to its own soundproof function, plants are also an important source of sound in nature. Broad-leaved trees can be planted around the garden to create a soundscape of wind-blown leaves and rain-beaten leaves. In addition, in order to introduce animal sounds such as bird calls and insect chirps, it is important to fully grasp the habits and migration patterns of various birds and focus on the diversity of tree species and richness of colors in plant selection [20]. At the same time, in order to create a more natural environment for birds, special bird nests can be set up, and a buffer zone can be added between the area where birds live and the surrounding areas where human activities are more frequent to avoid mutual interference.

In addition, water sound landscape can be introduced inside the garden to create a unique soundscape through different heights and water volumes, which can attract the attention of viewers and shield the background noise to create a more comfortable and pleasant campus soundscape.

4.3. Use of Sound-absorbing Materials

The road in the small garden is a normal asphalt concrete pavement, which can be paved with a single or double layer of porous asphalt pavement according to the demand of noise reduction. According to the study, the noise reduction of single-layer pavement can reach 5dB (A) and double-layer pavement can reach 10dB (A), which can reduce the noise impact brought by the passage to a certain extent and create a better sound environment experience.

5. Conclusion

The article examines various aspects of sound pressure level data measurement, soundscape influence factors, soundscape evaluation analysis, and the correlation between sound pressure level and sound comfort, and draws the following conclusions.

(1) Most of the subjects who participated in the questionnaire study were not highly satisfied with the overall acoustic environment of the small garden of the North Campus of *Henan Polytechnic University,* and the acoustic landscape in the garden needs to be improved to some extent.

(2) In the evaluation of the comfort and coordination of various sounds inside the garden, people have a higher evaluation of natural sounds such as birdsong, insects and wind, and a lower evaluation of radio sounds and mechanical noise.

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(3) Through in-depth analysis of experimental data, we know that there is a negative correlation between sound comfort and sound pressure level, the greater the sound pressure level, the lower the sound comfort, and reducing the sound pressure level can enhance the subjective sound comfort to a certain extent.

(4) In the process of optimizing the design of the small garden sound environment, the sound landscape can be improved by zoning the soundscape elements, introducing natural sound and using sound-absorbing materials for the garden roads.

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