Environmental noise has a major negative impact, causing interference for people to communicate, rest, sleep, and general annoyance. In order to control urban environmental noise, simulation-based optimisation for urban environmental noise is conducted. On the basis of the current acoustic environment of Zhaohui Campus of Zhejiang University of Technology, three optimisation plans that include noise barrier optimisation, greenbelt optimisation, and a combination optimisation of noise barrier and greenbelt are proposed. IQ_hesescenariosaresimulatedusingNoiseSystemsoftwaretoobtaintheirabilitytoreducenoiseanddeterminearauditoryperceptionbyusingdifferentcontrolmeasures. To determine the visual perception of the optimisation plan, 100 people of different age groups were randomly selected, and each person scored the noise barrier and the greenbelt in the simulated scenarios. Resultsofthecomprehensiveevaluationofauditoryandvisualperceptionshowthatnoise barriers can provide better auditory feelings, but greenbelts can provide a better auditory and visual subjective experience. Therefore, in addition to the application of noise control measures, their visual design must be fully considered. Moreover, the visual perception of plants is stronger than that of others.

1. Introduction

With the rapid development of the world economy and urbanization, environmental noise is ubiquitous in human lives in industrialised countries [1]. Besides, countries like India, China, Brazil, and South Africa, which are emerging countries, also suffer from noise pollution [2]. Studies have shown that traffic noise has a serious impact on the human body and mind [3, 4]. For example, roadway noise can cause stress, which can lead to mental illness [3] and sleep disorders and may affect persistent stress reactions of the respiratory health (Ikenna, et al., 2018). And the noise impact of the whole railway infrastructure is characterized in the urban environment [5]. The noise generated by passing trains can cause irritability, headaches, poor concentration, and insomnia for residents. The aircraft is the most disturbing noise sources among the transport infrastructures [6]. The noise surrounding airports impairs sleep [7]. Meanwhile, some noise level models in estimating urban traffic noise in roads of continuous traffic flow, such as a highway in an urban setting, are discussed [8]. These impacts are detrimental to human health and perception. Environmental noise should be considered in public policies. Annoyance is related to the nonauditory effects of noise, such as physical and mental health problems [9–11]. Basner et al. [12] believed that noise is ubiquitous in everyday life and may cause auditory and nonauditory health effects. Auditory health effects include hearing loss and tinnitus caused by noise, and the nonauditory health effects are perceptual disorders and annoyance, cognitive impairment, sleep disorders, and cardiovascular health problems. Studies have proven that persistent annoyance over a long period of time can serve as an intermediary between noise exposure and disease emergence [10, 13]. In addition, noise perception
is not always determined by sound pressure intensity; it also depends on the quality and background of the sound, current activities, and participation of the recipient, individual attributes, and attitude towards the sound source and so on [12, 14]. The noise problem in the city endangers the health of urban residents and poses a threat to the sustainable development of the city if it is not improved and controlled [15–18]. Especially, smart noise solutions should be provided to design smart cities [19].

Scholars have carried out extensive research on the methods to reduce the impact of noise and different noise reduction measures since the 1970s [20–26]. Many measures to control noise are currently available.

Among them, using environmental noise barriers to attenuate the impact of noise is considered very effective and feasible [25]. Recent studies have further shown that setting noise barriers in noise-sensitive areas can greatly reduce the effects of noise. Bougah et al. [27] found that noise barriers with ribbed structures can provide 10 dB to 15 dB insertion loss IL. Arenas [28] found that noise barriers can improve sleeping conditions, but noise barriers resulted in the loss of sunlight and visual impact. And the difference in sound pressure intensity at a fixed point in the sound field before and after the sound barrier was installed. Using plants to reduce noise is an effective and practical method in situations when the target is not very high [21]. A belt of grown trees whose width is greater than 7 m provides a medium attenuation of 2 dB to 4 dB [29]. A belt of tall and dense trees with a width of 15 m to 40 m provides 6 dB to 8 dB noise attenuation at low frequency (250 Hz) and high frequency (above 1000 Hz) [30]. Plants’ ability to reduce noise, which is better than that of open grassland, should be brought to attention [31]. Important factors for noise reduction include the visibility of the greenbelt (the distance at which an object becomes obscured by the forest belt), width, height, and length [32]. Improving road conditions also reduce noise effectively. Ogren et al. [23] found that the introduction of low noise tires or road surfaces reduced the exposure of urban residents to 55 dB equivalent sound pressure levels by 13% to 29% compared with the previous result. Tang and Wang [33] analyzed the effects of different urban forms on ambient noise intensity. Silva et al. [34] believed that the impact of noise on the facade could be minimized by adjusting city layouts.

The urban morphology has an important impact on urban environmental noise [35]. The soundscape which can be classified into relaxation, communication, spatiality, and dynamics is usually used as a key method to improve the sound quality in urban open spaces [36, 37]. Computer simulations can help evaluate the soundscapes of urban open spaces. These findings provide important guidance on urban design and the improvement of noise-sensitive areas affected by noise. However, most studies mitigated noise by adopting one single control measure, but using a combination of measures can reduce noise more effectively. Secondly, the single function of the study area leads to a shortage of improved methods for a multifunctional area affected by noise, and different functional zones have different requirements for noise reduction. For example, the sound pressure level acceptable for sports areas and squares is higher than that of residential areas. Finally, considering the interaction between sound and vision is important, that is, auditory perception can be improved by visual cues, and similarly, sound helps focus attention on related visual elements [38]. Besides, the prioritization process also should be considered in noise action plans [39].

Environmental noise is considered an important factor that affects human health. For example, traffic noise pollution has a significant impact on occupants’ health who live in high-rise buildings along noisy traffic arteries [40]. One of the main challenges facing urban planning is the creation of urban spaces to provide residents with a high quality of life. At present, in addition to the basic functions, visual effects and landscape quality are increasingly valued urban space requirements. People are not only satisfied with improved auditory perception in noise-exposed areas but also pay more and more attention to the visual effects of optimisation measures [41]. Hes et al. [42] believed that natural green plants can improve the perception of noise. In addition, as aesthetic preferences and expectations of noise reduction increase, barriers covered by plants can improve the perceived noise control performance, thereby amplifying their noise reduction capabilities [43]. If we do not focus on visual quality in noise reduction intervention, then the quality of spatial perception may deteriorate [41].

