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# Evaluation of noise barriers for soundscape perception through laboratory experiments

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Soundscape qualities have been investigated for the different types of urban noise barriers. Field measurements were performed: the SPLs in front and rear of the barriers were measured and the pictures were taken. Laboratory experiments were conducted to evaluate the soundscape quality when each noise barrier existed. The experiments consisted of three parts; 1) audio-only condition, 2) visual-only condition, and 3) audio-visual condition. As a result, the soundscape design elements for designing urban noise barriers were derived from the subjective preferences both in aesthetical and spectral characteristics of the noise barriers.

# 1 Introduction

Use of noise barrier has been increased as a means of mitigating road traffic noise in urban spaces. This reflects the growing concern of the general public about noise pollution caused by traffic noise from cars and trains in urban space. However, installation of noise barrier tends to cause adverse effect on landscape quality. Thus, several approaches on audio-visual perception through acoustic noise barriers have been conducted to suggest appropriate design guidelines [1, 2]. In particular, audio-visual interaction on the perception of noise as a concept of soundscape has been investigated through laboratory experiments and field surveys from previous studies [1-5]. However, acoustical characteristics on noise barriers' performance including insertion loss and absorption coefficients have not been fully considered in the previous studies. Thus, the present study aimed to investigate the effects of acoustic characteristics of noise barriers as well as visual effects on perception of urban soundscape through laboratory experiments.

# 2 Field measurement

Based on previous studies [1, 2], five material types of noise barrier including timber, metal, transparent acrylic and vegetation, were chosen as they represent some widely used types in urban spaces. Audio-visual recordings then were performed from fronts and rears of noise barriers in real urban space. A 3-min $L_{Aeq}$ (equivalent continuous sound level) was measured in front and behind of barriers. Still photographs of barriers were taken using a digital camera (Canon EOS 300D) at same angle of view. Variation of SPLs in from of barriers was from 65.1 to 80 dBA and those of behind was from 54.6 to 61.4 dBA.

# 3 Methodology

## 3.1 Acoustic and visual stimuli

Audio recording of road traffic noise from ten lanes traffic road in Seoul was conducted, using a binaural microphone (Type 4101, B&K) and a digital recorder (Fostex, FR-2). The width of the road was around 30m. Original sound pressure level of recordings for 3 min was 75.8 dBA. For laboratory experiment, 4 second audio sample was excerpted from the 3 min recording.

Insertion loss values at 1/1 octave band were calculated in terms of noise barrier types based on measured STC data in reverberation room and absorption coefficients. Height of barrier was fixed at 5m and receiver position was 2m apart from a barrier. Prediction of sound pressure levels for five kinds of road traffic noise attenuated by different types of barriers was conducted using acoustic simulation software Enpro (Environment Noise Prediction & Design Program). Predicted insertion loss data in term of noise barrier types were listed in Table 1.

Table 1: Predicted insertion loss using Enpro [dB]

| | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
|---|---|---|---|---|---|---|---|---|
| Timber | 2.0 | 2.5 | 9.7 | 13.1 | 15.9 | 17.9 | 18.0 | 18.0 |
| Metal | 2.2 | 7.7 | 16.6 | 19.0 | 19.6 | 18.9 | 19.0 | 18.7 |
| Transparent | 2.0 | 3.4 | 7.8 | 12.7 | 14.7 | 14.9 | 15.4 | 15.7 |
| Concrete | 14.7 | 14.4 | 17.7 | 19.0 | 19.6 | 19.9 | 20.0 | 20.0 |
| Vegetation | 6.3 | 7.3 | 12.3 | 17.0 | 18.6 | 18.9 | 19.3 | 18.0 |

Two kinds of cases are assumed in the present study. The first case is the condition where sound pressure level of road traffic noise is fixed at 75 dBA in front of a barrier then subjects listen to the noise attenuated by insertion loss of a barrier. Therefore sound pressure levels behind barriers were different from types of noise barriers as shown Figure 1(a). The second case is the situation when road traffic noises behind barriers are keeping at a constant SPL at 55 and 65 dBA whilst the spectral characteristics were changed in terms of insertion loss of barriers at 1/1 octave band. Figure 1(b) illustrates spectral characteristics of acoustic stimuli in condition 2 when $L_{Aeq}$ of rear side of barrier was fixed at 55 dBA. Each acoustic stimulus in terms of barrier types was manipulated based depending on insertion loss values at 1/1 octave band.

