The relationship between railway noise and community annoyance in Korea

Changwoo Lim[a)]
Center for Environmental Noise and Vibration Research, School of Mechanical and Aerospace Engineering, Seoul National University, Rm 205 Bldg 44, Seoul, 151-744, South Korea

Jaehwan Kim[b)]
School of Mechanical and Aerospace Engineering, Seoul National University, Rm 205 Bldg 44, Seoul, 151-744, South Korea

Jiyoung Hong[c)]
School of Mechanical and Aerospace Engineering, Seoul National University, Rm 205 Bldg 44, Seoul, 151-744, South Korea

Soogab Lee[d)]
School of Mechanical and Aerospace Engineering, Seoul National University, Rm 1303 Bldg 301, Seoul National University, Seoul, 151-744, South Korea

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A study of community annoyance caused by exposures to railway noise was carried out in 18 areas along railway lines to accumulate social survey data and assess the relationship between railway noise levels and annoyance responses in Korea. Railway noise levels were measured with portable sound-level meters. Social surveys were administered to people living within 50 m of noise measurement sites. A questionnaire contained demographic factors, degree of noise annoyance, interference with daily activities, and health-related symptoms. The question relating to noise annoyance was answered on an 11-point numerical scale. The randomly selected respondents, who were aged between 18 to 70 years of age, completed the questionnaire independently. In total, 726 respondents participated in social surveys. Taking into consideration the urban structure and layout of the residential areas of Korea, Japan, and Europe, one can assume that the annoyance responses caused by the railway noise in this study will be similar to those found in Japan, which are considerably more severe than those found in European countries. This study showed that one of the most important factors contributing to the difference in the annoyance responses between Korea and Europe is the distance between railways and houses.
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I. INTRODUCTION

Environmental noise pollution due to transportation noise continues to grow and has become a serious problem in many countries.[1] This problem is difficult to regulate because it involves direct and cumulative adverse effects of noise on health. In recent years, therefore, the percentage of respondents who felt "highly annoyed" has become a critical component of environmental impact analyses to support environmental decisions regarding transportation noise.

Noise annoyance produced many responses characteristic of psychological stress.[2–4] Annoyance reactions are sensitive not only to acoustical characteristics (source, noise level), but also to many nonacoustical factors such as social, psychological or economic nature.[5,6] There are considerable differences in individual reactions to the same noise.[7] Therefore, social surveys on transportation noise have been performed in many countries over the past 40 years, from which dosage-response relationships for transportation noise have been evaluated.[7–12]

A majority of studies in European countries reported that railway noise causes less annoyance than other transportation noise sources.[8,13–16] This is a so-called "railway bonus" in noise regulations of some European countries. However, recent Japanese studies have produced very different results.[17–20] They have shown that no railway bonus existed and that railway noise annoyance was nearly the same as or even a little higher than road traffic noise annoyance.

Although many social surveys on the effects of railway noise have been performed throughout the world, they have been carried out mainly in developed countries. Even with similar noise levels and sources, the results of the annoyance responses differ from country to country, because annoyance responses to railway noise are affected by several external factors including cultural differences, languages differences, variations in survey questions, and differences in climatic conditions.[2,16] Therefore, the objective of this paper is to

[a)]Electronic mail: glider20@snu.ac.kr
[b)]Electronic mail: kjh03@snu.ac.kr
[c)]Electronic mail: hongjy@snu.ac.kr
[d)]Author to whom correspondence should be addressed. Electronic mail: solee@plaza.snu.ac.kr

TABLE I. Distance data.

Distance (m)	$d<20$	$20<d<40$	$40<d<100$	$100<d<200$	$d>200$
Number of sites	3	4	7	2	2
Percentile (%)	16.7	22.2	38.9	11.1	11.1

accumulate the social survey data to assess the relationship between railway noise levels and annoyance responses in Korea, and to estimate the applicability of a railway bonus in Korea.

II. METHOD

The most common method of assessment for human response to railway noise is the combination of a field survey that consists of physical measurements and social surveys using a questionnaire. Noise measurements and social surveys were carried out simultaneously.

A. Noise Measurement

1. Site selection

Due to the high population density in Korea, a number of houses are situated close to railway lines and railways pass through the middle of several cities.

Field surveys were performed in 18 areas along Gyungbu and Honam railway lines in Korea. These sites were chosen based on the fact that they have high volumes of train operations that consist of heavy freights and passenger trains that use a diesel engine. The two lines are responsible for more than 60% of the passenger and freight transports in the whole railroad industry.

