Assessment of railway soundscape in rural areas

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ABSTRACT

In the present study, railway soundscape in rural areas was assessed by field measurements. Landscape merics of rural areas were analysed, then a total of 10 sites were chosen covering different composition of landscape metrics. Audio-visual recordings were carried out at selected sites; acoustical characteristics of train noises were analyzed in terms of sound quality metrics, ACF (auto correlation function) and IACF (interaural cross correlation function) parameters. It was found that noise levels of high speed trains ranged from around 70 and 90 dBA in terms of A-weighed equivalent noise levels. And it can be seen that IACC values of train noises were dependent on the layout of recorded sites, and perception of train noises were affected by background noise levels.

INTRODUCTION

The high speed train has been developed since the 1960s, particularly in Japan and Europe, and currently the high speed train has been adopted as a new transportation system in various countries. South Korea is the seventh country to develop a high speed train technology called the Korea Train eXpress (KTX). KTX was opened in 2004 and its maximum speed is around 300km/h. As the KTX has been used progressively as a major transportation system, noise problem caused by the high speed train has grown from a local to a national issue. Many complaints from the residents and visitors in rural areas have been directed upon the maximation of the speed of the high speed train.Previously many studies have been focused on community response to high speed trains, which have are based on the social survey and measurement of sound pressure level [1,2]. However, the perceptions of rural areas with high speed trains cannot be explained by only sound pressure levels since high speed trains are just one of the components of rural area consists of other variables. Therefore, perceptions of rural areas with high speed trains should be investigated as a concept of soundscape. In this study, audio-visual recordings were carried out in rural areas with high speed trains; acoustical characteristics of train noises were analyzed in terms of sound quality metrics, ACF (auto correlation function) and IACF (interaural cross correlation function) parameters.

RURAL SOUNDSCAPE

A rural area is an area outside of cities and towns which have a low population density, where noise levels are dependent on landscape metrics. The variation of noise levels in rural areas is larger, from quiet to noisy. However, in this study, only noisy rural areas have been investigated.

Table 1 shows nine landscape metrics which were chosen based on the research output of the landscape study [3,4]. Landscape metrics consists of two parts; natural and artificial features. Natural features contain agricultural crops, mountains, woods, and water features such as lakes and rivers. Artificial features include buildings, man-made constructions, traffic roads, elevated railways, tunnels, and noise barriers. Sites for audio-visual recordings were selected on the basis of analysis of landscape metrics.

FIELD MEASUREMENT

Site Selection

There are two KTX lines in Korea; the Gyunbu and Honam line. In this study a total of 10 sites, along with these two lines, were selected for field measurement. They are located in the Gyungi province near Seoul, where both KTX lines pass through. Table 2 shows the charactersistics of 10 sites chosen in different landscape metrics, covering 9 codes, to obtain data from a wide range of rural soundscapes.

Table 1. Landscape metrics of rural area

Code		Description
Natural features	1	· Agricultural crops (patch or rice field)
	2	· Undisturbed valley (mountain)
	3	· Woods
	4	· Water features (lake, reservoir, river)
Artificial features	5	· Buildings and manmade constructions
	6	· Traffic road (highway / state road)
	7	· Elevated railway and bridge
	8	· Tunnel
	9	· Noise barrier

Table 2. Characteristics of sites

Code	Sites									
	1	2	3	4	5	6	7	8	9	10
1		○	○	○	○	○	○	○	○	○
2	○	○				○				○
3	○		○				○			
4		○		○				○		
5		○	○				○		○	
6	○	○		○	○	○	○		○	○
7	○			○	○	○	○		○	
8										
9		○	○				○		○	

Table 3. Noise leves of rural soundscape

Type	Metrics	Sites									
		1	2	3	4	5	6	7	8	9	10
Train Noise	L_{Aeq}	80.7	70.5	83.3	82.7	88.0	81.1	73.2	76.6	69.0	74.2
	L_{A10}	85.2	84.1	88.7	87.7	93.1	85.6	77.0	80.9	74.5	79.9
	L_{A50}	72.5	78.5	58.1	72.4	69.7	75.4	69.9	69.4	57.5	53.0
	L_{A90}	56.8	71.6	47.6	57.9	59.2	56.3	56.4	58.4	46.1	45.6
	L_{Amax}	87.4	88.8	91.3	89.7	96.2	88.6	78.5	84.7	76.5	83.5
Ambient Noise	L_{Aeq}	62.2	71.6	59.4	60.6	64.6	61.0	58.1	54.2	43.4	42.9
	L_{A10}	63.2	72.8	64.2	63.1	59.4	63.5	62.1	57.9	46.2	44.1
	L_{A50}	56.1	69.3	54.6	59.9	54.7	58.7	53.9	49.4	42.2	42.3
	L_{A90}	54.4	68.0	47.4	55.3	51.9	57.2	50.8	47.2	38.2	41.5
	L_{Amax}	77.2	83.4	66.7	67.3	87.8	70.9	69.4	66.5	49.7	46.6