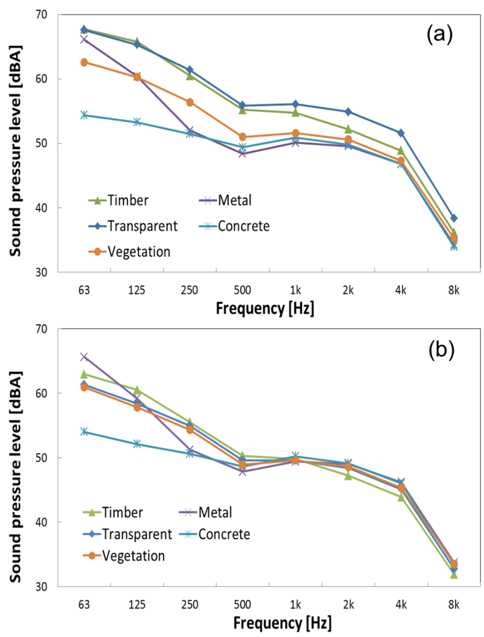


Figure 1: spectral characteristics of acoustic stimuli in condition 1 and 2

For visual stimuli, images of five types of barriers including timber, metal, transparent glass, vegetation and concrete barriers were created using Adobe Photoshop CS4 software. A view point was fixed in order to avoid influence of view angles. In addition small and large portion of ivy images were covered on the transparent and concrete barriers images in order to investigate the visual effect of vegetation. In total, nine visual images of noise barriers used in the laboratory experiments as shown in Figure 2.

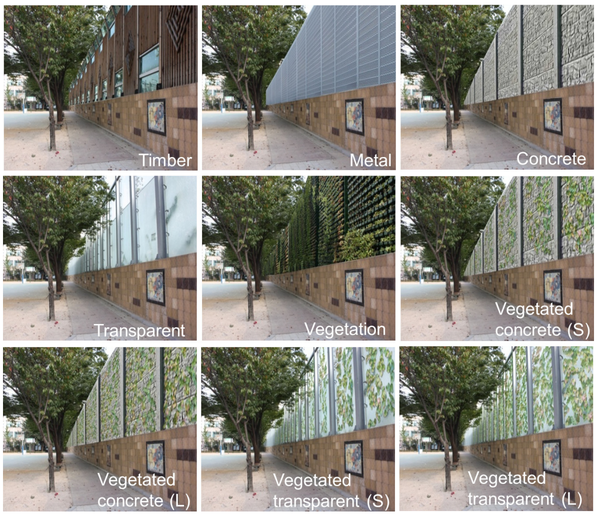

Figure 2: visual images in terms of noise barrier types

## 3.2 Experimental design

The laboratory experiments were performed to investigate the audio-visual interaction in urban soundscape. The laboratory experiments consisted of three conditions: 1) a visual-only condition, 2) an audio-only condition, and 3) a combined audio-visual condition, where, images were provided along with the sound stimuli during the experiment. The experiments were conducted using paired comparison method. In the audio only condition, the paired combination of five stimuli leads to a total of 10 pairs without reversal. Within a pair, a sound was successively presented and the subject was asked to judge which of the stimulus was more annoyed. In the visual only and audio visual condition, nine sound and visual stimuli were created and 36 pairs were presented to the subjects. In the visual only condition, visual preference of noise barriers and prediction of noise attenuation in terms of barrier types were evaluated. In the case of audio visual session, each subject was asked to select the preferred environment of each pair concerning both visual and acoustic qualities

## 3.3 Procedure

Twenty subjects participated in the experiment. During the experiments, acoustic and visual stimuli were presented through headphones (Sennheiser HD 600) and a beam projector (Sony VPL-CX6), respectively. The experiments were conducted in a testing booth (4×3 m) where the background noise level was approximately 25 dBA.

