# Exposure-response relationships on community annoyance to transportation noise

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## INTRODUCTION

The first synthesis study for the community response to noise was reported by Shultz in 1978 (Schultz 1978). It covers the response to all the traffic noise including aircraft as well as ground vehicles. Kryter found that the response to ground traffic noise differed from that to air traffic noise at the same exposure level (Kryter 1982). Finegold et al. reanalyzed the datasets and recommended three different curves to describe the community annoyance to aircraft, road traffic and railway noise (Finegold et al. 1994). Recently, Miedema et al. made a synthesis study from datasets of 45 different social surveys and established annoyance curves for each transportation noise (Miedema & Vos 1998; Miedema & Oudshoorn 2001).

Datasets used in those analyses were mainly obtained from either north American countries or from western European countries. The annoyance response could vary with different areas, different cultures, and different languages. The researches in various cultural areas are necessary for more comprehensive exposure-response relationships for transportation noise. This article presents synthesis results from an in-depth study made in Korea during several years. Exposure-response relationships based on all 87 datasets were established. Noise metrics and annoyance measures which were used here for analysis and the information of the field surveys are introduced. More details on this research are in preparation for publishing as a follow-up paper.

## METHODS

To establish the relationships between noise exposure and community annoyance, $L_{dn}$ was used as the descriptor of noise exposure from four different traffic modes. It is defined as a day-night average sound level, and applies a 10 dB penalty to noise at night. The definition is as follows:

$$L_{dn} = 10\log\left[\frac{15}{24}\times 10^{0.1\times L_{day}} + \frac{9}{24}\times 10^{0.1\times(L_{night}+10)}\right]$$

Here $L_{day}$ and $L_{night}$ are the long-term $L_{Aeq}$ as defined by ISO (ISO 1996-2 1987), each represents the average sound levels during the day from 07:00 to 22:00 and the night-time from 22:00 to 07:00, respectively.

ICAO (International Civil Aviation Organization) recommended WECPNL (Weighted Equivalent Continuous Perceived Noise Level) as a metric of the aircraft noise (ICAO 1971) and, in Korea, the modified WECPNL has been applied to evaluate the aircraft noise and to establish the noise criteria. This modified WECPNL was used, in this article, as the noise metric when the responses to aircraft noise are separately analyzed from those to other transportation noise. The definition is as follows:

$$\mathrm{WECPNL} = \bar{L}_A + 10\log(N_2 + 3N_3 + 10(N_1 + N_4)) - 27$$

where, $\bar{L}_A$ denotes the energy mean of all maximum aircraft noise levels during a day. $N_2$ and $N_3$ are the number of events during the day from 07:00 to 19:00 and the night-time from 19:00 to 22:00. $N_1$ and $N_4$ are the number of events from 00:00 to 07:00 and from 22:00 to 24:00, respectively.

Field survey for military aircraft noise was performed in 25 sites near the Suwon and Daegu airbase and the average number of daily flights is about 33. For commercial aircraft noise, the field survey was performed in 20 sites around two major airports. These airports have different volumes of flight operations, where the average number of flights in Gimpo and Gimhae airports is 160 and 80 a day, respectively. Aircrafts rarely operate at night, so the number of flight operations hardly includes the operations during the night-time. Eighteen sites along Gyungbu and Honam railway lines were selected to investigate the effects of railway noise. Railway traffic was composed of passenger trains and freight trains, where the mean number of daily operations was about 253 and the component ratio of two train types were 61 % and 39 %, respectively. For road traffic noise, 17 sites around the principle roads and the highways in Seoul city were selected. The operation was composed of two types of road vehicles: light vehicles and heavy vehicles including heavy trucks. The traffic volume at the principle roads is about over 50,000 a day and the component percentages of the daily traffic are 69 % for light vehicles and 31 % for heavy vehicles.

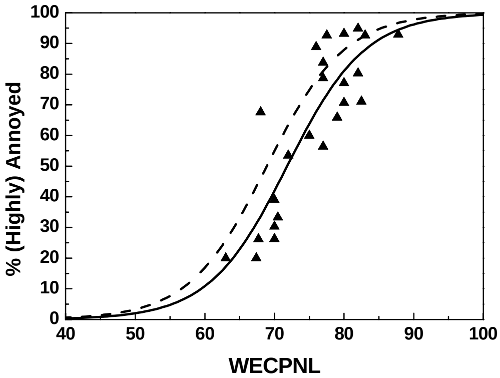
To assess the effects of noise, the percentage of respondents who felt highly annoyed (%HA) is selected as the indicator of noise annoyance in many researches. WHO also has recommended %HA as one of the environmental health indicators to explain the effects of noise on health (WHO 2000). In this study, respondents were asked to answer the question, ‘How much have you been bothered or annoyed from military aircraft (or commercial aircraft/railway/road traffic) noise when you are in and around the house for the last 12 months or so?’, by selecting one of 11 degrees of annoyance. A numerical scale from 0 (not annoyed at all) to 10 (extremely annoyed) was used in the survey. For the responses of exceeding 7, the percentage of the respondents is called the percentage of highly-annoyed population (%HA). In total 87 datasets derived from the questionnaire surveys have been used in the present synthesis. Table 1 gives the information on the demographic characteristics of 2,944 respondents for 87 datasets.

