Dose-response relationships for aircraft noise annoyance in Ho Chi Minh City and Hanoi

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INTRODUCTION

Community noise-control policies and guidelines on mitigating noise have been laid down in many developed countries, especially in Europe (European Communities 2002). Noise effects in developing countries are continuing to grow because of rapid urbanization in addition to bad planning and poor construction of buildings. However, environmental noise in these countries is insufficiently controlled because of the unavailability of adequate data. The data are insufficient to propose dose-response relationships and to establish appropriate criteria. Therefore, there is an urgent need to accumulate a reliable dataset to establish the relationship between noise and community annoyance in developing countries for both national and global noise management.

In order to meet this requirement, community response to transportation noise has been investigated in Vietnam's two largest cities, Hanoi and Ho Chi Minh City, since 2004. It has been found that the Vietnamese were less annoyed by road traffic noise by about 5 dBA than European people (Phan et al. 2010). The dose-response relationships for the Vietnamese were established for road traffic noise exposure and annoyance response. The present study, which assesses the effects of another type of transportation noise, that is, aircraft noise, is essential to generate a database for formulating Vietnamese and global noise policies. Since many residential areas are in the vicinity of main airports in Vietnam, aircraft noise, together with road traffic is a main noise source that is causing adverse effects on the quality of Vietnamese life. Therefore, this study investigates the impact of aircraft noise not only as a single but also as a combined source together with road traffic noise. The objectives of this study were (i) to propose a representative dose-response relationship for aircraft noise annoyance in Vietnam and (ii) to discuss the difference in annoyance among sites and between cities.

METHODS

Survey sites

Ten residential areas were selected around Tan Son Nhat Airport, Vietnam's largest international airport with around 200 takeoffs and landings per day, locating inside a crowded residential area of Ho Chi Minh City (Figure 1). Nine sites were selected around Noi Bai Airport which is located 45 km from downtown Hanoi in the hub of many national arterial roads and industrial zones (Figure 2). The site selection was intended to reflect the aircraft noise exposure covering locations at various distances from and directions relative to the airport. Because this study was planned to investigate aircraft noise both as a single and as a combined source, all the sites except Sites 9 and 10 in Ho Chi Minh City and Site 6 in Hanoi were selected from residential areas that had roads passing through them. The houses facing the roads were selected for the combined noise survey, and those set back from the road were selected for single aircraft noise surveys (Figure 3).

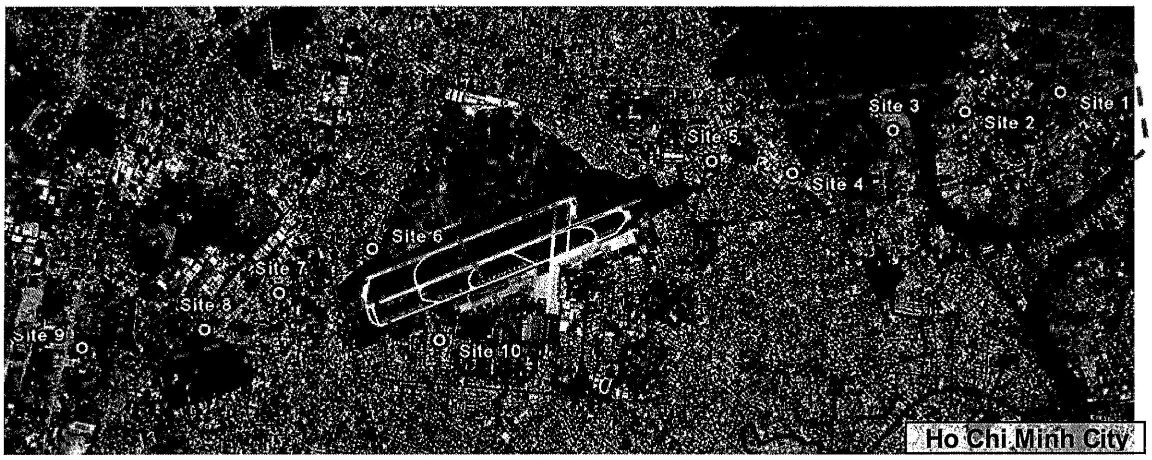

Figure 1: Map of survey sites in Ho Chi Minh City (Source: Google Earth)

