The Effectiveness of Quiet Facade on Account of Chinese Residential Layout

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Summary
In Europe, the concept of quiet facade (with traffic noise levels below 45 dB or 50 dB) has already gained a significant consensus, and it has been introduced into the legislation in some countries; however, it has not yet been discussed in China. Because most of Europe tends to have more closed housing blocks (courtyards), it is likely easier to obtain quiet facade. However, it is perhaps more difficult to achieve in China due to the parallel layout for multi-story row houses (which is chiefly related to the sunshine duration requirement). According to the position relationship between residents and roads, three residential layouts were investigated in this study: parallel, perpendicular, and closed. To state the question more clearly, several residential areas in Dalian, northern China, were selected to investigate the influence of the building layout on the least noise exposed facade by afield study. This paper showed that the quiet facade near the arterial road maybe difficult to achieve in China based on Europe's existing definition.

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1. Introduction

Noise has been recognised as a serious environmental problem and a threat to public health[1]. Traffic noise has been the strongest radiation and the widest influence of urban noise pollution sources. According to a survey in Beijing, the contribution of road traffic to urban environmental noise was 61.2 percent[2].With the rapid urbanization of China, urban-increased population has led to an increase of traffic flows and traffic density, and traffic noise has become a prominent problem.
The European Parliament and Council Directive for Assessment and Management of Environmental Noise (2002/49/EC), more commonly referred to as the Environmental Noise Directive (END), was published in the Official Journal of The EU in July 2002. This directive addresses noise from road, rail, and air traffic and from agglomerations. It demands that each member make a plan of action to reduce noise and make the EU noise policy enter a new stage. These results can offer examples for China including quiet facade research.
The study of quiet facades has had a long history[3], which shows that though outdoor noise may be high, if the house has quiet side, the noise annoyance of residents will be decreased to some extent. Also, quiet facades enable residents to sleep with their windows open without being disturbed by noise. In daytime, it allows them to leave a window open or enjoy outdoor gardens or balconies of that facade without undue disturbance from noise.
The END defines quiet facade as “The facade of a dwelling ... is more than 20 dB lower than at the facade having the highest value”. Therefore, quiet facade according to the END is perhaps not absolutely free from noise, but the noise level is much lower than on the other side. While the QSIDE project funded within the Life+ programme researched several cities that have been interviewed about their current approach with respect to quiet facades, it was found that all cities but one used a definition based on an absolute level[4].
The Qside project recommended that the least exposed facade of a dwelling is quiet facade (with respect to road traffic noise) if the noise level is preferably limited to 45 dB L_{den} and the noise level is not higher than 50 dB L_{den}. In this case, quiet facade may not be absolutely free from noise, but most people will not be annoyed because the noise level is sufficiently low.

2. Analysis of particularity to China

2.1. Difference of urban morphologies

In many European cities, it was common to build closed housing blocks (courtyards). From a noise point of view, closed housing blocks guarantee quiet side for all dwellings. [4]

However, in China, especially in the north of China, people prefer residential buildings to face south to obtain a sunshine duration that meets a mandatory national standard. A parallel layout for multi-story row house clusters in China can guarantee that every residential building will obtain an equal sunshine duration, thus causing an advantage in the building layout, which constitutes the main texture of urban China. According to the position relationship of residents and roads, three parallel investigated in this study: parallel, perpendicular, and closed.

2.2. Differences in transportation planning

In recent years, with the rapid expansion of Chinese cities, by the end of 2010, urban areas more than tripled than in the previous 20 years, and some cities have even expanded by more than 20 times[5].This level of development requires road traffic that provides more expressways, to guarantee high-speed travel, which has led to serious urban traffic noise pollution. Furthermore, China's urban road system was influenced by European planning theory, including "Traffic in Towns", "Neighbourhood Unit", and "Garden City", which tends to design a more hierarchical street and road system and adapt better to the increase of car traffic and car ownership, so almost all branches of vehicles are packed into arterial roads and expressways, causing an increased traffic flow and speed in a concentrated area, which makes traffic noise pollution more serious.

Furthermore, because of the high density of urban areas, much urban land on the side of arterial roads is inevitably planned for residential construction, whereas in the government, no traffic noise regulations have been made to avoid noise pollution.

2.3. Difference of living habits

In Europe, rest/relaxation indoors with the windows open may be a common occurrence, and the government is also concerned about resident complaints about noise. Because there are other topics that are more important than noise in China that need to be paid attention to, the neglecting of paying attention to noise pollution is inevitable. Many residents living near roads are used to closing their windows to sleep at night, even in the summer. Country standards to limit residential noise (Code for the Design of Sound Insulation of Civil Buildings, GB50118-2010) have clearly put forward the limited number that should be reached when the windows are open.

