Noise Mapping and Measurements for Sound Environment Assessment in a Typical Chinese Water-Rich Village

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Abstract. The construction of beautiful villages in China is carrying more and more demand for leisure and health care, thus increasing requirements for the quality of the village environment. In this paper, Huanggongwang in Fuyang, Zhejiang Province in China, a typical water-rich village, was selected as the research object to study the sound environment quality by adapting noise mapping and field measurements. A village acoustic simulation model was established by the layout of the villages, roads, and water system; the three-dimensional spatial distribution of sound pressure level was based on actual sound source identification and measurements for sound environment evaluation. The result shows that the combination of the arithmetic mean value method for sound pressure level and noise pollution index approach can better represent the characteristics of sound environment quality compared with traditional noise evaluation standards. The average sound pressure level measured on-site in the village was 62.4 dB(A), and the PN index was 0.83, which reveals the importance of resolving the issue of environmental noise in the villages. Moreover, this evaluation method excludes the chance of actual measurement results. Therefore, it provides a better measure of the quality of the rural sound environment, which serves as a basis for the scientific planning of rural construction.

Keywords: Rural sound environment; noise measurements; noise mapping; RAYNOISE simulation.

1. Introduction

With the rapid population aging in China, the construction of ecological and permaculture-oriented livable villages in the suburbs of cities has inspired much enthusiasm and interest. Compared to municipalities, residential buildings in rural areas are often more separated, there are fewer noise sources, and less severe noise pollution problems. Thus, the issue of noise pollution is far less of a concern than in urban areas. Due to the continuous promotion of urbanization and rapid economic development, projects that cause severe noise pollution, such as transportation, manufacturing, and processing industries, are gradually moved from cities to villages, and noise pollution problems are expanding from urban to rural areas [1]. In Chinese villages, noise is mainly emitted from traffic noise, such as railways, roads, and nearby industrial activity [2]. Among them, the traffic noise on the roads surrounding the countryside is the main noise source in the rural environment, which has traits of high intensity and wide coverage.

The majority of current studies on the acoustic environment in residential areas focus on urban locations. Wu Shuoxian et al., [3] comprehensively summarized the commonly used methods of noise reduction in residential area planning and design, which has significant implications for the enhancement of the sound environment. Liu Ziqiang et al., [4] conducted a thorough investigation into the sound environment in Tianjin’s residential areas and provided a general summary of the necessary actions to improve the sound environment. Meilan et al., [5] studied the sound environment of rural courtyards in the frigid northeast part of China and conducted a computer simulation to assess the sound of the courtyard. Dong Junyan et al., [6] studied a comprehensive and in-depth analysis of urban residential areas in Harbin to investigate the main factors of the sound environment and proposed corresponding strategies accordingly through field measurements, questionnaire surveys, and simulation analysis. Myung-Ho Han et al., [7] surveyed the residents of Mokpo, a port city located on the south-western tip of the Republic of Korea, examined the relationship between the respondents' residential and acoustic environments and their awareness of their sound environment, and the results confirmed the need for more balanced urban development planning. Noise is generally addressed through passive noise reduction measures. For example, road traffic noise is generally controlled through the installation of sound barriers, which are widely designed to combine different materials as part of the environment rather than simply serving to reduce noise [8-9]. Özge Gürsoy et al., [10] examine a holiday village to identify noise exposure conditions in outdoor areas. The results reveal the importance of resolving the issue of environmental noise most efficiently and cost-effectively in terms of settlement and planning. It can be seen that planning for a sound environment is limited to urban areas, and little consideration has been given to the planning and control of a sound environment in rural settlements. This paper generates noise maps based on the combination of on-site sound environmental measurements in Huanggongwang village and the RAYNOISE software, presenting the rural sound environment more intuitively with color maps and analyzing the current situation and existing problems of the rural sound environment in the village, proposes planning and control measures for Huanggongwang village, and provides a strong demonstration for the planning and construction of similar livable villages.