**Table 1:** Information on the demographic characteristics of the respondents

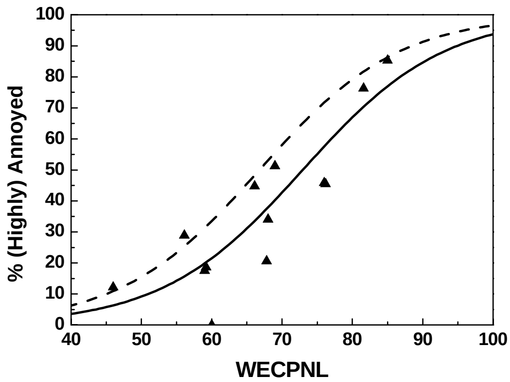
| Demographic characteristics | Noise source categories | | | |
|---|---|---|---|---|
| | Military aircraft | Commercial aircraft | Railway | Road traffic |
| Total number respondents | 1,031 | 753 | 653 | 779 |
| Male (%) | 12 | 33 | 24 | 25 |
| Female (%) | 88 | 67 | 76 | 75 |
| *Distribution of age* | | | | |
| ~ 20th (%) | 1 | 6 | 4 | 8 |
| 20th ~ 40th (%) | 66 | 37 | 52 | 51 |
| 40th ~ 60th (%) | 28 | 38 | 32 | 30 |
| 60th ~ (%) | 5 | 19 | 13 | 11 |
| *Marital status* | | | | |
| Single (%) | 9 | 19 | 13 | 24 |
| Married (%) | 91 | 81 | 87 | 76 |

## RESULTS

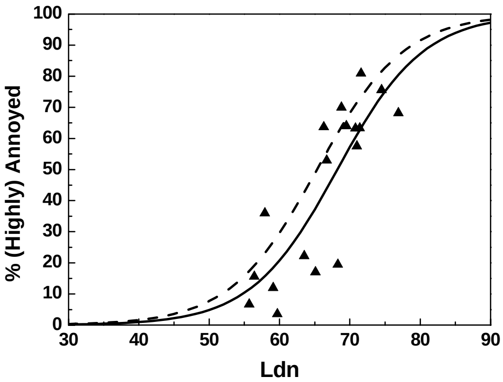
To establish the exposure-response relationships for each traffic mode, datasets obtained from the field survey have been accumulated. For a data-point contains at least 30 cases, corresponding %HA and %A are determined and plotted. A methodology used to determine the relationships follows the recently reported article by the authors (Lim et al. 2006). In Figure 1, data points and %HA (%A) prediction curves for four traffic modes were shown. For military and commercial aircraft, WECPNL was used as the noise metric and the relationships for railway and road traffic were established as a funtion of $L_{dn}$.



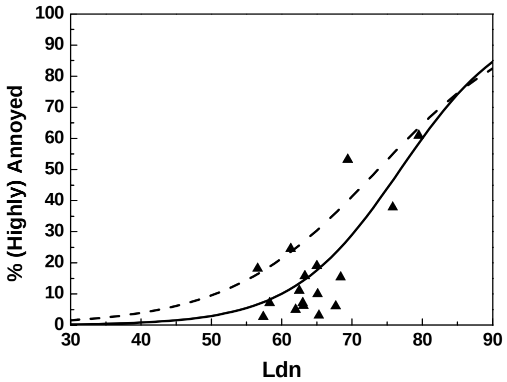

(a) Military aircraft




(b) Commercial aircraft




(c) Railway




(d) Road traffic

**Figure 1:** %HA (solid line; —) and %A (dashed line; – –) prediction curves with %HA data points (▲) for military aircraft, commercial aircraft, railway, and road traffics (in turns of (a), (b), (c) and (d))

Figure 2 shows the annoyance curves for four traffic modes together with respect to $L_{dn}$. At a given exposure level, both military and commercial aircraft cause the highest %HA, followed by railway and road traffic. Overall the railway curve lies below the aircraft curves and above the road traffic curve, indicating a substantial difference between these sources. The differences between the curves for four traffic modes were considered to be caused by non-acoustical factors as well as acoustical factors. For example, fear of a plane crash may cause people to be more annoyed to aircraft noise than others.