Site measurements of the campus acoustic environment were carried out at different time periods in a university with multiple functional zones to determine the current acoustic environment of the campus. Then, a campus noise simulation model was built and validated on the basis of the site measurement data. Taking the campus of Zhejiang University of Technology as an example, an optimisation plan corresponding to its acoustic environment is proposed by simulating three optimisation plans to analyze the degree of noise reduction and evaluate the noise levels of the entire campus and each functional zone after the noise reduction measures were applied. The effects of the three optimisation plans on human perception from auditory and visual subjective evaluations were comprehensively evaluated, given that the interaction of sound and vision affects human perception [41]. The evaluation was conducted using scores, and the plan with the highest auditory and visual comprehensive score was the optimal one.

Using a case of Zhaohui Campus of Zhejiang University of Technology, our specific objectives are to (1) establish the frame of simulation-based optimisation for urban environmental noise; (2) assess the current distribution of noise in Zhaohui Campus of Zhejiang University of Technology; (3) conduct the acoustic environment simulation after optimisation that includes noise barrier optimisation, greenbelt optimisation, and a combination optimisation of noise barrier and greenbelt; and (4) analyze the auditory and visual subjective evaluation.

2. Materials and Method

2.1. Study Area. Zhaohui Campus of Zhejiang University of Technology covers an area of 597000 m². Located in
downtown Hangzhou, it is surrounded by roads on all sides with two elevated roads to its west and north and boats crossing the river from time to time across campus (see Figure 1). Therefore, this area contains almost all the factors that affect the acoustic environment of the campus. The factors include noise sources, trees, and off-campus buildings.

We used functional zone and sound identifiers to indicate the function of different functional zones and sounds that can be heard frequently in different zones (see Figure 2). These sounds are related to the activities in this zone; although some activities take place outside the zone, they can still be heard clearly. However, some sounds can only be heard within a specific functional zone. Thus, we used specific approaches to describe typical zones.

The sound identifiers in Figure 2 indicate that the sounds that may be heard in different functional zones on the campus were identified. These sounds that come from the campus are recommended to be retained. It includes the sounds of peaceful everyday life around the dormitories and the sounds of active sports around the sports facilities during the day. Meanwhile, roadway noise can be mitigated by providing new activities on the campus to generate new sounds. For example, building soundscapes such as fountains and music corridors in appropriate places on the campus can generate new sounds.

2.2. Technical Route. The technical route is shown in Figure 3. The acoustic environment of the research object was measured on site, and the reliability of the simulation results was tested by comparing the simulation results of the regional model with the measured results. Subsequently, the three optimisation plans were modeled and simulated. Finally, the optimal optimisation plan was determined based on the auditory and visual subjective evaluation of different optimisation plans coupled with objective evaluation.

2.3. Measurement Method. In accordance with the Chinese standards of Measurement Method of Environmental Noise in Urban Area, each measuring point was measured once in the daytime between 8:00 and 11:30 am or 1:00 and 5:00 pm and once at night between 10:00 pm and 4:00 am. Duration of 10–15 minutes each time was selected in this study. Values that were measured for evaluation include the equivalent sound level $L_{eq}$, the maximum sound level $L_{max}$, and the minimum sound level $L_{min}$. The equipment used for the measurements is AS804. It is Class 1.

In accordance with the control map of the measuring points in the quiet zone and the noise-exposed zone, the points were evenly distributed, and typical dates (weekdays and weekends) were selected for measurement. The calculation grid with a height of 4 m was recommended by EC Directive 2002/49. And the calculation grid with a height of 1.2 m was recommended by Measurement Method of Environmental Noise in Urban Area in China. Meanwhile, ear height is generally 1.5 m. Therefore, the calculation grid was at a height of 1.5 m away from the building façade (4 m away). To more accurately determine the campus acoustic environment, 119 points were set on campus, eight on the road, and six in the off-campus gymnasium, with a total of 133 points (Figure 1(b)); each point was measured to obtain its equivalent A sound level. The grid size can be designed as $10 \times 10$ m since these areas are more densely populated areas [44]. Therefore, the size of the grid used to calculate the acoustic maps was $10 \times 10$ m in this study.

The speed of vehicles traveling on and off campus was not measured. The reason is that the simulation model does not need to set original vehicle speed, and the vehicle speed is obtained by inputting noise variables and vehicle flow measured by vehicles traveling on and off campus. Then the speed of vehicles can be assessed by the simulation model. Road noise is one of the main sources of noise [2]. The roads in the east, west, and north are the main roads with large traffic. There are about 750 small cars, 250 medium cars, and 120 large cars per hour on these roads. There are about 700 small cars, 200 medium cars, and 100 large cars per hour on the road in the south area.

Following Class 1 indicators in GB 3096–2008 [45] “Environmental Quality Standard for Noise” (Appendix, Table A1), we evaluated the measured and simulated values of the measuring points in the study area.

The UK’s planning policy guidance 24 (Appendix, Table A2) classifies the Noise Exposure Categories (NEC) into A to D [46]. A indicates an environment where noise is not the determining factor, D is the case where regular development should not be approved, and B and C involve noise control measures before development is considered acceptable. The policy will be used for auditory subjective evaluation in the auditory and visual subjective evaluation methods.

2.4. Simulation Method. The simulation model was established based on the current situation of Zhaohui Campus of Zhejiang University of Technology. The calculated height of the grid in the model is 1.5 m, which is consistent with the measured height of the selected measuring points. The number and position of acceptance points in the simulation software are the same as those of the actual measuring points, and these points are used only as acceptance points in the simulation software instead of sound sources in the calculation. They are used in the validation and evaluation of the simulation data and the actual measured data. The noise reduction method of the NoiseSystem software is the calculation model of sound attenuation due to outdoor propagation in the Chinese standard “Technical Guidelines for Environmental Impact Assessment—Sound Environment.” The NoiseSystem software is developed by Huan’an Technology Co., Ltd. The calculation formula is as follows: 

Octave band sound pressure level is calculated using the following equation:

$$L_p (r) = L_p (r_0) - (A_{div} + A_{atm} + A_{bar} + A_{gr} + A_{misc}),$$

(1)

where $L_p (r_0)$ is the octave band sound pressure level at the reference point; $A_{div}$ is the sound attenuation due to propagation; $A_{atm}$ is the absorption attenuation in the air; $A_{gr}$ is the absorption attenuation by the ground;
Figure 1: Zhaohui Campus of Zhejiang University of Technology: (a) campus map, (b) control map of acoustic environment measuring points, and (c) map of functional zones.

