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Influences of Building Community Form on Noise Distribution of Characteristic Industrial Towns

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Abstract: The Ministry of Housing and Urban-Rural Development of the PRC has established more than 400 characteristic towns within two years, and these towns are developing rapidly as an important economic carrier. Due to its special layout structure, that is, the industrial area is closely related to the residential area, and the acoustic environment of characteristic industrial towns is diverse and complex. In this study, with reference to morphological parameters, the Cadna/A acoustic environment simulation technology was used to discuss the influences of structural forms of various building communities in the town area on the noise changes of characteristic industrial towns based on factors such as distance and angle. The results show that the structure and form of the building community are closely related to the noise distribution of the towns. Based on this, corresponding planning strategies for optimizing the acoustic environment of industrial towns were proposed in this study.

1. Introduction

With the extensive promotion of the construction of characteristic towns and the rapid development of inter-city transportation systems, noise pollution in townships has become increasingly prominent. The spatial acoustic environment has a great influence on people's health and life^[1,2], and noise can greatly decrease people's quality of life^[3]. As the main settlement for the majority of the rural population to live and engage in various production activities, the township area urgently needs to solve the noise pollution.

In the current stage, there have been many advances in researches on how to control traffic noise in large and medium-sized cities^[4] and how to improve the structure of architecture and space receiving noise^[5]. For example, Germany has completed the mapping of nearly 500 urban noise maps, and the overall planning of these cities have also taken environmental noises into consideration^[6]. However, there are few researches on the distribution and governance of noises in villages and towns.

Therefore, with a characteristic industrial town in severe cold regions of China as the research object, this study aims to explore the variation of the noise environment in the town with different angles and distances between the building community and the main linear noise sources as well as how different spatial layouts affect the noise intensity in the building community.



2. Research Methods

2.1 Sample Selection and Regional Division

Jilin Province is a large agricultural province with a large township population, and its provincial capital, Changchun City, is an important rail locomotive industrial base and a transportation hub. Hence, Hexin Town, a characteristic industrial town with strict noise problems under the jurisdiction of Changchun City, was selected as the research object in this study. The study area is located near the City Highway in the west of Changchun City. Within the study area, a large area of industrial park coexists with the residential area, and the linear 106 Provincial Highway is the main noise source. The study area was divided into 6 building communities, i.e. A-F, according to their respective functions (Figure 1).



Figure 1. Architectural community morphology

2.2 Selection and Application of Morphological Parameters

Kang Jian further used the principal component analysis method to cut down the parameters, and finally selected 6 sensitive indicators that could objectively reflect the form of villages in severe cold regions, i.e. CAR, LSI_B, PD, RLF, RIF and LSI_R^[7]. It shows the morphological parameters summarized based on research experience to describe the structural characteristics of the town. They are all factors that affect the sound propagation outdoors, e.g. geometric divergence and ground effect^[8].

3. Noise Distribution

In this study, the outdoor sound pressure level (SPL) evaluation system was divided into 3 grades: SPL (LAeq) ≤ 50 dBA, which indicates a quiet acoustic environment; 50 dBA < SPL (LAeq) ≤ 60 dBA, implying a general acoustic environment remaining to be improved; SPL (LAeq) > 60 dBA, indicating an acoustic environment the villagers in the severe cold regions subjectively consider noisy, and at this time, residents outdoors are significantly annoyed by the traffic noise. Hereunder Q50 stands for the percentage occupied by the “quiet area” with a SPL (LAeq) less than or equal to 50 dBA in the total community area, L50-60 represents the percentage taken by the “general area” with a SPL (LAeq) larger than 50 dBA but less than or equal to 60 dBA in the total community area, and N60 denotes the percentage the “noisy area” with a SPL (LAeq) greater than 60 dBA accounts for in the total community area.

3.1 Analysis of Influences of Industrial Noises on Residents in the Building community

According to the actual interview and questionnaire survey results, people's perception of the acoustic environment is an overall comprehensive evaluation rather than a combined impression of several individual sounds. It shows that the interior of each building community is relatively open, and it is affected by the dominant environmental sound. This is caused by the “masking effect”, that is, mankind's auditory sensitivity to one sound is reduced by the presence of another sound.

By analyzing Table 1, it can be found that the average N60 of the six communities is 52.1%, whereas the Q50 is only 3.3%. The average SPL of the study area is 59.5 dBA, and at this time, the residents staying outdoors were generally significantly annoyed by the traffic noise. In addition, the sample villages greatly differ from each other in terms of the degree to which they are affected by the noises. For example, the largest difference between the SPLs of two villages reaches 6.5 dBA and that

between the background noises of two villages is up to 8 d BA.