In comparison of the annoyance response induced by commercial and military aircraft noise, it is found that the trend of curves of commercial and military aircraft noise turned to be reversed at 58 dBA. Over 58 dBA, military aircraft noise causes more annoyance than commercial aircraft noise at the same exposure level and vice versa below 58 dBA. Such a result as the comparison of community response between military and commercial aircraft noise has hardly been reported before the authors' recently conducted study (Kim et al. 2007).

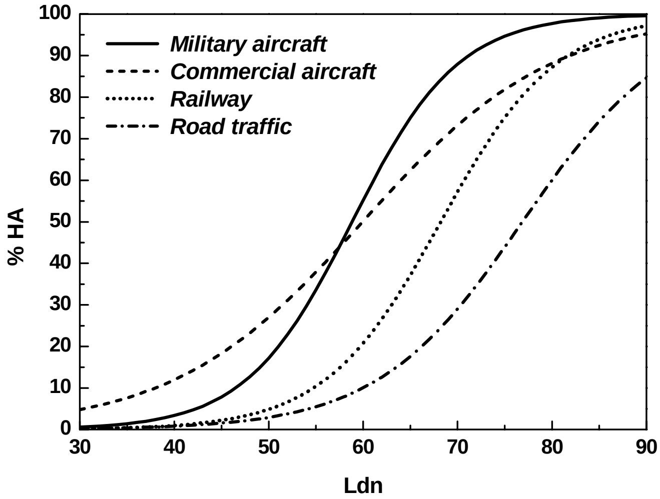



**Figure 2:** Comparison of %HA prediction curves for four traffic modes together as a function of $L_{dn}$

Exposure-response relationships for commercial aircraft were compared according to different background noise levels. Each dataset was divided into two groups by the difference between aircraft noise levels and background noise levels. The descriptor for background noise is $L_{Aeq,1h}$. The differences between aircraft noise levels in WECPNL and background noise levels in $L_{Aeq,1h}$ for group 1 are over 20 dB and those for group 2 are about 10 dB, where background noise levels of group 1 and group 2 are 42 and 55.5 dBA. Figure 3 shows %HA with respect to WECPNL in both groups and it is found that the annoyance response to aircraft noise was significantly affected by background levels.

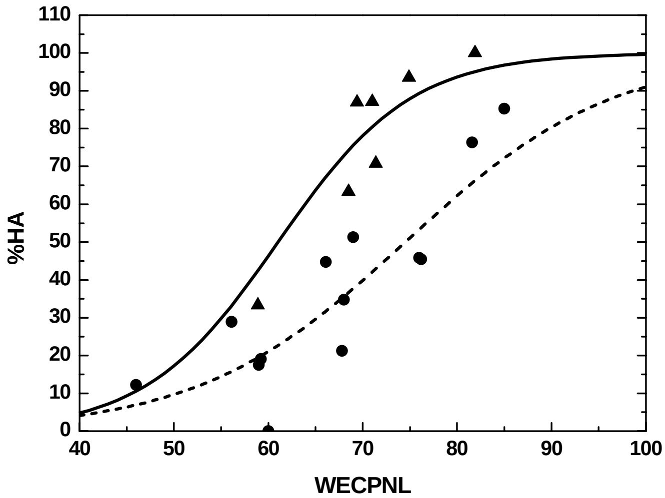
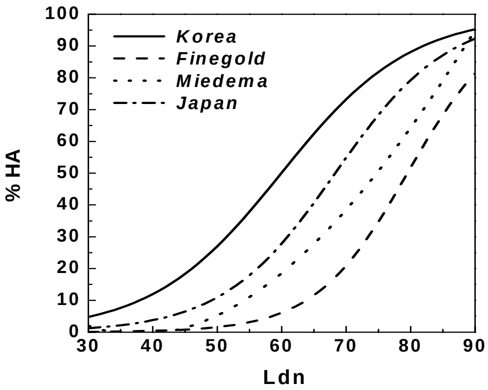
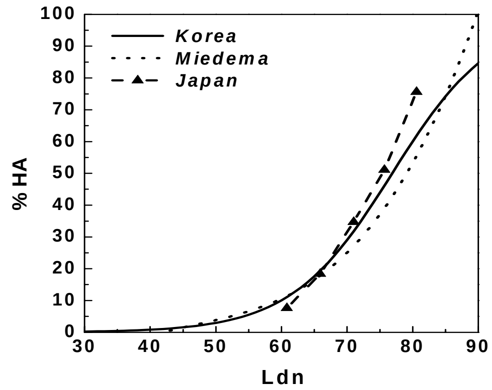