Audio-visual recording

From the field measurements, audio-visual recordings were conducted at each site. The dummy head (Type 4100; B&K) and the binaural microphone (Type 4101; B&K) were used for the audio recording. The height of the ears of the experimenter and dummy head was around 1.6 m from the ground. During the measurements, noises were recorded on a field recorder (Fostex, FX2) and DAT (Sony, PC208Ax).

In order to investigate the effect of visual image on the perception of soundscape, visual images were captured by using a camcorder (Samsung, HMX-H106). The measurements were carried out at two positions: 50 m and 100 m, perpendicularly away from the railway road. The recordings were conducted at daytime from 11:00 am to 3:00 pm, based on the assumption that outdoor activities are most frequent during this period.

ANALYSIS OF HIGH-SPEED TRAIN NOISE

Sound quality metrics and parameters extracted from autocorrelation function and interaural cross correlation function as well as sound pressure level (L_{Aeq}) and frequency characteristics were analysed in order to investigate the psychoacoustical characteristics of high speed train noise. Sound quality metrics: loudness, roughness, fluctuation strength, and sharpness were introduced; these were calculated using Pulse Software of B&K.

To observe the ACF/IACF parameters, the short-time IACF and ACF were calculated for the duration of the train noise. In all calculations, the integration interval was 0.5 s, and the running step was 0.1 s, as a same manner of the previous study [**5**]. The τ_1 and ϕ_1 are the delay time and amplitude of the first maximum peak of the normalized ACF. The longer the τ_1 and larger the ϕ_1, indicate a lower and stronger pitch. The IACC is the maximum peak of the normalized IACF.

When IACC is 1, the subjects can clearly perceive the direction of the incoming train noise, whereas the subjects can hear the train noise but it is diffused when IACC approaches 0.

Sound pressure level

Table 3 shows the noise levels of high speed train noise and ambient noise without high speed train noise. Previous studies indicated that percentile noise levels such as LA50 and LA90 as well as A-weighted equivalent noise level are useful to explain the background noise level of rural areas [6]. De Coensel also proposed the limit of quiet limit of rural soundscape as 41dBA in terms of LA50. LA50 levels of ambient noise for 10 sites in this study ranged from around 42 to70 dBA, thus there are no quiet rural soundscae according to his definition. Especially, noise level of site 2 was much higher than other sites showing 70 dBA, because of the highway nearby the site.

When high speed trains pass by, noise levels increased in most sites except for site 2. Therefore, residents and visitors of rural area can distinguish and perceive the noise from high speed trains. Even though the distance between the receiver and the railway was the same as 100 m, levels of high speed train noise showed large variations in terms of L_{Aeq}, from around 70 to 88 dBA. This is because different landscape metrics such as elevated railway and noise barriers had an effect on noise levels.

Table 3 shows the change in the L_{Aeq} of the sites as a function of time. The L_{Aeq} increased until the train passed the receiver, then decreased as the train went by. Maximum sound pressure levels were varied around 85 to 100 dBA because the heights of the railways were different and some sites had noise barriers and others did not.

It was also found that increase rates of sound pressure levels were different according to recorded sites. At site 5, noise level increased rapidly while levels of sites 3 and 9 slowly increased.

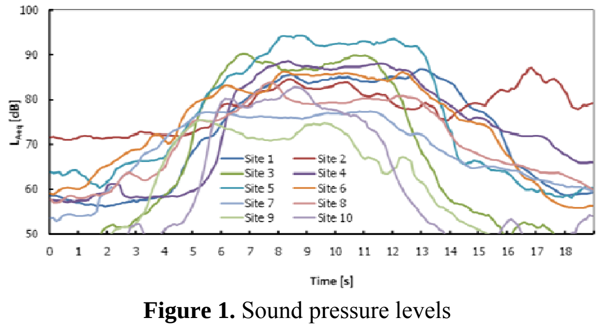


Figure 1. Sound pressure levels

Frequency characteristics

Frequency characteristics of high speed train noises are shown in Figure 2. Train noises showed a similar tendency even though noise levels are slightly different. For all trains, the noise level in dBA is mainly governed by high frequency as well as the low frequency component.