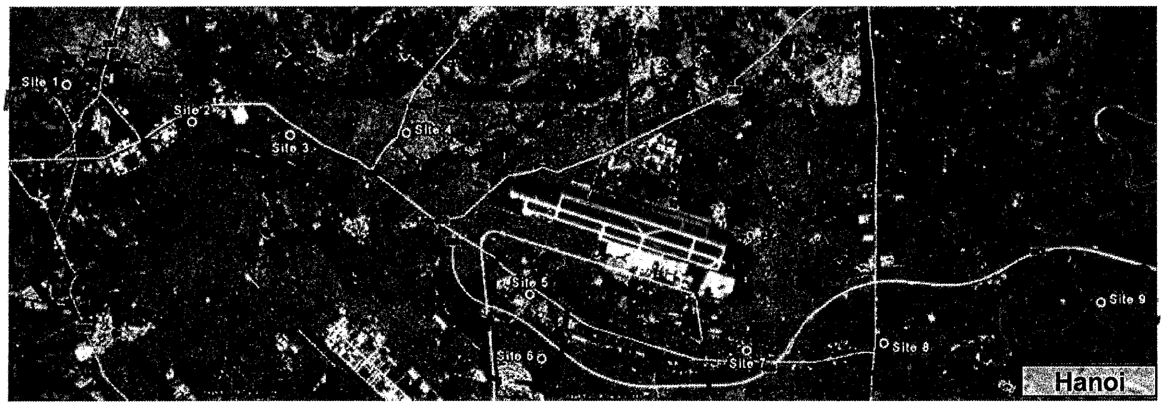

Figure 2: Map of survey sites in Hanoi (Source: Google Earth)

Social surveys

Social surveys on community response to aircraft noise and combined noise from aircraft and road traffic were conducted around Tan Son Nhat Airport in Ho Chi Minh City from August to September 2008 and around Noi Bai Airport in Hanoi from August to September 2009. The surveys were conducted with face-to-face interviews during the daytime on weekends. Two types of questionnaires were used in this study — one for the single noise survey and the other for the combined noise survey. The questionnaire used in the combined noise survey, besides containing the same question as the single noise survey, had additional questions related to the annoyance caused by road traffic and combined noise. In the questionnaire, two scales — 5-point verbal and 11-point numeric — constructed according to the ICBEN (International Commission on Biological Effects of Noise) method were used to evaluate the respondents' noise annoyance (Yano & Ma 2004).

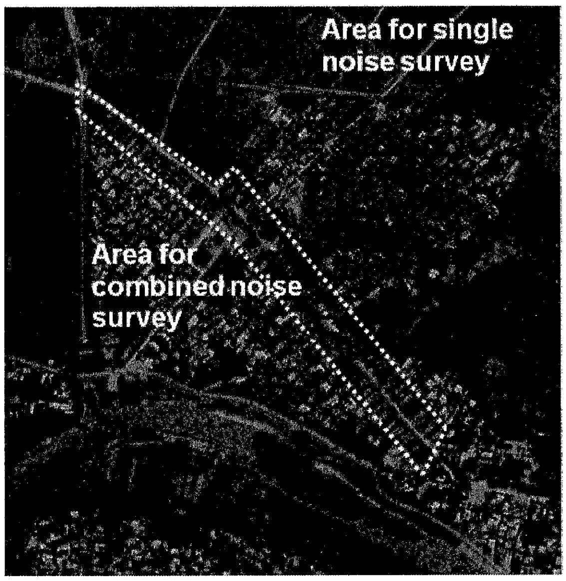

Figure 3: Example of areas for single and combined noise surveys at site 9 in Hanoi (Source: Google Earth)