Similarly, ignoring noise can also be embodied in house prices. In contrast to European findings that traffic noise may decrease house prices by 5%[6], traffic noise in China was not been deemed important in house transaction pricing[7]. This apparently aberrant response may be partially attributed to the low sensitivity towards noise in a congested Chinese city with a high ambient noise level. Exposure to traffic noise did not influence willingness-to-pay, implying a tolerance of a chronic environmental nuisance in the compact city.

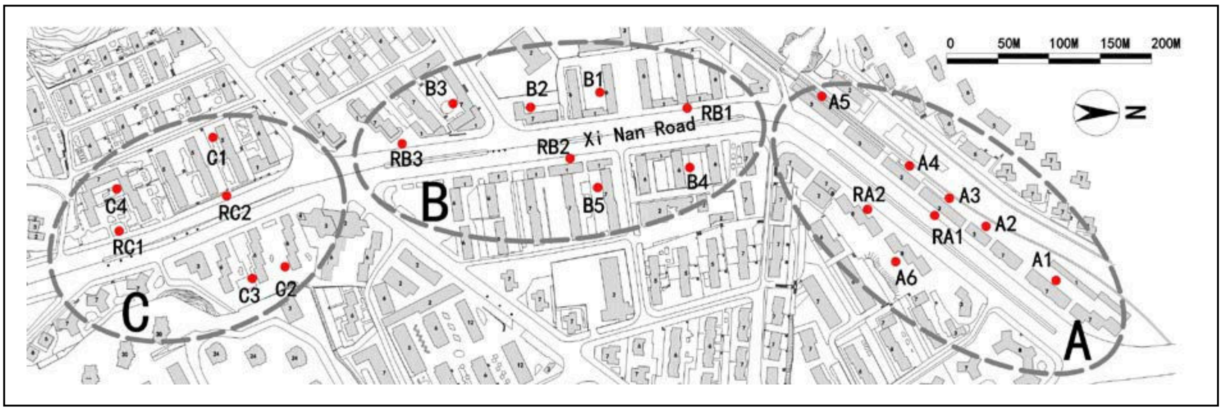


Figure 1. Site plan of the Xi Nan Road: identification of the buildings and of the 22 sampling points

3. Methodology

3.1. Characterization of the measurements area

The differences between China and Europe that have been mentioned above make the cities' noise and measures variance. To evaluate noise pollution levels on least noise exposed facades in Dalian, noise measurements were made along the urban arterial road of Xi Nan Road, Dalian, Liaoning Province, at 22 systematically selected locations. As shown in Figure 1, along the road (1.2 km) seven sampling points were chosen. On the least noise exposed facade, 15 sampling points were chosen.

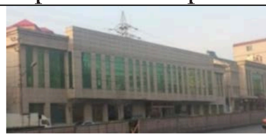
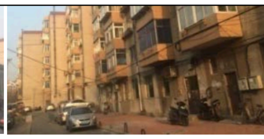
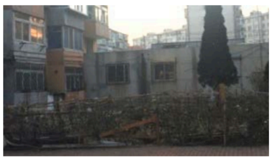
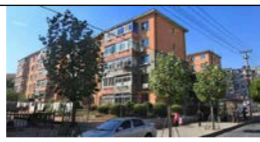
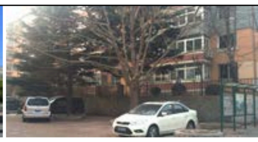
The Xi Nan Road section selected is a typical arterial road of Dalian, which has less traffic flow than others and has an appropriate distance with buildings on both sides, with bidirectional eight lanes that are 30m in width. According to the morphology characteristics and the relationship between the roads, the site is divided into four areas. From right to left, areas A, B, and C are parallel, perpendicular, and closed with Xi Nan road. Area R is a special area that represents the most noise-exposed facade, and it also represents the road traffic noise.

3.2. Noise measurement

The acoustic measurements were taken on Tuesday, November 4th, 2014, which is a typical period, excluding holidays, school vacations, and adverse weather conditions. These measurements were taken from 4:00 PM to 5:00 PM, aiming to cover the periods with the heaviest vehicle traffic on the avenues in question because these were the periods when the condition of continuous traffic streams occurred with the greatest frequency.