Peaks at high frequency could be assigned to aerodynamic noise and levels at low frequency are expected to be the results of engine noise. In general, peaks are observed around at 1 and 2 kHz because of rolling noise from wheel radiation.

But in this study, aerodynamic noise levels were larger than rolling noise levels, thus peaks at 1 and 2 kHz were not shown in this study.

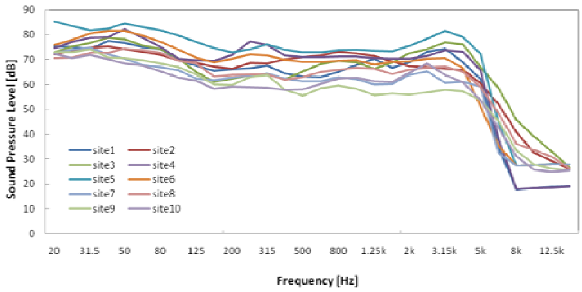
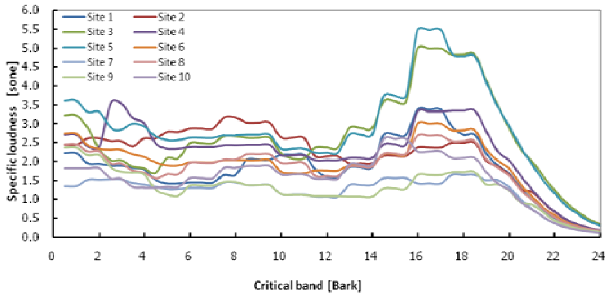


Figure 2. Frequency characteristics

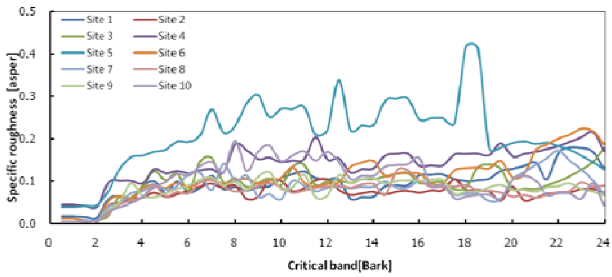
Psychoacoustic charactersistics

SQ (sound quality) metrics

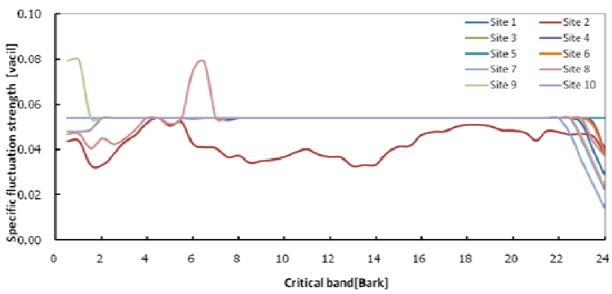
Figure 3 represents the calculated loudness, roughness, and fluctuation strength of high-speed train noises as a function of critical band. Loudness was dominant at high frequency in the range of 16 to 20 Bark contrary to frequency characteristic results. This indicates that the effects of high frequency components of high speed train noise would be larger than a low frequency component in terms of loudness. Roughness is a measure of the sensation for modulation between around 20 and 200 Hz. At most sites, roughness showed less variation as a function of Bark, but sites 3, 4, 10 had some peaks at low frequency and site 5 showed a peak at high frequency. This is because rattle noises from the railway affected the sound modulation in the range of 20 and 200 Hz. However, in the case of fluctuation strength, it is hard to indentify the differences between high speed train noises from the 10 sites. This means that different types of landscape metrics rarely have an effect on slow moving modulation of train noises.