2. Modeling of the Noise Map

2.1 Model of RAYNOISE Simulatios

This study establishes a village acoustic model through the RAYNOISE software. Based on the overall layout of Huanggongwang Village, a three-dimensional geometric model of the noise-sensitive area and its surrounding environment is presented. The model has been simplified without compromising accuracy by abbreviating details smaller than the main audio wavelengths based on the original diagram. The three main components of the acoustic simulation model are the sound source, the sound propagation path, and the receiving point. The propagation paths are mainly related to the creation of the AutoCAD model of the entire village, and all elements of the village that are directly tied to the simulation, such as buildings, water surfaces, wooded areas, and roads in the village, are required to be accurately located. In addition, the RAYNOISE software has two main types of receiving point establishment: independent receiving points and grid evaluation. The two and three-dimensional models of Huanggongwang village are given in Fig. 1.

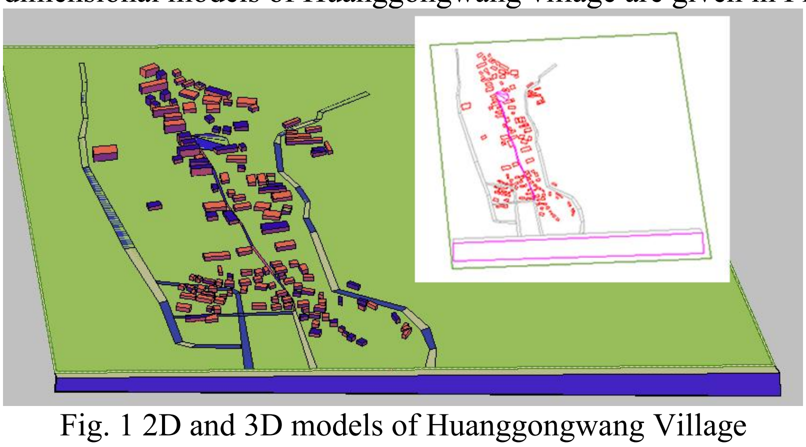

Fig. 1 2D and 3D models of Huanggongwang Village

After the geometric model of Huanggongwang Village has been created, the geometric model and the corresponding computational field points and surfaces need to be imported into the RAYNOISE software. Details of the geometric model import process are as follows (Fig. 2).

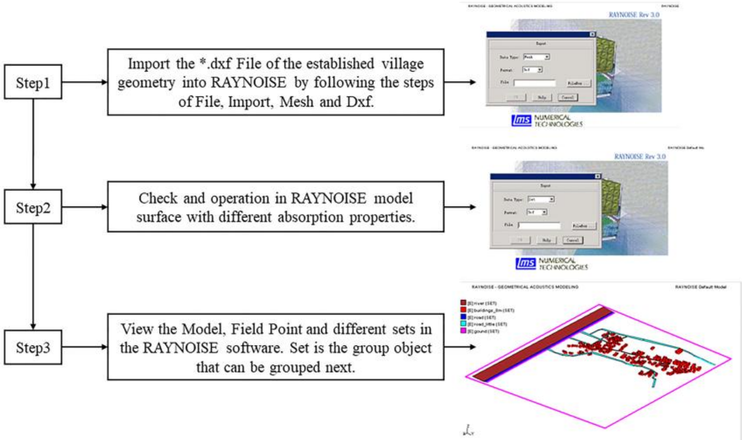

Fig. 2 Steps of importing the geometric model into RAYNOISE software

After importing the geometric model of the village into the RAYNOISE, the acoustic modeling calculation is to be performed. The positioning and definition of the sound source, the boundary conditions, and the placement of the reception point are the main components of acoustic modeling computation. And the sound sources in RAYNOISE's simulation platform must be defined and numbered first. The main sound sources in Huanggongwang village are traffic noise above Jiangbin East Avenue to the south of the village and social life noise from the village residents. The domestic noise in the hamlet is defined as a point source in the simulation model, whereas traffic noise is considered a line source. According to the site traffic noise measurement results, line sources here should be defined as 70 dB and point sources as 50dB. Roads, buildings, green areas, ponds, etc., have different acoustic boundary conditions; based on the investigation of the site, the simulation model of houses, roads, grass, and other diverse materials (Table 1.) determines the acoustic characteristics (Table 2.).