Figure 2: Diagram of functional zone and sound identifiers.
A bar is the attenuation caused by barriers; and A misc is the attenuation caused by other multiple factors. A sound level of predicted points is given by

\[ L_A(r) = 10 \log \left( \sum_{i=1}^{k} 10^{0.1(L_{pi}(r)-\Delta L_i)} \right). \]

where \( L_{pi}(r) \) is the \( i \)-th octave band sound pressure level at predicted point \((r)\), dB; and \( \Delta L_i \) is the correction value using the A-weighting network of the \( i \)-th octave band.

2.5. Auditory and Visual Subjective Evaluation. With the improvement of human quality of life, the subjective influence of noise on people has received increasing attention. In recent years, more studies have been conducted on the subjective evaluation of sound pressure levels. The relationship between annoyance and noise exposure (i.e., equivalent sound level \( L_{eq} \)) in particular has been studied thoroughly [47–50]. Lambert et al. divided traffic noise annoyance in the daytime into three levels: 55 dB, no annoyance; 55 dB to 60 dB, some annoyance; and >60 dB, annoyance [51].

The research area of this study is mainly affected by roadway traffic noise and less by other sound sources. Thus, analyzing the relationship between different sound pressure levels and annoyance is necessary. Following the roadway traffic noise exposure levels (ENC) in Appendix Table A2, the level of acceptance (the degree of annoyance caused by different sound pressure levels) is divided into four levels: level 1, no annoyance; level 2, little annoyance; level 3, certain annoyance; and level 4, severe annoyance. These levels correspond to A to D in the roadway traffic noise exposure level (ENC) table. Then, the level of acceptance in the study area is determined based on the average equivalent sound level of this area and is scored as follows: level 1, 10 points; level 2, 5 to 10 points; level 3, 0 to 5 points; and level 4, 0 points. Interpolation is used to determine the specific score in levels 2 and 3.

In recent years, the number of studies on the visual subjective influence of noise control measures has increased [43, 52]. Landscaping plants seen from the living room window facing urban ring roads significantly reduce noise annoyance [53]. Sanchez et al. [41] believed that improving the visual design of barriers can effectively provide more pleasure and that plants provide stronger visual perception than other objects.
Therefore, the visual perception of the three optimisation plans is evaluated. Each measure was given a score with a linear scale of 11. The score, ranging from 0 to 10 points, represents its visual perception. To evaluate the visual perception of different control measures, 100 people of different age groups were randomly selected and asked to fill in a questionnaire, thus enabling them to compare the visual perception brought by noise barriers and greenbelts with a score within the range of 0 to 10 points. If a control measure used a greenbelt and noise barrier in the study area, then the visual score of the area would be calculated on the basis of their weights in the length.

2.6. Selecting the Optimisation Plan. A reasonable acoustic environment optimisation plan not only has strategic significance for future noise control but is also essential for urban planning, selection of control measures, investment in human and financial resources, and human physiological psychology. Among various noise control measures, the use of plants and noise barriers to reduce noise intensity is considered effective and feasible [21, 25]. Song et al. [54] studied the temporal and spatial changes of sound elements in plant soundscapes, and Vogiatzis and Remy [25] believe that soundscape is a “landscape listening” that arouses aesthetic appreciation and sensitive response to sound, which can be considered the perceived quality of sound. Therefore, greenbelts, noise barriers, and their combination are used as optimisation measures for the study area.

3. Results and Discussion

3.1. Current Distribution of Noise. The equivalent A sound level was measured for the 133 measuring points (see Table 1). The average equivalent sound level is the average value of the equivalent sound pressure level in the study area, and the pass rate is the percentage of the area, where the equivalent sound level meets Class 1 standard in different areas (see Figure 4). The site measurement results show that in the daytime, the entire campus is relatively quiet, thus providing a favorable environment for teachers and students to study and relax. However, the average equivalent sound level at night is high, thereby affecting their sleep. The average equivalent sound pressure level in the functional zones adjacent to roads (sports zone, teaching zone 1, and test zone) is relatively high, with a pass rate lower than that of other functional zones.

3.2. Validation. The simulated results obtained by the NoiseSystem software are shown in Figure 5. The four simulation diagrams show a high sound pressure level in the campus peripheral area and the area adjacent to the river, given that most of these areas are exposed to noise and that the sound pressure level of some parts close to sound sources even exceeds 70 dB. By contrast, the acoustic environment of zones protected by other elements and located far from sound sources is relatively good.

The simulation results of the current conditions (see Table 2) indicate that the average equivalent sound pressure level of functional zones close to the road (sports zone and test zone) is above the standard, and people become affected by noise. Considering that buildings in important zones (dormitories 1 and 2, teaching zones 1 and 2, and the library) are far from other buildings in the same zone, the buildings along the road create a more enclosed and long space that isolates and attenuates traffic noise to protect the buildings behind them, thereby resulting in lower sound pressure levels in these five functional zones than in others. The library is highly qualified due to excessive protection and its location far away from the road. The simulation results (see Figure 5) also show that the sound pressure level at night in the same zone is generally lower than that during the daytime. In general, the simulation results are consistent with the site measurement.

To prove the reliability of the simulation results, the measured and simulated values of control points on the entire campus and in different functional zones need to be compared through validation (see Figure 6). The comparative analysis of the measured data and simulated data of all control points on campus showed that the accuracy rate is above 94% (the closer slope of the line to 1 indicates higher fitting degree), thereby indicating that the simulated values and the measured values are well fitted. It shows that the two functional partitions with great differences in different time periods are the library and the test area. Due to the small area of these two areas, fewer control points are arranged in them. The library is surrounded by a well-developed transportation network. Thus, the zone is relatively noisy, resulting in a higher measured value than the simulated data. Nonetheless, the overall simulated value is close to the measured value.