Noise measurements

Since there was a lack of available noise data in Vietnam, all noise databases for this study were compiled using field measurements. Noise measurements were performed in Ho Chi Minh City from September 22 to 28, 2008, and in Hanoi from September 10 to 17, 2009, by applying the same method in both cities. Aircraft noise exposure was measured every 1 s for seven successive days by using sound level meters (RION NL-21 and NL-22) in the areas of the single noise surveys. Flight numbers and conditions were obtained from the Airport Office at each airport.

The combined noise of aircraft and road traffic was measured every 1 s for 24 h in the areas covered in the combined noise surveys. Traffic volume was counted by panel-replaying the video recordings for 10 minutes every hour. Road traffic noise metrics were calculated by energy subtraction of aircraft from combined noise metrics.

RESULTS AND DISCUSSION

Results of social surveys

In total, 1,562 and 1,397 respondents participated in the surveys in Ho Chi Minh City and Hanoi, respectively. The response rates were very high in both cities: the average response rates were 87 % and 85 % in Ho Chi Minh City and Hanoi, respectively

(Table 1). Though there is a slight difference in ratio between the socio-demographic factors of the survey sites and the Vietnam population census, the respondents of all the surveys seem to represent the typical Vietnamese people.

Table 1: Outline of social surveys on community response to aircraft noise in Ho Chi Minh City and Hanoi

		Site ID										Total
		1	2	3	4	5	6	7	8	9	10	
Ho Chi Minh City												
Sample size	Single noise survey	85	86	90	90	90	83	90	88	89	89	880
	Combined noise survey	90	66	88	89	90	85	87	87			682
Response rate												87 %
Hanoi												
Sample size	Single noise survey	96	89	100	99	76	99	88	90	87		824
	Combined noise survey	99	70	53	27	67		81	77	99		573
Response rate												85 %

Traffic volumes and noise exposure

Figures 4 and 5 show the average number of flights in Ho Chi Minh City and Hanoi. It should be noted that between 9 and 10 p.m., more landings than takeoffs were observed in both cities. Tables 2–5 show the noise metrics calculated for aircraft and combined noise exposures at all the sites in both cities. The aircraft noise exposure ranged more widely in Ho Chi Minh City than in Hanoi. Aircraft and combined noise exposures were from 53 to 71 dB and 73 to 83 dB L_{den} in Ho Chi Minh City and from 48 to 61 dB and 70 to 82 dB L_{den} in Hanoi, respectively.

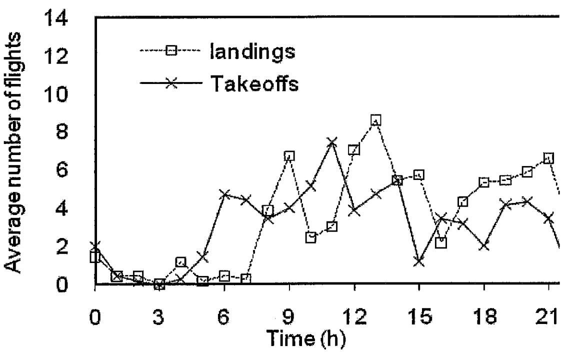

Figure 4: Number of flights in Ho Chi Minh City

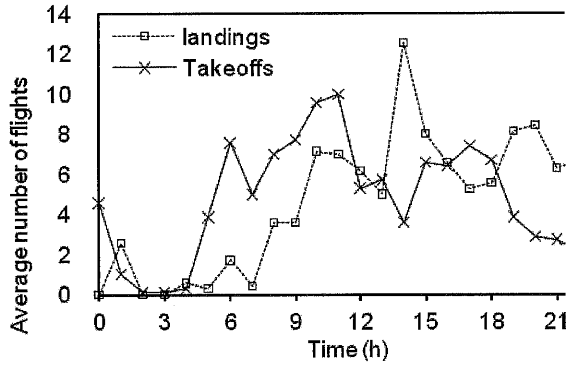

Figure 5: Number of flights in Hanoi

Table 2: Noise metrics calculated for aircraft noise exposure at all sites in Ho Chi Minh City