Table 1. Properties of materials selected for the simulation model of Huanggongwang Village

Location	Selection of materials in RAYNOISE
Fence, ground	Concrete Painted
House, Residence	Concrete
Grassland	Grass
Road	Pitch
Water surface	Water

The spectrum of sound absorption coefficients corresponding to each material in the table (Table 2.) is as follows.

Table 2. Sound absorption coefficients corresponding to octave center frequencies of boundary materials

Type/ Frequency(Hz)	Concrete	Grass	Concrete Painted	Pitch	Water
63	0.03	0.23	0.02	0.07	0.01
125	0.04	0.34	0.02	0.07	0.01
250	0.05	0.55	0.03	0.07	0.01
500	0.06	0.6	0.04	0.05	0.01
1k	0.06	0.42	0.04	0.05	0.02
2k	0.07	0.55	0.05	0.04	0.02
4k	0.09	0.56	0.07	0.31	0.02
8k	0	0.5	0	0.31	0.02

Before the simulation model is calculated, the receiving point must be specified. The sound environment quality map is generated under the joint action of traffic noise and social life noise in the village. Since all field measurement reference points took noise monitoring at the height of 1.2 m relative to the ground, all the receiving points were also set at the same height for the simulation calculation to keep in line with the field measurements. Therefore, the noise map of Huanggongwang Village calculates the receiving surface at the height of 1.2 m relative to the ground, and the calculation grid is 20 m×20 m.

2.2 Simulation Results and Discussion.

After establishing the geometric model of Huanggongwang Village, simulations were performed in the RAYNOISE. The sound field distribution is demonstrated (Fig. 3), and the simulation results of each measurement point in the residential area (Table 3.) are as follows.

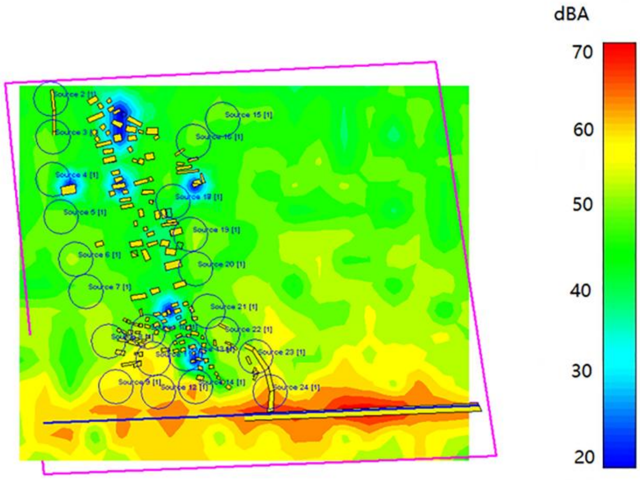

Fig. 3 Distribution of sound field in Huanggongwang Village

Table 3. Acoustic simulation results for each measurement point in Huanggongwang Village

Measurement points(dB)/ Frequency(Hz)	A1	A2	A3	A4	A5	A6
63	31	23.3	46	51.7	62.7	40.7
125	31	36.3	53.6	51.2	46.8	48.5
250	44.3	51.8	52.3	58	54.4	57.8
500	47	48.9	47.1	47.9	58.9	60.9
1k	45.6	48.5	48.4	48.6	62	62.9
2k	43.6	49.4	48.1	54.4	63.5	65.7
4k	42.9	48.5	43.5	41.5	62.2	63.9
8k	42.7	48.1	48.2	51	62.4	64.2
L_{Aeq}	39.7	45.3	45.2	48	59.2	61.2