Table 1. Average noise distribution in each community

Plot	Proportion of acoustic evaluation area(%)			Statistical sound level index		
	Q50	L50—L60	N60	Lmax	L50	Lmin
A	9.68	64.35	25.97	76.63	65.59	54.37
B	5.27	64.43	30.3	86.83	66.26	57.42
C	16.95	75.48	7.57	52.91	45.33	38.31
D	12.92	63.41	23.67	63.47	54.41	45.73
E	9.26	72.39	18.35	68.84	62.18	56.14
F	15.37	78.61	6.02	71.28	63.42	53.79

3.2 Influences of the Distance between the Building Community and the Highway on the Noise Environment

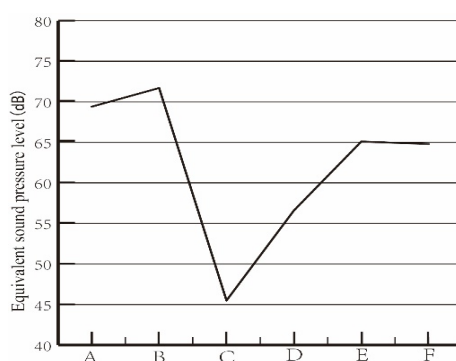


Figure 2. Average sound pressure level of each community

As indicated by the statistics of the survey results, the higher the level of the main highway, the higher its SPL (LAeq). The provincial trunk highway has the largest SPL, which is 67d B, and the average equivalent SPL of the county-level highway is 60d B. Besides, building communities close to the high-grade highways tend to have a higher noise level. The average equivalent SPL Communities A, B and F is higher than that of Communities C, D and E. (Figure 2)

Perpendicular to the highway, Communities C and D have the same morphological scale and morphological parameters. Besides, since Communities C and D are in adjacent locations, and the traffic variable has the same effect on the generation of their noises. The average SPLs of them are 45.5d BA and 56.6d BA, respectively. The reason for the difference is that the distances between them and the main noise source are different. Community C is 100m away from the highway, while Community D is close to the highway. This case also applies to Communities E and F whose average SPLs are almost the same, which are 65.1 d BA and 64.8 d BA respectively. The morphological parameters of Community F are better than that of Community E. There is no big difference between the SPLs of the two communities probably because of their different spatial layout. Community F is located on the side of the factory area, so its noise sources are diverse, while Community E is only affected by a single source of noise.

3.3 Influences of the Angle between the Building Community and the Highway on the Noise Environment

Communities E, B and F are the analysis objects, and the angles between them and the highway are 10°, 30° and 70° respectively. The average SPLs of the three are ranked from high to low as follows: LAeq-E > LAeq-F > LAeq-B. According to data analysis, there is no linear relationship between the

SPL changes and the angle. As a whole, the SPL of the community decreases as the angle increases, but this law is not applicable to Communities B and F.

To explore the impact of the angle between communities and the highway on the noise environment, Cadna/A simulation analysis was carried out on Communities A-F. Moreover, the terrain was optimized to eliminate the similarities between the three structures (Figure 3). The optimized communities basically include the extreme values and the medians of morphological parameters of the 6 communities.

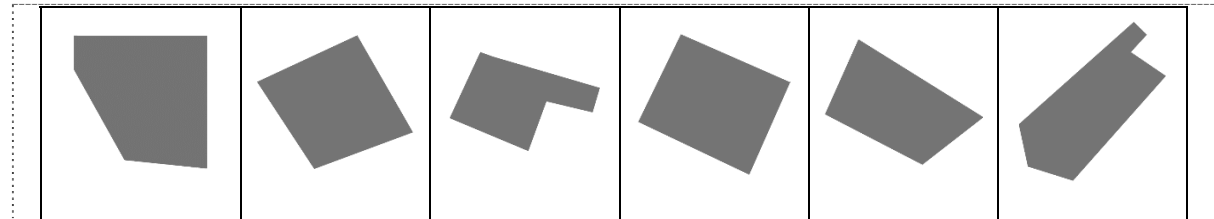


Figure 3. Optimized plot morphology

Figure 4 shows the influences of 10 angular relationships on Village N60. The angular relationship was obtained by rotating the highway clockwise around the village at a starting angle of 0° from the north-south direction of the west side of the village.

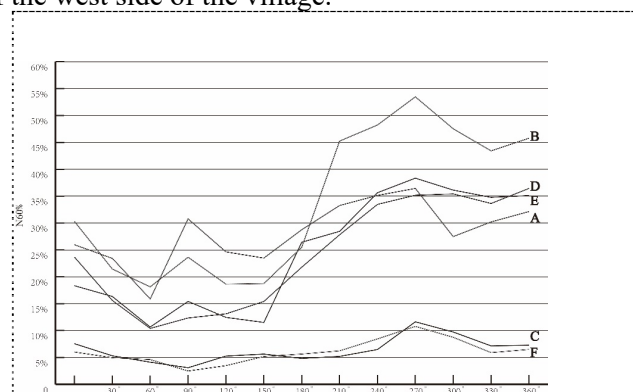


Figure 4. The influence of the angle formed by the community and the road on the N60

As shown in Figure 4, the variation of N60 between the angles of Village F is only 5.5%, showing that the characteristics in different directions are the same. When it comes to Village A and Village D, the characteristics in different directions are obviously not the same, and the change in the angle can lead to a change of N60 between 10% and 20%. Community B experienced the most significant change, which is, as the angle changed from 75° to 135° , N60 floats up to 32.8%. It can be seen that the change in the angle has a significant impact on the N60 of villages in severe cold regions.