Noise index (dB)	Site1	Site2	Site3	Site4	Site5	Site6	Site7	Site8	Site9	Site10	Ave-rage
$L_{Aeq, day}$ (07:00~22:00)	55.7	50.8	49.9	53.3	66.8	60	60.7	57.6	57	55.1	56.7
$L_{Aeq, night}$ (22:00~07:00)	51.5	44.7	48	49.2	61.7	55.8	57.7	54.8	54.2	52.6	53.0
$L_{Aeq, evening}$ (19:00~22:00)	54.9	47.3	48.2	52.7	67.7	60.9	61.7	58.4	57.8	55.2	56.5
L_{dn}	58.9	52.8	54.8	56.7	69.5	63.2	64.8	61.8	61.2	59.5	60.3
L_{den}	59.3	53.2	55.1	57.2	70.6	64.2	65.6	62.3	61.7	60	60.9
$L_{Aeq,24h}$	54.2	49.4	49.4	52	65.8	59	59.8	56.8	56.2	54.4	55.7
L_{95}	43.7	49.1	46.5	41	42	44.6	46.3	43.9	49.5	42.1	44.9
% highly annoyed	5.2	0.0	6.7	8.9	52.2	48.8	34.4	10.7	3.4	1.2	17.2

Table 3: Noise metrics calculated for aircraft noise exposure at all sites in Hanoi

Noise index (dB)	Site1	Site2	Site3	Site4	Site5	Site6	Site7	Site8	Site9	Ave-rage
$L_{Aeq, day}$ (07:00~22:00)	51	52	58.3	54.1	45.6	46.2	54.1	57	48	51.8
$L_{Aeq, night}$ (22:00~07:00)	46.7	48.8	51.3	44.2	39.5	41.2	48.3	53.8	45.2	46.6
$L_{Aeq, evening}$ (19:00~22:00)	52	51.7	59.3	53.9	44.2	44.1	53.5	55.3	45.1	51.0
L_{dn}	54	55.8	59.9	55.4	47.5	48.8	56.2	60.8	52.2	54.5
L_{den}	54.7	56.2	60.9	56.3	48	49.2	56.8	61.1	52.4	55.1
$L_{Aeq,24h}$	49.8	51	56.8	52.5	44.2	44.9	52.7	56.1	47.2	50.6
L_{95}	39.7	45.3	47.9	38.8	41.7	47.1	40.7	42.7	43.6	43.1
% highly annoyed	6.5	11.5	57.0	68.4	18.4	4.1	8.3	20.0	4.7	22.1

Table 4: Noise metrics calculated for combined noise exposure at all sites in Ho Chi Minh City

Noise metrics (dB)	Site1	Site2	Site3	Site4	Site5	Site6	Site7	Site8	Ave-rage
$L_{Aeq, day (07:00~22:00)}$	72.5	77.6	70.8	72.1	76.4	75.8	75.4	72.6	74.2
$L_{Aeq, night (22:00~07:00)}$	67.5	75.5	64.9	66.2	73.7	70.5	69.5	70.5	69.8
$L_{Aeq, evening}$ (19:00~22:00)	70.8	76.3	69.6	73	75.9	75	75.6	72.8	73.6
L_{dn}	75	82.2	72.8	74.1	80.6	78.2	77.4	77.3	77.2
L_{den}	75.5	82.5	73.4	74.9	81	78.7	78.1	77.7	77.7
$L_{Aeq,24h}$	71.2	76.9	69.4	70.7	75.6	74.5	74	71.9	73.0
L_{95}	41.4	64.7	43.5	49.1	56.9	53.4	45.7	53.8	51.1
% highly annoyed	4.7	0.0	50.0	0.0	34.5	25.3	26.4	25.9	20.9