From the above results, it can be observed that the traffic noise on Jiangbin East Avenue has a relatively limited impact on the residential area of Huanggongwang Village due to the long and narrow layout of the village from south to north along with the green belt of about 20m width between the Avenue and the residential area of the village. Table 3. shows the acoustic simulation results of A1-A6 within Huanggongwang Village when only the traffic noise impact is considered. It can be seen that the traffic noise around the village does not have a significant impact on the village's acoustic environment. Furthermore, due to the long and narrow shape of the village layout from south to north, the sound pressure level at points A1-A4 is lower than 50 dB, except for the two points A5 and A6, which are closer to Jiangbin East Avenue. The above results show that a reasonable village layout and road traffic planning like Huanggongwang can make the sound environment of the residential areas less affected by traffic noise, and the reference to such village layout and traffic planning can effectively improve the sound environment of roadside villages and enhance the quality of life of their residents.

3. Sound Environment Measurement

3.1 Sound Environment Evaluation Method.

Since noise has many adverse effects on physical and mental health, regulatory standards are required to limit the permissible range and control standards for noise. Among the numerous standards for acoustical environment evaluation, the evaluation standards related to residential area acoustical environment mainly include GB3096-1993 “Urban Area Ambient Noise Standards” [11], HJ/T2.4-1995 “Technical Guidelines for Environmental Impact Assessment - Acoustical Environment” [12]. And in field measurement and simulation analysis of the sound environment, GB/T3222-94 “Acoustic Environmental Noise Measurement Methods” [13], GB/T15190-94 “Technical Specification for the Classification of Applicable Areas of Urban Regional Environmental Noise” [14], GB12523-90 “Noise Limits for Construction Site Boundaries” [15], GB12524-90 “Construction Site Noise Measurement Method” [16], and many other sound environment evaluation standards are involved. The arithmetic means the method is as follows.

$$\mathrm{L} = \frac{1}{n}\sum_{i=1}^{n} L_i \quad (1)$$

Where is the value of the sound pressure level monitored at the ith monitoring point, and n indicates that there are n monitoring points.

For the comprehensive evaluation of the regional sound environment, the pollution index method is commonly applied, and the following formula determines the regional noise pollution index.

$$P_N = \frac{L_{eq}}{L_b} \quad (2)$$

Here, L_{eq} is the regional average equivalent A sound level, and L_b is the benchmark value, generally taking the outdoor high annoyance noise level of 75 dB(A) as the benchmark value. After calculating P_N, the sound environment quality level was found below (Table 4.).

Table 4. Sound environment quality level

Grade	Classification Name	P_N	Leq(dB(A))
I	Quiet	<0.60	<45
II	Quieter	0.60 - 0.67	45 - 50
III	General	0.67 - 0.75	50 - 56
IV	Make a lot of noise	0.75 - 1.0	56 - 75
V	Very noisy	>1.0	>75

Although the arithmetic average has certain defects, the measured sound pressure level value for each monitoring point is, to some extent, highly contingent. However, if the evaluation of the noise source characteristics is excluded, the derived mean is not very valuable for improving the sound environment. Therefore, in this study, the arithmetic means method and the noise pollution index method are combined to evaluate the overall sound environment quality in Fushui village, and the sound environment of the village is visually represented at different levels.

3.2 Measurement Scheme and Results.

Huanggongwang Village, located in Dongzhou Street, Fuyang District, Hangzhou City, Zhejiang Province, 7 km east of Fuyang District, is one of the model villages of beautiful countryside with a superior location. To the south of the village, the city’s first-class highway Jiangbin East Avenue crosses the village, and two cement roads cross the north and south of the village, with a width of 6 meters. There is a pond in the village and a ditch connecting the pond runs through the village, and the Fuchun River is to the south of the village. The geographical location of Huanggongwang Village (Fig. 4) is as follows.

