A SURVEY ON THE ACOUSTIC ENVIRONMENT OF RESIDENTIAL AREAS CLOSE TO URBAN EXPRESSWAYS IN A MOUNTAINOUS CITY

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Urban expressways usually generate excessive noises to the surrounding residential areas, and it tends to be more complex in the mountainous city, due to its undulating terrain and dense population. In this paper, three residential areas close to urban expressways were selected for field measurement and questionnaire survey, in a typical Chinese mountainous city named Chongqing. The nearest distances between the studied areas and expressways are only 12m, 30m and 42m, respectively. For each residential area, approximately 10 receiver points were arranged, with both road-side and quiet locations considered. According to the measurement results, the night-time levels at most of the road-side areas exceeded the recommended levels. Moreover, for the road-side receiver points, the differences between the day-time and night-time noise levels were insignificant. As expected, traffic and air conditioners were the major noise sources, and some positive sounds could be heard, like bird song. In addition, 74.2% of road-side residents identified their acoustic environments severe or relatively severe, and 48.3% of road-side residents regarded the acoustic environment as the priority to be improved appropriately.

1. Introduction

Noise, defined as ‘unwanted sound’, is perceived as an environmental stressor and nuisance [1]. It could affect people both psychologically and physiologically, with a number of negative effects including hearing loss, cardiovascular stimulation and increased gastric secretion [2-4]. In China, noise pollution has been one of the major urban environmental issues for more than a decade.

Chongqing is a typical mountainous city in Southwestern China with a population of nearly 30 million. The area is featured by mountain and hills, with large sloping areas at different heights. The natural mountainous terrain that many road projects in Chongqing are built on makes the urban sound environment more complicated, in conjunction with the significant street canyon effect. In particular, the residents in roadside high-rise buildings suffered from the traffic noises. Different from the ordinary urban roads, urban expressways are very special in Chongqing, in terms of higher speed limits, more traffic flow, and numerous flyovers [6]. The total length of urban expressway in Shapingba District, Chongqing is 9 kilometres approximately, and the average traffic flow is over
10,000 per hour during the peak time [7]. Since the local government plans to improve the road conditions within the next few years, wider urban expressways tend to worsen the urban sound environment in Chongqing.

Most of previous studies in the mountainous cities were only simple noise level surveys with limited acoustic indices considered. The effects of urban expressways and subjective reactions have largely been ignored. Therefore, this paper aims to investigate the acoustic environment of three residential areas in Chongqing, through a series of field measurements and questionnaire survey.

2. Methodology

2.1 Study areas

Three residential areas in Shapingba District, Chongqing were chosen as the case sites, from August to October, 2013. Shapingba is one of the most densely populated areas in Chongqing, with a population of around one million. The number of households ranged from 300 to 1500, and the nearest distances between the studied areas and urban expressways are only 12m, 30m and 42m, respectively. Bainianshijia (Residential district A) and Xuelinyayuan (Residential district B) are two mixed commercial-residential districts, whereas Jiangongdongcun (Residential district C) is a residential district in Chongqing University, as shown in Figure 1. Only the buildings in Residential district C installed single glazing, and the others used double glazed windows. In order to make comparisons, both the road-side locations and quiet areas inside the residential districts were taken into account.

![Figure 1. Plans of Residential district A (a), B (b) and C (c), with the corresponding receiver points, and Building X, Y and Z.](image)

2.2 Field measurements

For all the residential districts, the field measurements were conducted during non-peak hours on weekdays, with both typical daytime and night-time considered. Five acoustic indicators were analysed, namely equivalent ($L_{Aeq}$), maximum ($L_{max}$), minimum ($L_{min}$), background ($L_{90}$), intrusive ($L_{10}$) noise levels as well as spectrum analysis. As illustrated in Figure 1, there were 14, 14 and 11 receiver points in Residential district A, B, and C, respectively.

In addition, one apartment in Building X of District A, the closest to the nearby urban expressways, was chosen as the 24-hour measurement site for outdoor and indoor noise levels. Meanwhile, two more buildings (Y and Z) of District C were selected to measure noise level variations at different floors and different period of time (daytime and night-time).