Table 5: Noise metrics calculated for combined noise exposure at all sites in Hanoi

Noise metrics (dB)	Site1	Site2	Site3	Site4	Site5	Site7	Site8	Site9	Ave-rage
$L_{Aeq,\ day\ (07:00\sim22:00)}$	68.2	73.5	73.6	70.3	72.4	72.5	79.4	66.9	72.1
$L_{Aeq,\ night\ (22:00\sim07:00)}$	61.2	71.8	71.8	65.3	67.1	67.1	72.5	62.8	67.5
$L_{Aeq,\ evening}$ (19:00~22:00)	66.2	72.7	72.8	69.5	68.2	68.3	80.4	62.1	70.0
L_{dn}	69.6	78.5	78.5	72.8	74.8	74.8	80.9	70.1	75.0
L_{den}	70.1	78.8	78.8	73.3	75	75.1	81.8	70.3	75.4
$L_{Aeq,24h}$	66.6	73	73	69	71.1	71.1	77.9	65.8	70.9
L_{95}	36.1	47.6	47.6	45.9	41.4	41.4	51.4	42.3	44.2
% highly annoyed	4.0	10.1	73.1	61.5	7.5	2.6	33.3	3.2	24.4

Dose-response relationships

A logistic regression function was applied to plot the dose-response curves for aircraft noise annoyance. This was evaluated by the percentage of people highly annoyed in the single and combined noise surveys in Ho Chi Minh City and Hanoi; the day-evening-night average sound level (L_{den}) was chosen as the independent variable. Following the European Union (EU) position paper, in which the cut-off point for the highly annoyed was defined as the top 28 %, the authors defined the top three categories of the 11-point numeric scale (top 27 %) as highly annoyed.

Figure 6 shows the relationships for general annoyance in Ho Chi Minh City and Hanoi using synthesized data from the single and combined noise surveys. When the percentage of highly annoyed is higher than around 20 %, the two curves are almost parallel to each other with a noise level difference of approximately 8 dB. Hanoi's curves are higher than Ho Chi Minh City's. In other words, respondents in Hanoi were more annoyed by aircraft noise than those in Ho Chi Minh City at the same noise level.

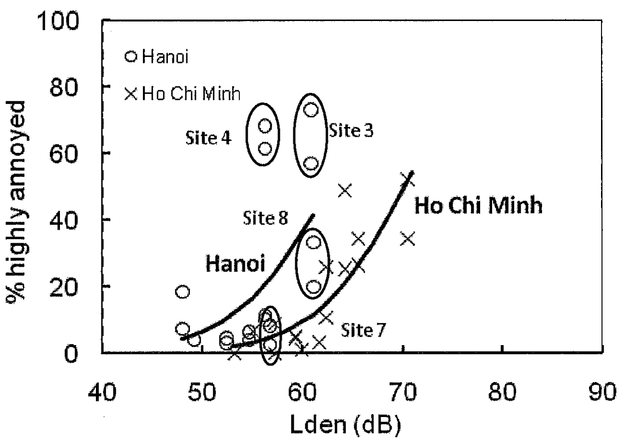

Figure 6: Dose-response relationships for general annoyance in Ho Chi Minh City and Hanoi using synthesized data from single and combined noise surveys