The acoustic data were collected using an AWA 6228 Mediator Class 1 integrating sound level meter. According to the National Standard of China for the evaluation of noise in urban environments (GB/T 3222.2-2009), the sound level meter was supported on a tripod at a height of 1.20

Table I. Characterization of the site plan

Characterization	Representative photos
Area A: Parallel with the road 1. Sampling points A2, A3, A4, and A5 are arranged behind the building with three floors parallel to the road, 60 m to 25 m in length, and 6 m lateral spacing. 2. Sampling points A1 and A6 are arranged behind the building of eight floors and of 50m in length. 3. Sampling points are all chosen at the middle position of the building to ensure that quiet noise is obtained.	  RA1 A1   A4 A6
Area B:Closedtotheroad 1. The residential building is perpendicular to the road, and other buildings are closed to the road. 2. Sampling points B1 and B4 has a single floor commercial building along the road, which enclosed a courtyard with others. 3. Sampling points B2 and B3 are near the L-shaped building with seven floors and located at the corner.	  RB2 B3   B1 B2
Area C:Perpendicular to the road 1. On both sides of the sampling points C1,C2, and C3,the residential buildings are five to six floors, 50m in length, and perpendicular to the road, while the courtyard has no shelter from the road. 2. Sampling point C4 is located at the courtyard and open to the road without any shelter, enclosed with U-shaped residential buildings with seven floors which have two wings that are 52m in length.	  RC2 C4   C3 RC1/C4

m from the ground, keeping a distance of 2 m from reflective surfaces (walls) and facing road traffic. The instrument was calibrated before and after each measurement, using an AWA 6221A sound calibrator. The measurements were A-weighted and are therefore expressed in dBA, according to the National Standard of China GB/T 3222.2-2009, and fast-response time-weighted[8].

The recorded noise descriptors include L_{Aeq}, L_{max}, L_{min}, L_{AN}, TNI, octave-band pressure level, and the standard deviation of noise levels. Traffic counts were made (vehicle flow and composition) during the same periods as the acoustic measurements.

L_{Aeq}, L_{max}, L_{min}, and L_{AN} were measured two times on the A-weighted scale, each for a 20-min duration. Octave-band pressure levels were also measured two times, each for a 10-min duration.

As suggested by Yang and Kang [9] the subjective evaluation of the sound level generally relates well with the mean equivalent level (L_{Aeq}). which should be obtained emphatic analysis.

The subscript N in L_{AN} represents the percentage of time the recorded A-weighted noise level exceeds L_{AN}. The most frequently used values of N in China are 10, 50, and 90. L_{A10} is used in the assessment of road traffic noise and L_{A90} is considered as the background prevailing noise level. The traffic noise index (TNI) is a measure of the annoyance behaviour of humans exposed to vehicular generated noise and estimated using the formula:

TNI = 4*(L10- L90)-L90+30.

4. Results and discussion

4.1. Traffic characteristics

During the same period of noise measurement, traffic characteristics of areas A, B, and C were recorded for one hour duration. The measured period belongs to traffic concentration during rush hour, when there is less congestion. As shown in Table II, the highest mean of L_{Aeq} is area A, and the smallest mean of L_{Aeq} is area C, with the difference being 1.7 dBA. Because the difference is so small, the traffic noise of the three areas as well as the high noise of the building facade can be treated as equal; then, the noise of the building quiet facade can be directly compared.

4.2. Influence analysis of morphologies

A statistically significant difference was found among the urban morphologies (parallel layout, closed layout, perpendicular layout) in regard to L_{Aeq}($F(2,41)=76.31, p=0.00$), L_{A10} ($F(2,13)= 39.51, p=0.00$), L_{A50} ($F(2,13)=18.14, p=0.00$), L_{A90} ($F(2,13)=8.89, p=0.04$), TNI ($F(2,13)=43.60, p=0.00$), Table III indicates that the mean L_{Aeq} is 53.3dB for parallel layout, 53.5dB for closed layout, and 60.0dB for perpendicular layout. Post hoc Tukey HSD test indicated that there was a significant difference between parallel layout and perpendicular layout($p<0.05$, $d=3.84$), in regard to their L_{Aeq}. Also, there was a significant difference between closed layout and perpendicular layout ($p<0.05$, $d=4.73$), in regard to their L_{Aeq}.

B and C both have residential buildings perpendicular to the road, and they have similar floor number and spacing distances; the only difference lies in the building shape of area B (U-shape or the L-shaped along the road), which results in obvious noise reduction of quiet facade close to area A.