3.3. Acoustic Environment Simulation after Optimisation

3.3.1. Noise Barrier Optimisation. Noise barriers with a height of 4 m were installed in zones under the influence of severe traffic noise and along the river (see Figure 7). Zones under the influence of severe traffic noise include sports zone, teaching zone 1, and peripheral test zone. Installing sound barriers around noise-sensitive zones on the campus can greatly lower the sound pressure level near the barriers, thereby reducing the disturbance of background noise and allowing people to better receive the sound they need. Even with a probable increase in traffic noise, the campus acoustic environment can still be protected. The simulation results are shown in Figure 8. The simulation results show that installing sound barriers in appropriate places can significantly improve the campus acoustic environment, and the equivalent sound level of each functional zone is lower by varying degrees.

According to Tables 2–4, because of the installation of sound barriers, the average equivalent sound pressure level of the campus was reduced by approximately 2 dB, and the pass rate in the daytime and at night increased by over 6.3% and 12.5%, respectively. The acoustic environment of each functional zone also improved to varying degrees. The teaching zone 1, which is close to the roadway noise, obtained the maximum noise reduction (3 dB to 4 dB) because...
it became much more quiet after the installation of noise barriers, and the pass rates in the daytime and at night increased by approximately 9.15% and more than 22%, respectively. The level of annoyance in this zone became much lower, especially when the windows are open during favorable weather conditions. The test zone is close to the roadway noise, and this zone is relatively small, allowing no more space for noise reduction. Therefore, it obtained the smallest reduction in the sound pressure level (0.06dB to 0.11dB) and the least increase in the pass rate. In general, the acoustic environment of important zones was greatly improved after the installation of sound barriers.

### 3.3.2. Greenbelt Optimisation

The current block- or strip-shaped green space on the campus slightly affects noise reduction because it is only for decoration and mainly contains single plant species, such as block-shaped lawns and strip-shaped low shrubs. Therefore, greenbelts that are 10m high are set up in zones that are severely affected by noise and along the river. Zones that are severely affected by noise include sports zone, teaching zone 1, and peripheral test zone. Mainly used for noise reduction, they also perform soundscape and leisure functions. The specific action plan is shown in Figure 9.

The simulation results are shown in Figure 10. The increase in the green and yellow areas compared with the simulation map of the current status. The introduction of greenbelts as an optimisation measure has brought a certain level of improvement in the acoustic environment of the entire campus. The simulation results in Tables 3 and 4 show that under the optimisation plan of using greenbelts, the average equivalent sound levels of the campus during daytime and at night on weekdays and on weekends are 49.89 and 49.45dB, and 48.04 and 48.13dB, respectively, indicating a reduction of approximately 1.5dB compared with the simulation results of the current status (Table 2). The pass rate of the campus also increased, with more than 3.3% increase during daytime and 11.4% at night. The sound pressure level of each functional zone was also reduced to varying degrees, especially in the library, where the noise was reduced by 3dB, and the average pass rate at night increased to over 94%.

### 3.3.3. Combination Optimisation of Greenbelts and Noise Barriers

This optimisation plan combines the advantages of noise barriers and the advantages of greenbelts. The advantage of noise barriers is easy to install and good noise reduction. Meanwhile, the advantage of greenbelts is

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**Table 1: Average equivalent sound level in each zone.**

| Zone            | Weekdays daytime AESL (dB) | Weekdays daytime Pass rate % | Weekdays nighttime AESL (dB) | Weekdays nighttime Pass rate % | Weekends daytime AESL (dB) | Weekends daytime Pass rate % | Weekends nighttime AESL (dB) | Weekends nighttime Pass rate % |
|-----------------|-----------------------------|------------------------------|-----------------------------|-------------------------------|-----------------------------|-------------------------------|-----------------------------|-------------------------------|
| Campus          | 55.50                       | 63.03                        | 48.02                       | 23.53                         | 55.07                       | 47.90                         | 47.42                       | 23.53                         |
| Sports zone     | 56.63                       | 38.89                        | 52.14                       | 0.00                          | 57.76                       | 22.22                         | 51.07                       | 0.00                          |
| Teaching zone 1 | 56.73                       | 47.37                        | 51.01                       | 0.00                          | 56.47                       | 26.32                         | 50.00                       | 0.00                          |
| Teaching zone 2 | 52.49                       | 86.67                        | 46.14                       | 46.67                         | 54.37                       | 60.00                         | 45.17                       | 33.33                         |
| Library         | 53.72                       | 66.67                        | 50.67                       | 0.00                          | 55.52                       | 55.56                         | 50.57                       | 0.00                          |
| Dormitory 1     | 54.61                       | 66.67                        | 45.02                       | 51.52                         | 52.79                       | 63.64                         | 44.83                       | 45.55                         |
| Dormitory 2     | 53.73                       | 76.19                        | 47.02                       | 14.29                         | 55.54                       | 57.14                         | 46.62                       | 19.05                         |
| Test zone       | 57.53                       | 33.33                        | 46.90                       | 33.33                         | 55.90                       | 33.33                         | 46.23                       | 33.33                         |

AESL: average equivalent sound level.
reducing noise, landscaping, absorbing dust, lowering the temperature, and increasing humidity. Noise barriers are installed in zones that are severely affected by noise (the periphery of teaching zone 1 and the test zone), and greenbelts are set up along the river and around the sports zone. The action plan is shown in Figure 11.

Figure 12 shows that the overall campus acoustic environment has greatly improved, thereby reducing the level of annoyance of the teachers and students. The simulation results in Tables 2–4 show that the average equivalent sound pressure level of the campus is reduced by more than 1.7 dB, the pass rate of the daytime is over 76.7%, and the average pass rate at night is increased by 12.87%. Among all functional zones, teaching zone 2 obtained the greatest noise reduction of above 2.83. However, the noise reduction in the test zone is only approximately 0.1 dB, due to its relatively