Fig. 4 Overview of Huanggongwang Village (Red line area in the figure)

Sound environment monitoring was conducted for the whole village to have a detailed understanding of the acoustic environment of Huanggongwang Village. Considering that the noise sources in the village are mainly the traffic noise produced by the vehicles on Jiangbin East Avenue and the social life of the village residents, the measurements focused on the traffic noise and the monitoring of the sound environment in the village. All noise monitoring times were chosen to be conducted in clear, windless weather conditions. The main equipment employed in the measurements is shown in Table 5. In the layout of Huanggongwang Village, the red area is the residential area of the village; the green area is the Fuchun River at the south of the village; the magenta area is the pond and small river in the village, and the gray area is the main road in the village (Fig. 5). A1-A6 are the measurement points of the residential area in the village, and R1-R5 are the measurement points of the road traffic noise.

Table 5. Sound environment measurement equipment in Huanggongwang Village

Number	Equipment name	Quantity
1	Norsonic Model N118 Sound Level Meter	2 sets
2	B&K Sound Level Calibrator (Model 4230)	1pc
3	Auxiliary recording equipment	2 sets

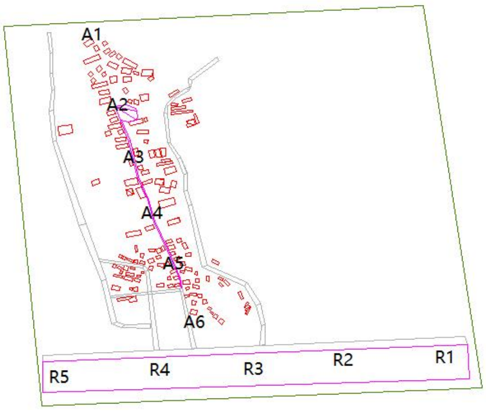

Fig. 5 Location of sound environment measurement points in Huanggongwang Village

In the first measurement, through the preliminary survey and site investigation, we found that the most influential external factor for the sound environment in Huanggongwang Village is the traffic noise on Jiangbin East Avenue. Jiangbin East Avenue, along the Qiantang River, is one of the main roads connecting both downtown Hangzhou and Fuyang, and it is a two-way 6-lane road with a speed limit of 80 kilometers per hour. To properly grasp the noise condition of Jiangbin East Avenue, five points were designated along the roadside within the village area. Each measurement was conducted for 20 minutes (Nor118 sound level meter microphone at the edge of Jiangbin East Avenue 1.2 meters above ground level). Noise measurements were taken while manually recording the one-way traffic flow of all types of vehicles near the village side. And road traffic noise measurements (Table 6.) and traffic flow data (Table 7.) are as follows.

Table 6. Noise Measurement results of Jiangbin East Avenue in the evening

Measurement points(dB)/ Frequency(Hz)	R1	R2	R3	R4	R5
63	65	69.9	67.9	74.2	69
125	58	63	59.4	65.5	63.9
250	51.3	62.4	57.1	66.2	63.8
500	50.9	58.9	52.9	60.7	60.1
1k	53.2	55	54.6	58.8	60.1
2k	51.1	50.8	50.4	54.6	58.7
4k	66.8	59.6	52.6	53.9	55.3
8k	70.6	61.4	55.2	54.1	55.3
Leq	73.6	77.5	74.3	80.4	77.8
LAeq	72	70.3	64.6	69.4	70.9

Table 7. Traffic flow of Riverside East Avenue in the evening

Measurement points(dB)/ Type	R1	R2	R3	R4	R5
Sedan	61	109	71	92	178
Lorry	5	7	4	9	11
Large Bus	15	14	13	11	15
Total	81	130	88	112	204
Equivalent hourly traffic flow	405	650	440	560	1020
Heavy Vehicle Ratio	24.20 %	16.20%	19.70%	17.90%	13%

In the second measurement, measurements of the sound environment of Jiangbin East Avenue were carried out mainly at night to investigate the effect of traffic noise on the village sound environment in nighttime conditions. The same points R1, R2, R3, R4, and R5 were selected for monitoring and measured with a Nor118 sound level meter. 20 minutes of measurements were taken at each point in turn. Furthermore, the one-way traffic flow of all vehicles near the village side was manually recorded simultaneously as the measurements. The results of road traffic noise measurements (Table 8.) and the traffic flow data (Table 9.) are shown as follows.