(a) Loudness

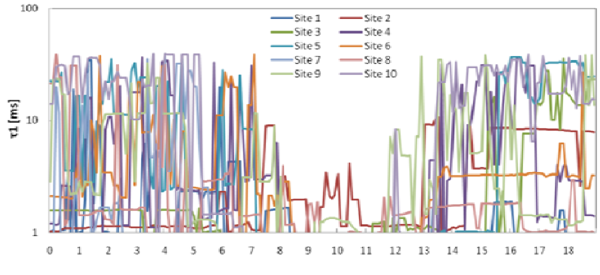


(b) Roughness

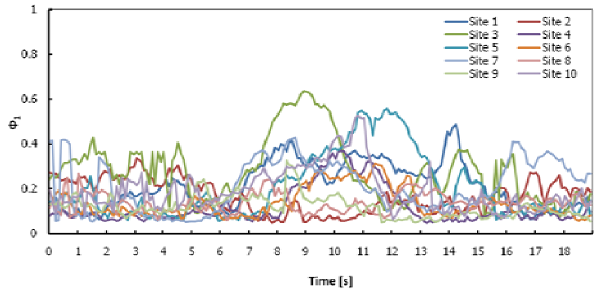


(c) Fluctuation strength

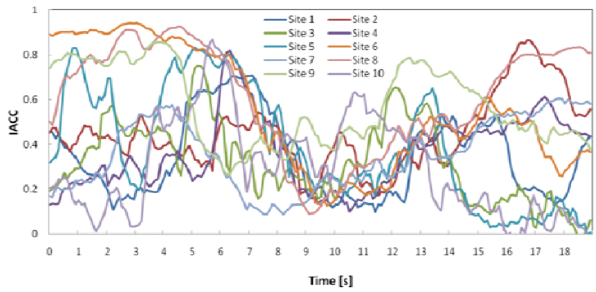
Figure 3. Analysis results of sound quality metrics



(a) τ_1



(b) ϕ_1



(c) IACC

Figure 4. Analysis results of ACF/IACF parameters

ACF/IACF parameters

The τ_1 and ϕ_1 are related to the pitch sensation and its strength respectively. As shown in Figure 4(a), τ_1 varied from 0.2 ms to 50 ms corresponding to 5 kHz and 100 Hz, respectively, and ten sites showed similar tendency as a function of time. When trains were approaching and leaving, τ_1 values were large but when they passed by, τ_1 values dramatically decreased. Thus, the perceived pitch of train noises would be different when trains are approaching and leaving or passed by.

The values of ϕ_1 were less than 0.3 when trains were approaching and leaving. This indicates that pitch in accordance with τ_1 could not be perceived. Therefore, residents and visitors perceive high speed train noise as simply noise without any specific tonal component at that time. But the ϕ_1 values increased when trains are coming to the receivers, thus the pitch corresponding to τ_1 could be perceived by listeners.

Figure 4(c) shows the results of the IACC. The values of IACC were largest when trains were approaching then, much decreased and slightly increased when those were leaving.

Thus, direction of the noise source is perceived clearly when trains were approaching and leaving. And listeners can perceive the highest subjective diffuseness when trains are passing by in front of listeners due to the low IACC values.

The values of IACC showed large variations according to the landscape metrics of recorded sites. In the case of sites 6, 8, and 9, the changes of IACC were large. This is because those sites are open space, thus listeners can easily perceive the noises from approaching and leaving trains. However, IACC values of sites 2, 3 and 7 were not much changed. This result represents that the IACC of high-speed train noise is dependent on surrounding environments of rural area as well as noise itself.

DISCUSSIONS

Perception of high speed train noise may have an effect on background noise levels. For brief comparison, sites 9 and 2 were chosen with low and high background noise levels. Figure 5 represents that train noise level was much higher than background noise level thus listeners can easily perceive train noise. However, in the case of site 2 with small level differences between train noise and background noise, train noise was masked by road traffic noise nearby.

Figure 5. Effect of background noise level

Time history of train noises were also affected by layout of recorded sites. If the right and left sides of the site were opened, listeners can hear train noise from far away. Therefore, noise level increased slowly, for instancesite 8 as shown in the figure 6. But if the right side of the site was closed by obstacles such as mountains and valleys, then the train would appear suddenly and noise levels would increase rapidly. In this case, train noise can produce startling effects.

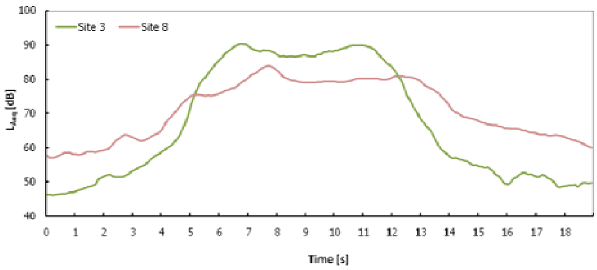


Figure 6. Effect of layout of sites

SUMMARY AND FUTHER STUDIES

In the present study, acoustical characteristics of rural soundscape with high speed train were investigated by field measurements. It was found that the landscape of rural soundscape is an aggregate of natural and man-made features. Especially in Korea, soundscape of rural area showed a variation of openness. Acoustical characteristics of high speed train noises were analyzed. Train noise levels varied in the range of around 70 and 90 dBA. And it was found that IACC values of train noises were dependent on the layout of recording sites, and the perception of train noises affected by background noise levels. In the future, preference test on rural soundscape with high speed trains will be carried out through laboratory experiments.

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