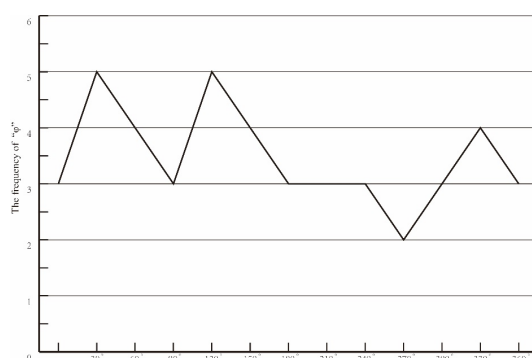


Figure 5. The frequency of ϕ varies with angle

Ordinal data conversion was conducted on N60, " ϕ " represents the case less than or equal to the average N60 of the 6 typical villages, and the frequency statistics of " ϕ " was performed. The higher the frequency of the village " ϕ ", the better its acoustic environment is. When the frequency of " ϕ " is greater than 4, it is an angle with a relatively good acoustic environment, and if the frequency of " ϕ " is less than or equal to 2, it is an angle with a relatively serious noise environment. As it can be seen from Figure 5, favorable angles and unfavorable angles alternated, and for N60, unfavorable angles are in the majority. As shown in Figure 5, $30^\circ \sim 60^\circ$ and $120^\circ \sim 150^\circ$ are the feasible angular relationships with comparatively weak noise impact, whereas $60^\circ \sim 90^\circ$, 180° , $240^\circ \sim 300^\circ$ and 360° are angular relationships with strong noise impact that need to be avoided. The change of the angular relationship can reduce the influence of noises on the township building communities probably because variation of the angle can change the shielding effect of the building and the acoustic transmission of the village's highway system.

3.4 Influences of Spatial Distribution of the Building Community on the Acoustic Environment

$LA_{eq-F} > LA_{eq-B} > LA_{eq-D} > LA_{eq-C}$, Community F has better morphological parameters than Community B. Under the influence of the main linear noise sources, the theoretical data of Community F should be better than that of Community B, but the measured data is the opposite. Community F was replaced by Community B and Community G with the optimal morphological parameters respectively. The LA_{eq-F1} and LA_{eq-F2} obtained are 65.4d BA and 63.7d BA, respectively, which are close to 64.8 d BA of the raw data LA_{eq-F} . The noise source of Community F was controlled only to the highway. Community A was replaced by vacant land and the residential community successively to obtain LA_{eq-F3} and LA_{eq-F4} , which are 59.4d BA and 57.6d BA, respectively. The analysis shows that both the spatial layout of the community and its peripheral functional configuration affect its noise distribution to a certain degree, and the industrial building community in Hexin Town has a negative impact on the adjacent residential building community.

4. Conclusion

Towns and villages in severe cold regions in China face serious noise pollution. In this study, the relationship between township communities and noise distribution was explored to reduce the negative impact of noises on towns and villages and improve the acoustic environment quality of building communities. In addition, the following conclusions were drawn.

First of all, the negative impact of noises shows a decreasing trend as the distance between the community and the highway increases. The quality of the space within the community can be effectively improved by increasing the distance between the two. However, the noise effects on building communities of different structures are quite different. When the distance is less than 100 m, the traffic noise is regularly attenuated as the distance increases. According to the simulation

calculation, when the distance is 300 m, N60 is 0, which can reach Level 2 stipulated by the 3096-2008 Environmental Quality Standard for Noise.

Second, according to the influence of the angular relationship between the community and the highway on the acoustic environment, the favorable and unfavorable angles alternate. Moreover, for N60, there are more unfavorable angles that cause negative noises. In the severe cold regions of China, an angle of $30^{\circ}\sim 60^{\circ}$ and $120^{\circ}\sim 150^{\circ}$ should be used, whereas an angle of $60^{\circ}\sim 90^{\circ}$, 180° and above 240° should be avoided.

Third, towns and villages are supposed to learn from relevant mature experience of urban planning by making clear divisions to reduce negative noises caused by disorderly functions, thus affecting the acoustic environment quality of building communities. Relevant vegetation can also be used to isolate the industrial communities, so as to isolate the noise source and cut off the noise transmission route.

Acknowledgments

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