**Figure 3:** Comparison between %HA prediction curves of commercial aircraft noise according to background noise levels (▲and ●, field survey data in group 1 and group 2, respectively; —, %HA prediction curve of group 1, N=487; – –, %HA prediction curve of group 2, N=212)

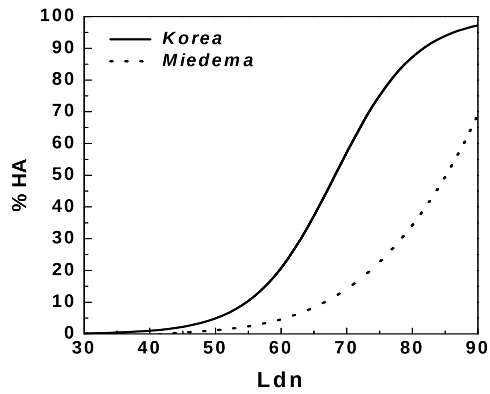
A comparison of exposure-response relationships with those reported by other researchers has been undertaken. Figure 4 shows the comparison between the annoyance curves in this research and others in European, American and Japanese surveys for different traffic modes. There are significant differences between curves from various researches for aircraft and railway noise. Especially with respect to railway noise, a number of studies in foreign countries showed that railway noise causes less annoyance than other transportation noise. This is called a "railway bonus" in European countries. Some researchers explain that railways are socially considered as more acceptable than other traffic modes because of safety, economic efficiency, and convenience (Fields & Walker 1982).

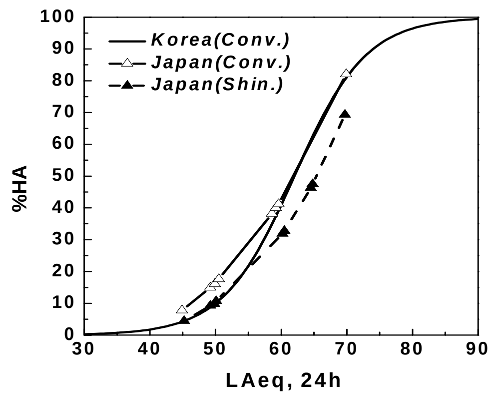



(b) Commercial aircraft




(a) Road traffic




(c) Railway

**Figure 4:** Comparison between %HA prediction curve of commercial aircraft noise in Korea and those in other countries (in Figure 4 (c), Conv; Conventional railway, Shin; Shinkansen express railway)

Recent Japanese studies have reported different results (Igarashi 1992; Kaku & Yamada 1996; Yano et al. 1997; Morihara et al. 2004), where railway noise annoyance in Japan is much higher than in European countries. Figure 4 (c) shows that the result of this research is similar to that of the survey in Japan. %HA response to the conventional railway noise of Korea shows the same result with Japan's at over 60 dB. The distance between the railway and the house may be an important cause of the difference in the annoyance responses. A number of houses in Korea are situated closer to railway lines than those in Western countries due to high population density (Lim et al. 2006; Hong et al. 2007). Therefore, vibration levels caused by train passages are usually higher than those of Western countries. Unlike the results of aircraft and railway noise, there is no significant difference between the road traffic annoyance curve in this survey and that in European's as well as Japan's. The situation of surroundings near the roads is mostly similar in many countries, so the results supposed to be similar.

## CONCLUSIONS

An in-depth study on the community response to transportation noise has been made in Korea during several years and this article presents synthesis results. Exposure-response relationships to long-term noise exposure has been established from large-scaled investigations. The annoyance response to military aircraft noise has been examined in distinction from that to commercial aircraft noise which has been usually focused in the most of previous researches. We have obtained an interesting conclusion reached by comparing two annoyance curves for commercial and military aircraft noise, which has not been reported yet. As an important factor on community annoyance, background noise has been assessed concerning commercial aircraft noise areas. The response shows much more annoying when background noise levels are considerably lower than aircraft noise levels.

In most of European and American researches for the community response to transportation noise, it has been shown that railway noise is less annoying than road traffic noise as well as aircraft noise. The result is reflected in noise regulation of some European countries as a so-called "railway bonus". On the contrary, the annoyance response to transportation noise in Korea has shown the opposite trend, where railway noise is more annoying than road traffic noise. From this investigation on community annoyance to transportation noise, the authors attempt to establish the relationships and provide background information for policy-making activities. The results presented in this article might be representative responses of Korean to transportation noise.

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