# 4 Results

## 4.1 Audio only condition

Figure 3 shows the results of respondents' annoyance on road traffic noise reduced by barriers from audio only condition in case I. Subjects evaluated that noise attenuated by the transparent barrier was the most annoying while that by concrete is the least annoying. It can be seen that the responses were largely depending on the sound pressure levels mitigated by insertion loss.

Scale values of annoyance on noise for audio only condition in case II were illustrated in Figure 4. It was found that noise reduced by metal barrier was the most annoying. Similar to the result of case I, respondents rated audio stimulus from concrete barrier as least annoyed. It can be seen that the responses were largely depending on spectral characteristics influenced by insertion loss at 1/1 octave band. As shown in Figure 1(b), the noise reduced by insertion loss of metal barrier showed relatively higher sound pressure level at low frequency while noise reduction of concrete at low frequency was the largest.

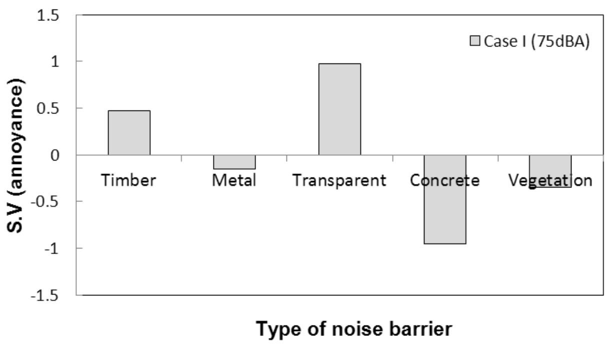

Figure 3: Scale values of annoyance on acoustic stimuli (Case I)

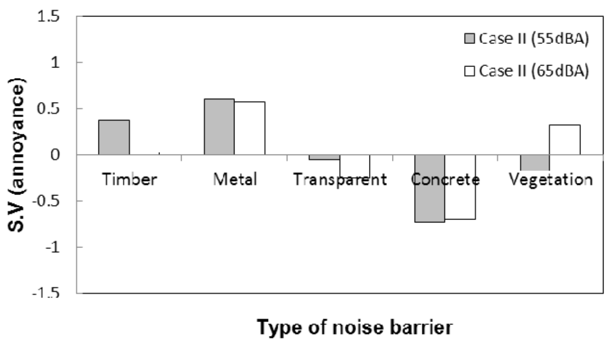

Figure 4: Scale values of annoyance on acoustic stimuli (Case II)

## 4.2 Visual only condition

Figure 5 illustrates the results of visual only condition. White circles indicate scale values for preconception on the perception of the barrier performance. Black circles represent the visual preference in terms of noise barrier types. It can be seen that most respondents rated vegetation and timber as their most preferred barrier based purely on aesthetics. Metal and concrete barrier obtained relatively lower rating in terms of visual preference. This indicates that the barriers made of natural materials were preferred than other materials.

In terms of preconception for noise attenuation, concrete covered with ivy was higher than any other types of noise barriers. It can be demonstrated that, without actually hearing any audio stimulus, the respondents predicted that concrete would be the most effective. In contrast, subjects predicted that transparent barriers would not enough reduce the noise. This shows good agreement with the result of previous study [1]. In addition, it is interesting to note that coverage of vegetation increased the visual preference as well as preconception of noise attenuation for noise barriers as shown in Figure 5.