Table 8. Noise measurement results of Jiangbin East Avenue at night

Measurement points(dB)/ Frequency(Hz)	R1	R2	R3	R4	R5
63	70.4	71.1	66.5	63.9	68.6
125	65	63.2	59.6	57.6	60.7
250	64.9	70	57.4	59.3	63.9
500	60.6	62.6	53.6	56.4	62.1
1k	54.1	59.6	55.8	54.6	55.9
2k	48.6	55.8	50	50	54.7
4k	56.7	47.9	49.3	51.6	48.7
8k	57.4	48.8	50.3	53	46.9
Leq	78.9	77.1	73.6	73.1	76.5

Table 9. Traffic flow on riverside avenue east at night

Measurement points(dB)/	R1	R2	R3	R4	R5

Type					
Sedan	31	67	54	61	68
Lorry	2	2	3	3	4
Large Bus	5	3	5	5	8
Total	38	72	62	69	80
Equivalent hourly traffic flow	185	310	310	345	400
Heavy Vehicle Ratio	19.40%	6.90%	13.50%	11%	14.80%

3.3 Analysis of Measurement Results.

In the two measurements, traffic noise monitoring was conducted on Jiangbin East Avenue in the evening rush hour and at night when the traffic flow was relatively low. And detailed measurements of the overall sound environment in the village were performed during the morning and afternoon hours, and the data from these two measurements were used as the primary basis for analysis. For Huanggongwang Village, although the southern part of the village has Jiangbin East Avenue and the road traffic volume is high, the measured results indicate that the equivalent A sound level on Jiangbin East Avenue is about 70 dB(A), and the measured sound pressure levels at points A1-A6 exceed 60 dB(A). Therefore, the interference of Jiangbin East Avenue noise on the sound environment in the village is persistent.

From the above actual measurement data, it can be noticed that during the first measurement of the local sound environment of Huanggongwang Village, it was found that the equivalent A sound level at all selected measurement points exceeded 60 dB(A), and the equivalent A sound level at point A5 during the second measurement was more than 80 dB(A). According to the arithmetic mean method, the average sound pressure level L = 62.4 dB in Huang Gongwang Village during the first measurement, and then according to the noise index method, it was concluded that the regional PN = 0.83, resulting in a sound environment quality level of noisy in Huanggongwang Village.

4. Conclusion

Based on the theoretical analysis, the results show that the combination of the arithmetic mean method and the noise pollution index method can better represent the characteristics of sound sources in the outdoor environment and exclude the chance in the actual measurement results, thus better measuring the quality level of the rural sound environment compared with the traditional noise evaluation standards. The average sound pressure level measured on-site in Huanggongwang Village was 62.4 dB(A), and the PN index was 0.83, classified as a noisy environment. The quiet rural sound environment in the past no longer existed. Based on the layout of houses, roads, and water systems in Huanggongwang Village, the project established a local rural acoustic simulation model using RAYNOISE; the model can directly calculate and display the sound pressure level at any location in the three-dimensional space based on the distribution of arbitrary sound sources on the three-dimensional model, and validate the model with actual measurement results. By calibrating the traffic noise and domestic noise sound sources in the Huanggongwang Village, the accuracy of the noise map can be improved, which is conducive to the generation of intuitive and highly accurate noise maps for assisting in optimizing the planning of rural roads, water systems, and excursion routes, which can lessen the impact of noise on residential areas and help create a quiet and beautiful countryside.

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