Table II. Characterization of the traffic

	Traffic flow(h^{-1})	Heavy veh. (%)	Road width (m)	L_{Aeq} (dBA)
A	1237	15.52%	30	70.7
B	1075	11.91%	30	69.7
C	1057	9.74%	30	69.0

4.3. Analysis of quiet facade

As mentioned above, the definition of quiet facade is divided into two types, one concerning the absolute value and the other concerning the relative value. Statistical values should be checked, according to absolute and relative values.

From the view of an absolute value analysis, three types of layouts of L_{Aeq} all had values greater than 50 dBA. A one-side T test for area A, which has a

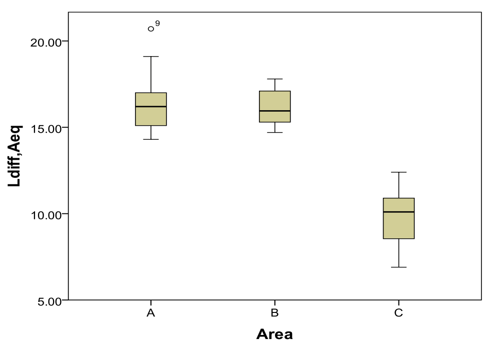


Figure 2. Distribution of $L_{Diff,Aeq}$

minimum noise level, is made to judge significance with 50dBA, which $p < 0.05$, proving that the overall average is more than 50 dBA. The same conclusion can be drawn from areas A and C.

Furthermore, a analysis in regard to relative values was conducted, that is, an analysis of the difference between high noise and low noise of the residential building facade. The comparison was performed through a gap analysis, as shown in the formula:

$L_{Diff}=L_{noisy,facade} - L_{quiet\ facade}$

where $L_{noisy,facade}$ is the mean of the noise level (dBA) measured in area R and $L_{quiet,facade}$ is the noise level (dBA) measured near the least noise-exposed facade. As illustrated in Figure 2, $L_{Diff,Aeq}$ of every area is less than 20 dB and cannot meet the definition of the END for the quiet facade.

Table III. Statistical values by the sample time period (dBA)

		L_{Aeq}		L_{Amax}		L_{A10}		L_{A50}		L_{A90}		L_{Amin}		TNI	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Area	A	53.3	1.7	69.5	4.6	54.2	1.9	50.8	2.4	47.7	2.9	44.7	3.2	43.7	3.9
	B	53.5	1.0	74.4	3.4	54.5	1.2	51.3	1.3	48.2	1.1	44.8	1.6	43.4	2.2
	C	60.0	1.8	77.6	2.5	62.9	1.8	58.3	2.3	53.4	2.1	49.4	0.4	61.2	3.0
	R	69.7	1.1	85.2	3.0	72.9	1.7	67.0	1.6	60.2	1.4	54.1	2.0	81.0	8.0

A similar calculation was performed for the octave band sound pressure level, and the attenuation of the noise spectrum can be obtained. As shown in Figure 3,the noise reduction caused by the building block of two areas of A and B have mainly attenuation at a high frequency, in other words, the buildings parallel or closed to the road can obtain a

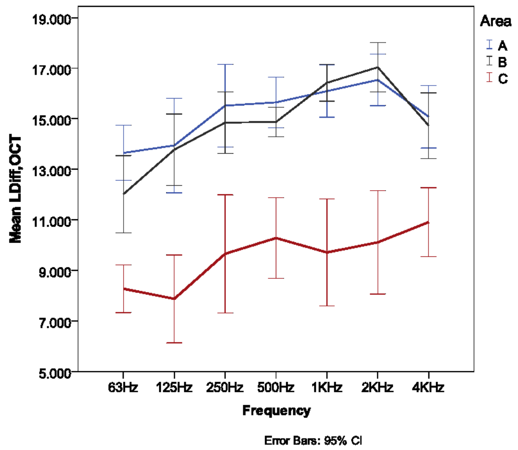


Figure 3.Distribution of $L_{Diff,OCT}$

greater improvement at a high frequency than at a low frequency, achieving a maximum reduction at 2KHz.The noise reduction of the buildings perpendicular to road without any shade in areas C are mainly caused by an attenuation due to distance, achieving a maximum reduction at 500 Hz and 4 KHz.

5. Conclusion

Quiet facade can decrease noise annoyance to some extent; however, it needs to be further studied in China, including such issues as how to accurately define what quiet facade is. Under China's present condition of traffic noise, it is difficult for quiet facade of a building near an arterial road to meet Europe's existing definition, and the values should be corrected based on the current situation in China.

Furthermore, differences in urban morphologies can significantly influence the spatial distribution of the traffic noise, and they need to be guided at the planning and design stage.

Acknowledgement

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