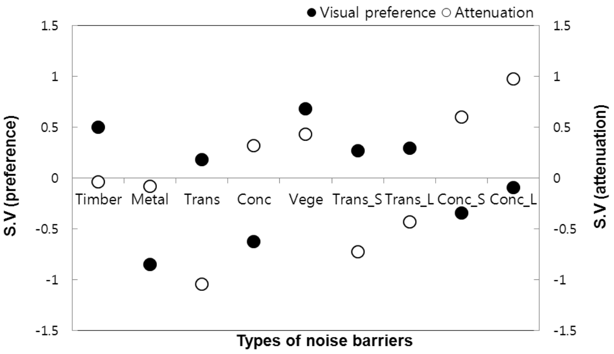


Figure 5: Results of respondents' preference and preconception of noise attenuation in terms of noise barriers

## 4.3 Audio-visual condition

Figure 6 and 7 show the results of subjects' responses in audio visual condition for case I and II, respectively. Subject rated preference on overall environment concerning acoustic and visual aspects in each case.

It was revealed that amount of noise reduction caused by noise barriers are dominant factors affecting overall impression in case I. It indicates that actual noise barrier performance to attenuate the sound pressure level of noise is more important factor than aesthetic preference to enhance overall environment.

Unlike the results of case I, metal barrier obtained lowest rating in terms of overall impression. Vegetated concrete barriers shows higher preference scores than those of others. It is deemed that in the case II, the barrier which can reduces the low frequency level would be appropriate to enhance overall soundscapes.

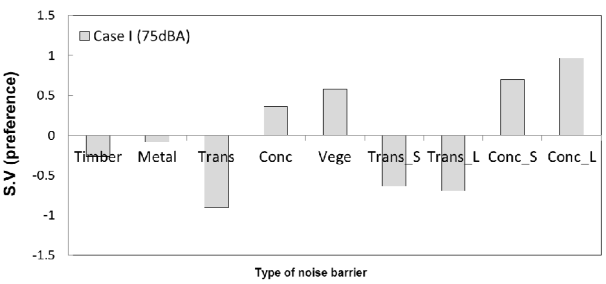


Figure 6: Results of preference of overall environment in terms of noise barriers (Case I)

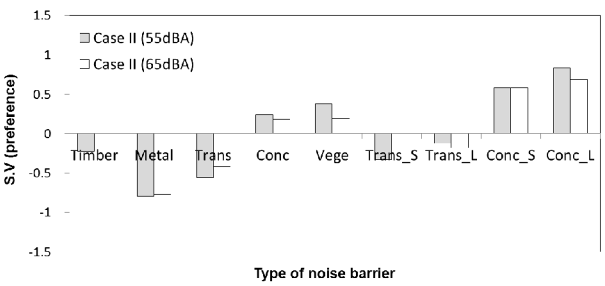


Figure 7: Results of preference of overall environment in terms of noise barriers (Case II)

## 4.4 Audio-visual interrelation

Table 2 shows the correlations between audio and visual interaction. As listed in Table 2, visual preference scores of noise barriers are lowly correlated with the results of overall impression in all cases. This implies the fact that influence of visual preference on subjects' responses to overall environment was not significant. In contrast, overall impression was highly correlated with the predictions of noise attenuation in every case. Especially, in case I, the correlation coefficient was the highest at 0.81. It indicates that subjects tended to consider acoustic comfort rather when they judged preference of environment.

Table 2: Correlation coefficients between overall impression and visual preference and preconception of attenuation (*p<0.05, **p<0.01)

| Audio-visual (Overall impression) | Case I | Case II | |
|---|---|---|---|
| | | 55dBA | 65dBA |
| Visual only (Visual preference) | -0.12 | 0.17* | 0.12 |
| Visual only (Preconception of noise attenuation) | 0.81** | 0.61** | 0.53** |

# 5 Conclusion

In the present study, evaluation of noise barrier types was conducted to investigate the effects of audio-visual interaction on the perception of overall soundscape using laboratory experiments. From the results, it was found that amount of noise reduction in terms of noise barrier performance was an important factor for perception of noise barriers. In addition, spectral characteristics of insertion loss affected overall impression. In particular, a barrier which can reduce the low frequency level could be appropriate to enhance overall environment. It was also found that images of vegetation could enhance the visual preference of noise barriers. In the future, psychoacoustical characteristics of acoustic stimuli will be analysed.

# Acknowledgments

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