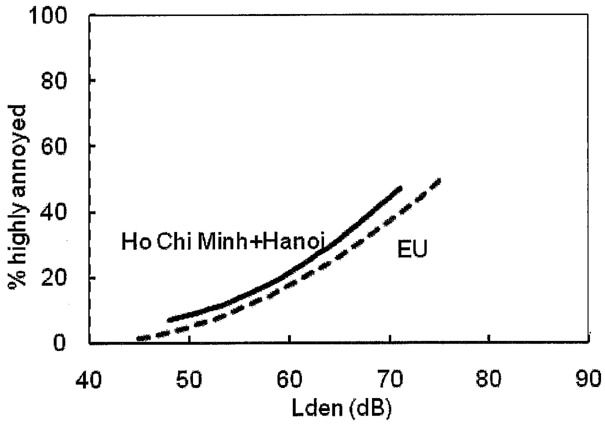

Figure 7: The synthesized curve of Ho Chi Minh City 2008 and Hanoi 2009 surveys in comparison with the EU's curve

Finally, the synthesized curve of Hanoi 2009 and Ho Chi Minh City 2008 surveys was plotted and compared with the EU's (Figure 7). At the same noise level, the percentage of highly annoyed respondents in Vietnam was slightly higher than those in the EU. In other words, there is 2 to 3 dB difference between the two curves at the same percentage of high annoyance.

Difference in response among sites

In this section, the possible causes of high annoyance particularly at Sites 3 and 4 in Hanoi will be discussed through a comparison with Sites 7 and 8, which have the equivalent noise levels. Though respondents at Sites 3 and 8 were exposed to almost the same aircraft noise levels, 60.9 and 61.1 dB, respectively, those at Site 3 were found to be more highly annoyed by aircraft noise than those at Site 8 as shown in Table 3 and Figure 6. The same finding was also gained between Site 4 (L_{den} = 56.3 dB) and Site 7 (L_{den} = 56.8 dB). These results suggest that annoyance is affected not only by noise exposure levels but also by other factors.

It is noteworthy that Sites 3 and 4 and Sites 7 and 8 are, in pairs, located under the landing and takeoff paths, respectively. In the questionnaire survey, the respondents were asked to indicate how frequently they were disturbed by the airborne vibration from aircraft (Table 6). The results showed that, in the aircraft and combined noise surveys, the residents at Sites 3 and 4 were more frequently disturbed by the airborne vibration from aircrafts than those at Sites 7 and 8.

Table 6: Chi-square test of frequencies of respondents almost everyday and once or twice in a week disturbed by airborne vibration between sites under landing and take ff routes

	Site 3	Site 8	Chi-square	P	Site 4	Site 7	Chi-square	P
Single survey	55	45	1.9	>.05	73	7	82.8	<.001
Combined survey	64	43	5.4	<.05	65	3	52.7	<.001

In addition, the frequency of use of airplanes by the respondents at each site was assessed. As can be seen in the Table 7, the percentages of respondents who did not use airplanes at all were 89 % and 95 % in the aircraft noise areas of Sites 3 and 4, while these were only 50 % and 57 % at Sites 7 and 8, respectively. The differences are slightly smaller when considering combined noise areas at these sites.

Table 7: Chi-square test of frequencies of respondents who do not use airplanes at all between sites under landing and takeoff routes

	Site 3	Site 8	Chi-square	P	Site 4	Site 7	Chi-square	P
Single survey	89	57	24.0	<.001	95	50	44.6	<.001
Combined survey	76	57	4.9	<.05	77	55	3.9	<.05

Since sleep disturbance is also a main effect of noise on humans, the time at which respondents went to bed was investigated (Table 8). The results indicated that, with the exception of the aircraft noise area of Site 8, more respondents at Sites 3 and 4 went to bed between 9 and 10 p.m. than those at Sites 7 and 8. In addition, there are more landings than takeoffs observed during this period of the night (Figure 5). These facts might cause higher sleep disturbances at Sites 3 and 4, which were under the landing path of the aircraft, than at Site 8 at the same noise level. All the above reasons could be used to explain the higher annoyance found at Sites 3 and 4 than at the other sites.