| Zone            | Weekdays daytime AESL dB (A) | Pass rate (%) | AL Score | Weekdays nighttime AESL dB (A) | Pass rate (%) | AL Score | Weekends daytime AESL dB (A) | Pass rate (%) | AL Score | Weekends nighttime AESL dB (A) | Pass rate (%) | AL Score |
|-----------------|-----------------------------|---------------|----------|-------------------------------|---------------|---------|-------------------------------|---------------|---------|-------------------------------|---------------|---------|
| Campus          | 51.34                       | 72.02         | 1.00     | 10.00                         | 49.46         | 27.09   | 1.37                          | 8.15           | 50.93   | 74.57                         | 1.00          | 10.00  |
| Sports zone     | 57.62                       | 29.59         | 1.33     | 8.35                          | 54.50         | 0.03    | 1.79                          | 6.05           | 57.33   | 31.02                         | 1.29          | 8.55    |
| Teaching zone 1 | 50.28                       | 88.65         | 1.00     | 10.00                         | 47.88         | 52.76   | 1.24                          | 8.8            | 49.62   | 91.95                         | 1.00          | 10.00  |
| Teaching zone 2 | 46.67                       | 99.55         | 1.00     | 10.00                         | 45.43         | 68.55   | 1.04                          | 9.8            | 46.54   | 99.62                         | 1.00          | 10.00  |
| Library         | 47.71                       | 100.00        | 1.00     | 10.00                         | 46.74         | 82.51   | 1.15                          | 9.25           | 47.60   | 100.00                        | 1.00          | 10.00  |
| Dormitory 1     | 51.55                       | 88.70         | 1.00     | 10.00                         | 49.61         | 16.51   | 1.38                          | 8.1            | 50.72   | 94.45                         | 1.00          | 10.00  |
| Dormitory 2     | 50.73                       | 79.25         | 1.00     | 10.00                         | 49.75         | 36.35   | 1.4                           | 8              | 50.73   | 79.22                         | 1.00          | 10.00  |
| Test zone       | 56.40                       | 45.96         | 1.18     | 9.10                          | 53.85         | 0.00    | 1.74                          | 6.3            | 56.37   | 52.41                         | 1.17          | 9.15    |

AL: acceptance level.
Figure 6: Theoretical curve of simulated and measured values in different time periods of each functional zone: (a) weekdays daytime, (b) weekdays nighttime, (c) weekends daytime, and (d) weekends nighttime.
low sound pressure level requirements, indicating that people will not feel annoyed even if they perceive a sound pressure level higher than the standard.

3.4. Subjective Evaluation

3.4.1. Auditory Subjective Evaluation. The simulation results of the current situation in Table 2 show that the level of acceptance of the entire campus is 1.00 with a pass rate of over 72%, and only some zones evoke annoyance due to their proximity to roads. The average level of acceptance at night is 1.38, with an average pass rate of only 28.46%. Thus, people feel annoyed in most areas of the campus at night. Among the seven functional zones, the pass rate of the sports zone is only approximately 30% during the daytime. The pass rates of the test zone during the daytime on weekdays and on weekends are 45.96% and 52.41%, respectively, indicating that these functional zones are relatively noisy and
people feel annoyed in most areas. In addition, they have a pass rate of 0 at night, confirming that the two functional zones are more seriously affected by roadway noise at night.

Tables 5 and 6 show that the campus acoustic environment has improved to varying degrees after optimisation, and the level of acceptance of the entire campus has increased under different improvement plans. The installation of noise barriers reduced the level of acceptance of the entire campus the most by a total of 0.3, followed by the combination of greenbelt and sound barriers. The level of acceptance was reduced the least by the greenbelt alone, indicating that the acoustic environment of the whole campus has greatly improved by installing noise barriers. Under different optimisation plans, the acoustic environment of each functional zone has also improved to varying degrees, the level of acceptance of each zone has reduced, and the optimisation plan of using noise barriers alone is better than others. The

Figure 9: Diagram of greenbelts in the simulation zones.

Figure 10: Simulation results of the campus of Zhejiang University of Technology with greenbelt optimisation: (a) weekdays daytime, (b) weekdays nighttime, (c) weekends daytime, and (d) weekends nighttime.
### Table 3: Average equivalent sound pressure level and pass rate of each zone under different optimisation plans.

| Zone         | Noise barrier | Greenbelt | Combination arrangement |
|--------------|---------------|-----------|-------------------------|
|              | AESL dB (A)   | Pass rate | AESL dB (A) Pass rate | AESL dB (A) Pass rate | AESL dB (A) Pass rate |
|              | Weekdays daytime |            | Weekdays nighttime |            | Weekdays nighttime |            | Weekdays daytime |
|              | AESL dB (A) Pass rate | AESL dB (A) Pass rate | AESL dB (A) Pass rate | AESL dB (A) Pass rate | AESL dB (A) Pass rate |
| Campus       | 49.14 78.68 47.68 39.75 48.94 80.90 | 47.85 44.82 49.89 75.48 | 48.04 36.32 49.45 77.88 | 48.13 43.4 | 49.51 76.74 | 47.78 39.16 49.11 78.62 | 47.97 43.5 |
| Sports zone  | 55.19 40.78 51.66 0.75 54.89 43.43 | 51.60 3.61 56.51 32.69 | 53.19 0.16 56.15 33.79 | 53.05 2.49 | 55.33 32.34 | 52.07 0.63 55.00 33.46 | 51.94 3.17 |
| Teaching zone 1 | 46.88 99.52 44.79 75.13 | 46.4 99.38 | 45.5 19.14 91.20 | 46.76 65.51 48.52 92.75 | 47.15 71.85 46.63 99.76 | 45.05 84.29 46.13 100.00 | 45.44 84.93 |
| Teaching zone 2 | 44.56 100.00 43.84 95.37 | 44.17 95.86 | 44.66 99.66 | 43.54 94.1 | 44.51 99.71 | 44.65 99.66 | 43.73 82.49 44.79 99.97 | 43.95 94.95 |
| Library       | 46.18 100.00 44.17 93.62 | 46.05 100.00 | 44.40 100.00 | 44.72 100.00 | 44.84 94.48 44.88 100.00 | 44.10 96.29 45.06 100.00 | 45.38 93.58 44.94 100.00 | 45.55 94.20 |
| Dormitory 1   | 49.32 91.47 49.02 24.73 | 49.11 97.20 | 49.18 33.19 50.65 90.62 | 48.72 25.76 49.68 96.79 | 48.75 34.20 50.90 90.03 | 48.47 22.72 50.05 95.73 | 48.64 30.66 |
| Dormitory 2   | 49.29 87.59 48.20 46.86 | 49.29 88.05 | 48.34 44.87 48.78 87.31 | 47.97 46.76 48.88 88.04 | 48.03 53.75 49.22 87.39 | 48.63 44.87 49.17 87.72 | 48.85 50.56 |
| Test zone     | 56.29 46.86 53.79 0.00 | 56.26 53.29 | 54.23 0.00 56.01 52.75 | 53.35 0.00 55.86 59.36 | 53.7 0.00 56.3 46.88 | 53.79 0.00 56.25 53.33 | 54.23 0.00 |