2.3 Social survey

A total of 104 valid questionnaires were collected from roadside and non-roadside residents. Firstly, interviewees were asked to provide information about their gender, age, occupation, window type, and residence duration. In the questionnaire, there were several 5-point scale questions as follows. ‘Q1: How noisy is the sound environment in your apartment?’ ‘Q2: how much does the noise affect the natural ventilation in your apartment? ‘Q3: ‘How much do the major noise sources (traffic, industry, construction, entertainment, social life) disturb or annoy you?’ ‘Q4: How much does the noise affect your work and daily life?’ ‘Q5: How much does the noise affect your health?’ Similar answers were provided as ‘not at all, slight, moderate, relatively severe or severe’ for Q1-Q5. A multi choice question was added in the end, ‘Q6: of the following five environmental factors (acoustics, air quality, humidity, thermal, lighting), which one should be improved as the priority?’

3. Results and discussion

3.1 Environment noise level

3.1.1 Residential areas

Figure 2 displays the environmental noise level of three residential districts. Due to effect of noise barrier, the noise levels of three roadside receiver points (R12, R13 and R14) were measured around 60dBA during the daytime, however, less than 2dBA was reduced at night (R12 and R14). R13, where a kindergarten is situated, is only 46m away from the expressway, but its noise level was lower than the other two roadside points. A possible reason might be the simple noise barrio between R3 and unban expressway. It is noted that, although R1, R2 and R3 were not close to expressway, their daytime $L_{Aeq}$ were more than 65dBA, as they were close to the main road.

In Residential district B, one location near the main road (R1) were higher than the expressway-side position R5 during the daytime and night time, by 2.7dBA and 1.5dBA correspondingly. The day-night differences were 8.1dBA and 10.7dBA for R2 and R3, which were arranged at the sloping roadside. The engine noises from the uphill vehicles roared in the daytime. The green space (51.8%) of this residential district is higher than Residential district A (33.0%), more birds and insects were attracted to inhabit, birdsong can be heard in the daytime. Waterscapes had also been designed here; the sound of toads could be heard at night.

Residential district C is within the university, and generally its acoustic environment is better than the first two districts. R1, R2 and R3 are roadside test points near expressway. Due to the construction in the university, as a result, the daytime $L_{Aeq}$ of R4, R5 and R8 were higher than other internal points 2.2-11.3dBA, significantly. As investigated, traffic and air conditioners were the major noise sources, commonly. In District C, construction noise could be heard for the duration of the daytime.

The 24-hour measured data was collected in an apartment of the Building X, as provided in Figure 3 and Table 1. It is noted that, the bedroom is inhabited so that 4 periods (8:00-9:00, 14:00-14:30, 19:00, and 22:00) were interfered by resident activities in indoor equivalent sound level, outdoor data was not disturbed by them during the test. As Figure 3 demonstrates, there were three obvious peak hours in the outdoor noise measurements, namely 7:00, 12:30 and 19:30. The noisiest time appeared at 7:00, which was 71.3dBA, and the quieter time was obtained during 2:00 to 5:00 on the early morning, below 67dBA.
Figure 2. Environmental noise levels measured at 2 time periods (daytime and night-time), in terms of $L_{Aeq, 10mins}$ for Residential district A (a), Residential district B (b) and Residential district C (c).

Figure 3. Equivalent sound levels (dBA) measured over a 24hours period in a private house (11F, road-side building in District A), for every 30 minutes, $L_{Aeq,30mins}$.

Table 1. Logarithmic averages and standard deviations of sound level $L_{Aeq}$, maximum sound level $L_{max}$, minimum sound level $L_{min}$, statistical sound level indicators ($L_{10}$, $L_{90}$) over the 24-hour period (dBA), together with the sound level differences between daytime and night-time.

<table>
<thead>
<tr>
<th></th>
<th>$L_{Aeq}$</th>
<th>$L_{max}$</th>
<th>$L_{min}$</th>
<th>$L_{10}$</th>
<th>$L_{90}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All day</td>
<td>outdoor</td>
<td>68.9 (2.73)</td>
<td>89.4</td>
<td>52.6</td>
<td>65.1</td>
</tr>
</tbody>
</table>
Table 1 demonstrates the comparison of five noise indicators, namely the equivalent, maximum, minimum, spatial background and intrusive noise levels of this private house. Similar to the results of environmental noise levels of roadside receivers, the daytime noise level (69.3dBA) was up to standard, whereas the night-time level (68.2dBA) outside this private house exceeded the recommended levels. The difference is only 1.1dBA which between daytime and night-time sound level outside. Besides, the sound levels in this bedroom, whether the daytime (48.9dBA) or night-time (45.8dBA) was not meet the regulations which provided the noise level \( \leq 45 \text{dBA} \) (daytime) and \( \leq 37 \) (night-time) in the bedroom where the roadside buildings of urban expressways.