Table 8: Chi-square test of frequencies of respondents who go to bed till 22:00 between sites under landing and takeoff routes

	Site 3	Site 8	Chi-square	P	Site 4	Site 7	Chi-square	P
Single survey	34	33	0.0	>0.05	38	16	11.4	<.001
Combined survey	21	15	1.9	>0.05	48	7	23.2	<.001

Difference in response between cities

The results of previous studies indicated that individuals tended to judge the annoyance of an unwanted sound in terms of its relationship to background noise (Lim et al. 2008). The background noise level, in this study, is defined as the 95th percentile (L_{95}), as shown in Tables 2–5. It can be easily observed that the background noise levels at almost all sites of Ho Chi Minh City are higher than at those of Hanoi. While the average L_{95} values in Hanoi are 43 dB and 44 dB for single and combined noise surveys, respectively, they are 45 and 51 dB in Ho Chi Minh City. The outstandingly larger traffic volume in Ho Chi Minh City might yield the higher background noise level there. It can be speculated that the noise of aircraft events in Hanoi when the background noise levels are lower might be generally more noticeable than in Ho Chi Minh City. Bivariate correlations were calculated between those noise metrics and each of three variables — individual annoyance score, average annoyance score, and percent highly annoyed. The results showed that L_{95} was statistically significantly correlated at the 0.01 level with individual annoyance score evaluated by the respondents of all surveys. This finding emphasized the role of background noise level on the annoyance of respondents in Ho Chi Minh City and Hanoi.

CONCLUSIONS

This study provided a broader knowledge on exposure situations as well as annoyance of aircraft noise in Vietnam. Aircraft and combined noise exposures ranged from 53 to 71 dB and 73 to 83 dB L_{den} in Ho Chi Minh City and from 48 to 61 dB and 70 to 82 dB L_{den} in Hanoi, respectively. The dose-response curve for aircraft noise for Vietnam was established and fitted onto the curve for the EU. It has been found that the curve for Vietnam was 2 to 3 dB higher than that for the EU at the same percentage of high annoyance.

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Evaluation of urban space as a concept of soundscape

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ABSTRACT

Although considerable effort has been made in community noise control, reducing the sound level does not necessarily lead to better acoustic comfort in urban spaces. Therefore, it is essential to consider the environmental conditions of urban environments and how they can attract people. Recent studies on the soundscape of urban space have shown that various kinds of contexts contribute to overall perception, and ISO/TC 43/SC 1/WG 54 has started to work on standardization of evaluation procedures. The present study deals with methodologies for evaluation and improvement of urban space as a concept of soundscape. Individual soundwalk methodology has been proposed for assessment of urban space and derivation of the design elements. In addition, sound masking methodology using water sounds has been investigated for improving soundscape perception.

INTRODUCTION

Urban open spaces have contributed to the social and ecological effects of lifestyles and attitudes to nature and sustainability. The acoustical environment is a critical factor in the overall comfort of urban open spaces (Kang 2006). Therefore, considerable effort has been devoted to community noise control so as to investigate the relationship between the level of noise and the annoyance level of people. However, reducing the sound level does not always lead to improved acoustic comfort in urban spaces (de Ruiter 2004) and it is often not realistic to reduce community noises in open spaces. Therefore, the concept of soundscape has been adopted for the evaluation of the outdoor environment.

The initial concept of soundscape was proposed as an attempt to construct an analytical perspective that would describe the total acoustic environment over time and across cultures. Therefore, most soundscape studies concern the qualitative analysis of soundscapes. Schulte-Fortkamp & Fiebig (2006) adopted the Grounded Theory as a sociological approach, and Berglund & Nilsson (2006) proposed a tool for measuring soundscape quality by attribute profiling. However, the methods for evaluating a soundscape are different according to the purposes of the studies and the researchers, and thus it is difficult to directly compare the results of these studies. Even though many recent studies adopted the soundwalking methodology to identify the perception of an urban acoustic environment (Berglund & Nilsson 2006; Jeon et al. 2010a), the standardization of the procedures for assessing soundscapes are still being discussed in the ISO TC43 SC1 WG 54 (perceptual assessment of soundscape quality).