AESL: average equivalent sound level.
Table 4: The average equivalent sound level reduction of each area compared with the current simulation results under different optimisation measures (dB (A)).

| Zone            | Noise barrier |                  |                  | Greenbelt |                  |                  | Combination arrangement |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |
|-----------------|---------------|-----------------|-----------------|-----------|-----------------|-----------------|------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | Weekdays daytime | Weekdays nighttime | Weekends daytime | Weekends nighttime | Overlay | Weekdays daytime | Weekends nighttime | Overlay | Weekdays daytime | Weekends nighttime | Overlay | Total |                 |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |
| Campus          | 2.20          | 1.78            | 1.99            | 1.84      | 7.81            | 1.45            | 1.42                  | 1.48            | 1.56            | 5.91            | 1.83            | 1.68            | 1.82            | 1.72            | 7.05            | 20.77 |
| Sports zone     | 2.43          | 2.84            | 2.44            | 2.89      | 10.06           | 1.11            | 1.31                  | 1.18            | 1.44            | 5.04            | 2.29            | 2.43            | 2.33            | 2.55            | 9.6             | 24.7 |
| Teaching zone 1 | 3.40          | 3.09            | 3.22            | 3.18      | 12.89           | 1.14            | 1.12                  | 1.10            | 1.20            | 4.56            | 3.65            | 2.83            | 3.49            | 2.91            | 12.88           | 30.33 |
| Teaching zone 2 | 3.12          | 1.59            | 2.07            | 1.66      | 8.44            | 3.01            | 1.89                  | 2.03            | 2.02            | 8.95            | 2.77            | 1.70            | 1.75            | 1.71            | 7.93            | 25.32 |
| Library         | 1.55          | 2.35            | 1.55            | 2.61      | 8.26            | 2.99            | 2.90                  | 3.02            | 3.00            | 11.91           | 2.65            | 1.43            | 2.66            | 1.46            | 8.2             | 28.37 |
| Dormitory 1     | 2.23          | 0.59            | 1.61            | 0.61      | 5.04            | 0.90            | 0.89                  | 1.04            | 1.04            | 3.87            | 0.65            | 1.14            | 0.67            | 1.15            | 3.61            | 12.52 |
| Dormitory 2     | 1.44          | 1.55            | 1.44            | 1.63      | 6.06            | 1.95            | 1.78                  | 1.85            | 1.94            | 7.52            | 1.51            | 1.12            | 1.56            | 1.12            | 5.31            | 18.89 |
| Test zone       | 0.11          | 0.06            | 0.11            | 0.10      | 0.38            | 0.39            | 0.50                  | 0.51            | 0.63            | 2.03            | 0.10            | 0.06            | 0.12            | 0.10            | 0.38            | 2.79 |
exposed area of the sports zone significantly reduced under all three optimisation plans due to its proximity to the roads, thereby leading to the greatest changes in the level of acceptance in this zone under all improvement plans. The maximum reduction in total acceptance was 1.07, indicating that the acoustic environment has greatly been optimised. The levels of acceptance of this zone on weekdays and on weekends are 1.02 and 1.00, respectively, showing a reduction by 0.31 and 0.29 and a score of 9.90 and 10. The levels of acceptance at night are 1.56 and 1.55, indicating a reduction by 0.23 and 0.24 and a score of 7.20 and 7.25. The current average equivalent sound pressure level of teaching zone 2 is very close to Class 1 standard in Appendix Table A1. Thus, this zone obtained the least changes in the total level of acceptance under all optimisation plans at only 0.15.

Figure 11: Diagram of setting up combination optimisation of greenbelts and noise barriers in the simulation zones.

Figure 12: Simulation results of the campus of Zhejiang University of Technology with combination optimisation of greenbelts and noise barriers: (a) weekdays daytime, (b) weekdays nighttime, (c) weekends daytime, and (d) weekends nighttime.
Table 5: Acceptance level and scores of different regions under different optimisation measures.

| Zone       | Noise barrier |          |          |          |          |          |          |          |          |          |          |          | Combination arrangement |
|------------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|--------------------------|
|            | Weekdays      | Weekdays | Weekends | Weekends | Weekdays | Weekends | Weekends | Weekdays | Weekends | Weekdays | Weekends | Weekends | Weekends | Weekends |
|            | daytime       | nighttime| daytime  | nighttime| daytime  | nighttime| daytime  | nighttime| daytime  | nighttime| daytime  | nighttime| daytime  | nighttime|           |
|            | AL | Score | AL | Score | AL | Score | AL | Score | AL | Score | AL | Score | AL | Score | AL | Score | AL | Score | AL | Score | AL | Score |
| Campus     | 1.00 | 10.00 | 1.22 | 8.90 | 1.00 | 10.00 | 1.24 | 8.80 | 1.00 | 10.00 | 1.25 | 8.75 | 1.00 | 10.00 | 1.26 | 8.70 | 1.00 | 10.00 | 1.23 | 8.85 | 1.00 | 10.00 | 1.25 | 8.75 |
| Sports zone| 1.02 | 9.90 | 1.56 | 7.20 | 1.00 | 10.00 | 1.55 | 7.25 | 1.19 | 9.05 | 1.68 | 6.60 | 1.14 | 9.30 | 1.67 | 6.65 | 1.04 | 9.80 | 1.59 | 7.05 | 1.00 | 10.00 | 1.58 | 7.10 |
| Teaching zone 1 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.01 | 9.95 | 1.00 | 10.00 | 1.15 | 9.25 | 1.00 | 10.00 | 1.18 | 9.10 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.04 | 9.80 |
| Teaching zone 2 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 |
| Library    | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.00 | 10.00 | 1.03 | 9.85 | 1.00 | 10.00 | 1.05 | 9.75 |
| Dormitory 1 | 1.00 | 10.00 | 1.34 | 8.30 | 1.00 | 10.00 | 1.35 | 8.25 | 1.00 | 10.00 | 1.31 | 8.45 | 1.00 | 10.00 | 1.31 | 8.45 | 1.00 | 10.00 | 1.29 | 8.55 | 1.00 | 10.00 | 1.30 | 8.50 |
| Dormitory 2 | 1.00 | 10.00 | 1.27 | 8.65 | 1.00 | 10.00 | 1.28 | 8.60 | 1.00 | 10.00 | 1.25 | 8.75 | 1.00 | 10.00 | 1.25 | 8.75 | 1.00 | 10.00 | 1.30 | 8.50 | 1.00 | 10.00 | 1.32 | 8.40 |
| Test zone  | 1.16 | 9.20 | 1.73 | 6.35 | 1.16 | 9.20 | 1.77 | 6.15 | 1.13 | 9.35 | 1.70 | 6.50 | 1.11 | 9.45 | 1.73 | 6.35 | 1.16 | 9.20 | 1.73 | 6.35 | 1.16 | 9.20 | 1.77 | 6.15 |