### 3.1.2 Comparison of roadside and non-roadside residential buildings

As shown in figure 4(a). It is noted that in consideration of different base elevations of each buildings, the ground floor of the non-roadside building was seen as the roadside building’s third floor. As the result shown in Figure 4(b), the differences between day and night could be seen that the difference of roadside building (0.2-2.1dBA) is smaller than non-roadside building (5.3-7.6dBA) obviously. Due to different noise source types, the noise level of roadside building from ground floor to eleventh floor increases linearly, while a peak value arose at seventh floor of non-roadside building.

![Diagrammatic sketch of a roadside building(Building Y) and a non-roadside building (Building Z) in Residential district C (a); Environmental noise levels measured at 2 time periods (daytime and night-time), in terms of L_Aeq-10min; measured from different storeys of a roadside building and a non-roadside building in Residential district C (b)](image)

### 3.2 Subjective response

Table 2 demonstrates the social characteristics of sample population around three residential areas, that including age, residing time, roadside type and windows type.

<table>
<thead>
<tr>
<th>Age</th>
<th>&lt;20</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>&gt;50</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>9.80</td>
<td>47.10</td>
<td>25.50</td>
<td>7.80</td>
<td>9.80</td>
</tr>
<tr>
<td>Percentage number of people</td>
<td>9.80%</td>
<td>47.10%</td>
<td>25.50%</td>
<td>7.80%</td>
<td>9.80%</td>
</tr>
</tbody>
</table>
Residing time | <1 | 1-3 | 4-6 | >7
---|---|---|---|---
Percentage number of people % | 31.4% | 27.5% | 13.7% | 27.5%
Roadside type | road-side | non-roadside | non-roadside | road-side
Percentage % | 60.8% | 39.2% | 60.8% | 39.2%
Windows type | single | double | single | double
Percentage % | 58.8% | 41.2% | 58.8% | 41.2%

Figure 5 illustrates that 74.2% of road-side residents identified acoustic environments of their houses as severe or relatively severe, only 21.5% residents who live in non-roadside buildings feel likewise. Besides, 67.8% road-side residents insisted the affected extent of the ventilation severe or relatively severe. Thus a certain correlation between loudness of environmental noise and affected extent of the ventilation by noise was found (p<0.05). What’s more, 54.9% and 42.0% roadside responders considered that noise brought negative influence on their daily life and health severely or relative severely, severally. While, with regard to the non-roadside responders just 16.7% and 19.0% of them realized the current situation of noise impact on their daily life and health as relatively severe, and no one chosen severe.

![Figure 5](image1)

**Figure 5**. The results of Q1, Q2, Q3, Q4 for roadside residents (a), for non-roadside residents (b).

![Figure 6](image2)

**Figure 6**. The result of Q5 for roadside residents (a), for non-roadside residents (b).

Figure 6 exhibits that traffic noise was regarded as the noise source which bother, disturb, or annoy themselves severely or relative severely by 74.2% of roadside residents. On other hand, 19.1% of non-roadside residents construction noise ranked the top which bother, disturb, or annoy them as severe or relatively severe. Five main physical environmental factors displayed in Figure 7. 48.3% of road-side residents regarded the acoustic environment as the priority to be improved appropriately. While air quality is considered as the urgent one by 35.0% non-roadside residents.

In addition, 80.4% respondents were awoken by outdoor noise, traffic noise account for 65.9% of those noise. Moreover, traffic noise was treated as the most annoying sound by 52.9% respondents. In seven listed department strategies of noise control, including improved building’s...
facade, using high performance window, install high performance noise barrier, plant trees, quiet pavement, low noise motor vehicle or sound masking design, 62.7% of respondents chose using high performance windows and low noise motor vehicle was selected by 58.8% respondents.

![Image of bar chart]

**Figure 7** The priority to be improved physical environmental factor

4. Conclusions

This paper investigated the acoustic environment of three typical residential areas which close to urban expressways in a mountainous city, through field measurement and questionnaire survey. The daytime noise levels were normally below the local guideline values, whereas the night-time levels at most of the road-side areas exceeded the recommended levels. Moreover, for the road-side receiver points, the differences between the daytime and night-time noise levels were insignificant. As expected, traffic and air conditioners were the major noise sources, and some positive sounds could be heard, like bird song. In addition, 74.2% of road-side residents identified their acoustic environments severe or relatively severe, and 48.3% of road-side residents regarded the acoustic environment as the priority to be improved appropriately. Traffic noise was treated as the most annoying sound by 52.9% respondents.

5. Acknowledgement

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REFERENCES