AL: acceptance level.
Table 6: Reduction in acceptance level of each region compared to the simulation results under different optimisation measures.

| Zone            | Noise barrier Weekdays | Noise barrier Weekdays | Noise barrier Weekends | Noise barrier Overlay | Greenbelt Weekdays | Greenbelt Weekdays | Greenbelt Weekends | Greenbelt Overlay | Combination arrangement Weekdays | Combination arrangement Weekdays | Combination arrangement Weekends | Combination arrangement Overlay | Total |
|-----------------|-------------------------|-------------------------|------------------------|-----------------------|-------------------|-------------------|-------------------|-------------------|-------------------------------|-------------------------------|-----------------------------|-----------------------------|-------|
|                 | Weekday                | Weekday                | Weekends               |          | Weekdays            | Weekdays            | Weekends           |          | Weekdays                | Weekdays                | Weekends                | Overlay                |       |
| Campus          | 0.00                   | 0.15                   | 0.00                   | 0.15     | 0.30               | 0.00                | 0.12               | 0.00               | 0.13             | 0.25             | 0.00             | 0.14             | 0.00             | 0.14     |
| Sports zone     | 0.31                   | 0.23                   | 0.29                   | 0.24     | 1.07               | 0.14                | 0.11               | 0.15               | 0.12             | 0.52             | 0.29             | 0.20             | 0.29             | 0.21     |
| Teaching zone 1 | 0.00                   | 0.24                   | 0.00                   | 0.27     | 0.51               | 0.00                | 0.09               | 0.00               | 0.10             | 0.19             | 0.00             | 0.24             | 0.00             | 0.24     |
| Teaching zone 2 | 0.00                   | 0.04                   | 0.00                   | 0.01     | 0.05               | 0.00                | 0.04               | 0.00               | 0.01             | 0.05             | 0.00             | 0.04             | 0.00             | 0.01     |
| Library         | 0.00                   | 0.15                   | 0.00                   | 0.17     | 0.32               | 0.00                | 0.15               | 0.00               | 0.17             | 0.32             | 0.00             | 0.12             | 0.00             | 0.12     |
| Dormitory 1     | 0.00                   | 0.04                   | 0.00                   | 0.05     | 0.09               | 0.00                | 0.07               | 0.00               | 0.09             | 0.16             | 0.00             | 0.09             | 0.00             | 0.10     |
| Dormitory 2     | 0.00                   | 0.13                   | 0.00                   | 0.13     | 0.26               | 0.00                | 0.15               | 0.00               | 0.16             | 0.31             | 0.00             | 0.10             | 0.00             | 0.09     |
| Test zone       | 0.02                   | 0.01                   | 0.01                   | 0.01     | 0.05               | 0.05                | 0.04               | 0.06               | 0.05             | 0.2              | 0.02             | 0.01             | 0.01             | 0.05     |

Complexity
Table 7: Visual subjective scoring of optimisation measures in different zones.

| Zone          | Weekdays daytime | Weekdays nighttime | Weekends daytime | Weekends nighttime |
|---------------|------------------|--------------------|------------------|--------------------|
|               | Noise barrier score | Greenbelt score | Combination arrangement score | Noise barrier score | Greenbelt score | Combination arrangement score | Noise barrier score | Greenbelt score | Combination arrangement score | Noise barrier score | Greenbelt score | Combination arrangement score |
| Campus        | 3.55             | 8.46               | 6.14             | 3.55               | 8.46               | 6.14             | 3.55             | 8.46               | 6.14             | 3.55             | 8.46               | 6.14             |
| Sports zone   | 3.55             | 8.46               | 7.37             | 3.55               | 8.46               | 7.37             | 3.55             | 8.46               | 7.37             | 3.55             | 8.46               | 7.37             |
| Teaching zone 1 | 3.55             | 8.46               | 3.55             | 3.55               | 8.46               | 3.55             | 3.55             | 8.46               | 3.55             | 3.55             | 8.46               | 3.55             |
| Teaching zone 2 | 3.55             | 8.46               | 6.89             | 3.55               | 8.46               | 6.89             | 3.55             | 8.46               | 6.89             | 3.55             | 8.46               | 6.89             |
| Library       | 3.55             | 8.46               | 8.46             | 3.55               | 8.46               | 8.46             | 3.55             | 8.46               | 8.46             | 3.55             | 8.46               | 8.46             |
| Dormitory 1   | 3.55             | 8.46               | 6.66             | 3.55               | 8.46               | 6.66             | 3.55             | 8.46               | 6.66             | 3.55             | 8.46               | 6.66             |
| Dormitory 2   | 3.55             | 8.46               | 7.55             | 3.55               | 8.46               | 7.55             | 3.55             | 8.46               | 7.55             | 3.55             | 8.46               | 7.55             |
| Test zone     | 3.55             | 8.46               | 3.55             | 3.55               | 8.46               | 3.55             | 3.55             | 8.46               | 3.55             | 3.55             | 8.46               | 3.55             |
### Table 8: Score table of visual and auditory subjective evaluation of each zone.

| Zone            | Weekdays daytime | Weekdays nighttime | Weekends daytime | Weekends nighttime |
|-----------------|------------------|--------------------|------------------|--------------------|
|                 | Noise barrier score | Greenbelt score | Combination arrangement score | Noise barrier score | Greenbelt score | Combination arrangement score | Noise barrier score | Greenbelt score | Combination arrangement score | Noise barrier score | Greenbelt score | Combination arrangement score |
| Campus          | 13.55            | 18.46              | 16.14            | 12.45              | 17.21              | 14.99            | 13.55            | 18.46              | 16.14            | 12.35            | 17.16              | 14.89            |
| Sports zone     | 13.45            | 17.51              | 17.17            | 10.75              | 15.06              | 14.42            | 13.55            | 17.76              | 17.37            | 10.8             | 15.11              | 14.47            |
| Teaching zone 1 | 13.55            | 18.46              | 13.55            | 13.55              | 17.71              | 13.55            | 13.55            | 18.46              | 13.55            | 13.5             | 17.56              | 13.35            |
| Teaching zone 2 | 13.55            | 18.46              | 16.89            | 13.55              | 18.46              | 16.89            | 13.55            | 18.46              | 16.89            | 13.5             | 18.46              | 16.89            |
| Library         | 13.55            | 18.46              | 18.46            | 13.55              | 18.46              | 17.31            | 13.55            | 18.46              | 18.46            | 13.5             | 18.46              | 18.21            |
| Dormitory 1     | 13.55            | 18.46              | 16.66            | 11.85              | 16.91              | 15.21            | 13.55            | 18.46              | 16.66            | 11.8             | 16.91              | 15.16            |
| Dormitory 2     | 13.55            | 18.46              | 17.55            | 12.2               | 17.21              | 16.05            | 13.55            | 18.46              | 17.55            | 12.15            | 17.21              | 15.95            |
| Test zone       | 12.75            | 17.81              | 12.75            | 9.9                | 14.96              | 9.9              | 12.75            | 17.91              | 12.75            | 9.7              | 14.81              | 9.7              |
3.4.2. Visual Subjective Evaluation. The visual perception survey, which randomly selected 100 people, shows that if the study area only has noise barriers as optimisation, then its final visual score is only 3.55 because sound barriers cannot provide people with a good visual experience. If the greenbelt is used alone for optimisation, then the final visual score of this study area is 8.46 because of the good visual experience brought by greenbelts.

Table 7 shows that in different time periods, the visual scores of each zone with sound barriers and greenbelts alone as optimisation are 3.55 and 8.46, respectively. The visual score of the entire campus under the optimisation plan of using sound barriers and greenbelts is 6.14. Among all functional zones, test zone and teaching zone 1 are equipped with sound barriers only, and its visual score is 3.55. The zone with greenbelts only is the library, whose visual score is 8.46. For the functional zones with sound barriers and greenbelts, the length of the greenbelt in dormitory zone 2 accounts for a large proportion of the total length of optimisation measures in this zone. Thus, it has the highest visual score of 7.55. However, the length of the greenbelt in dormitory zone 1 accounts for a small proportion of the total length of optimisation measures in this functional zone, thereby resulting in the lowest visual score of 6.66.

3.4.3. Auditory and Visual Subjective Evaluation and Decision-Making. Among the three optimisation plans used in the entire campus, regular noise barrier alone provides the best noise reduction (Table 4). Using a greenbelt alone is relatively weak in reducing noise, and the combination of greenbelt and regular noise barrier falls in between, but with the advantage of a flexible setup given that the specific positions of noise barriers and greenbelts can be determined in accordance with specific needs whilst meeting the sound pressure level requirements in the functional zone.

Table 8 shows that the subjective score of the entire campus under the optimisation plan of greenbelts alone is higher than that under other plans. Although using noise barriers alone can greatly reduce noise, its subjective score is the lowest after taking into account human visual and auditory subjective feelings; this situation can also be found in each functional zone. Thus, although noise barriers improve human auditory feelings, greenbelts result in better subjective feelings. Therefore, the visual design must also be fully considered whilst assessing the noise reduction ability of a noise control measure. People feel more comfortable since the noise decreases. However, the influence of visual design is even greater, and among all common noise reduction measures, plants provide the best visual perception [41].

4. Conclusions

Among the three noise optimisation plans, using noise barriers alone best reduces noise and provides people with a better hearing experience. However, if human visual subjective feelings are considered, then the other two measures are better choices. Greenbelts provide people the best visual and auditory subjective experience, which proves that the visual quality must be valued whilst considering the amount of noise reduction of noise control facilities.

(1) Setting greenbelts: Fang and Ling [32] found that shrubs scatter noise rapidly due to their dense leaves and branches, making the most effective in reducing noise. The belts of trees, which are sufficiently high, demonstrate advantages in noise diffusion and absorption. Most shrubs are very short and the trees have very few leaves and branches at a low height. Thus, planting shrubs under the trees can result in the best noise reduction effect of tree belts. The width and visibility of tree belts are determined in accordance with the target noise reduction amount. If the target noise reduction amount is 6 dB, then the trees can be planted with a visibility of 1 m and a width of 5 m or visibility of 10 m and a width of 18 m. Therefore, when the target noise reduction amount is moderate, greenbelts should be prioritized when conditions permit.

(2) Installation of noise barriers: using noise barriers in places where noise needs to be reduced to a very low level is effective. The visual design of this noise reduction measure must be fully considered because improving the visual design of low barriers can provide more comfort than further increasing the height of the sound barrier [41]. In addition, by placing a linear control source array and a vertical linear error sensor array on top of the noise barrier, we can improve noise control in the shaded area of the barrier by using two control sources and adjusting their angles and directions [54]. Furthermore, by using more control sources, we can further increase the spatial scope of the area where sound pressure is reduced. This method can effectively reduce the height and width of the noise barrier, thereby reducing the urban space it occupies.

In this study, the sound pressure levels used were equivalent sound pressure levels, and the maximum and minimum sound pressure levels were not considered in the validation and simulation data analysis. This approach can be a future direction for further analysis. The scoring of the visual quality of a noise control measure may vary from person to person, and the expected quality may be affected by the expectations for this measure. Future research is expected to solve this problem, and different types of noise barriers and greenbelts may provide different visual perceptions.

This study provides an action plan for urban planners and urban designers. It shows that whilst applying noise reduction measures, we should consider human visual and auditory subjective feelings. If we only focus on sound intervention but not on visual quality, then the quality of the urban environment may deteriorate. During conceptual design, we can use acoustic environment simulation software to predetermine the acoustic environment of the simulated area. By adjusting the layout and shape, design of buildings, roads, green spaces, and noise barriers minimizes the influence of noise in noise-sensitive areas.
Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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Supplementary Materials

Table A1: environmental noise limit dB(A). Table A2: PPG 24 recommends various noise exposure level limits for homes with nearby noise sources [46]. (Supplementary Materials)

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