Most of the houses in the field survey areas are apartment buildings built out of ferroconcretes. Table I shows the distances between the railway lines and the survey sites in this study. The average distance was 90 m, but about 80% of the sites were situated within 100 m from the railway lines. Figure 1 shows an example of some of the selected sites in which field surveys were carried out. As shown in this figure,

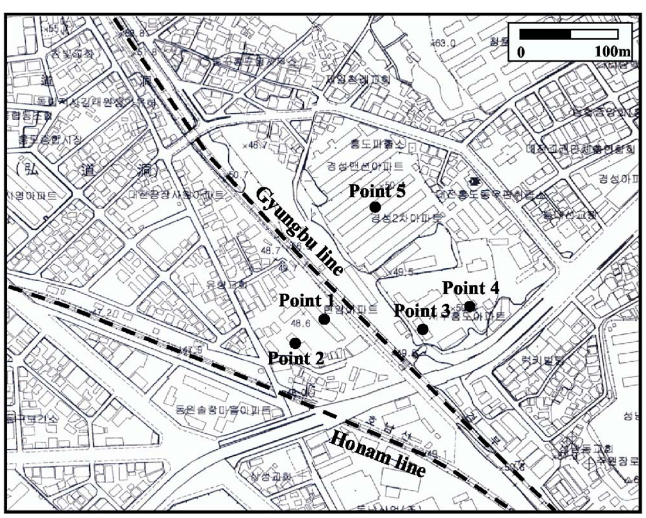

FIG. 1. Some selected sites in which field surveys were carried out.

distances of points 1 through 5 are about 20, 60, 27, 80, and 85 m, respectively. Measurement sites that were chosen were also flat and free of obstacles.

2. Noise measurement

Table II shows information regarding the details of the train operations of Gyungbu and Honam railway lines. Noise levels were calculated around the two railway lines with different volumes of train operations. The average number of train operations of Gyungbu line is about 250 a day and that of Honam line is about 51 a day.

Railway noise levels were measured with portable sound-level meters (B&K type 2238 and LD 812) at 18 sites. The equipment was mounted on a tripod on the rooftop of houses to avoid obstacles between the railway and the receiver. The microphone was positioned at a height of 1.5 m above the flat, and at least 1 m from any other reflecting surfaces.

It was necessary to carry out extensive measurements, in order to calculate the railway noise levels. So, measurements were taken for three successive days in June 2004. The relative humidity and temperature of the sites varied from 62.5% to 64.6% and 18 °C to 23 °C, respectively, at the time of measurements.

To analyze the relationship between railway noise levels and annoyance responses, day-night noise level L_{dn} was calculated. The day-night noise level L_{dn} was calculated from the formula.[21]

$$L_{\mathrm{dn}} = 10 \log\left[\frac{15}{24} \times 10^{0.1\times L_{\mathrm{day}}} + \frac{9}{24} \times 10^{0.1\times (L_{\mathrm{night}}+10)}\right], \tag{1}$$

where L_{day} and L_{night} represent the day and night-time average sound levels which were calculated from A-weighted sound exposure levels L_{AE} observed for every passing train. The day-time period was defined as 07:00 to 22:00 and the night-time period was defined as 22:00 to 07:00.

B. Social survey

Subjective responses to railway noise were measured by means of a social survey using a questionnaire. The survey

TABLE II. Information on the train operations.

	Type of trains (diesel)		Number of trains per day	
	Passenger	Freight	Day time	Night time
Gyungbu line	152	98	178	72
Honam line	32	19	41	10

was performed in order to investigate the individual's attitude and opinion in regard to different aspects of the railway noise, and it was administered to residents within about 50 m of field survey sites. Therefore, one can assumed that all of the respondents were exposed to similar railway noise levels.

Questionnaires were comprised of questions relating to the assessments of railway noise as well as some general questions about the residents, even if they do not relate to noise. Questions were arranged in three basic sections. The first section sought to obtain demographic data, the second asked questions about the nuisance perceptions of railway noise and vibration, and the third dealt with questions regarding health-related symptoms. Therefore, the questionnaire contained demographic questions, degree of noise annoyance, interferences with daily activities, perception of vibration, psychological and physiological health-related symptoms, and reaction to railway noise. In order to assess the annoyance responses to railway noise, specifically, people were asked questions like "how much were you bothered or annoyed by the railway noise, while staying at home, in the last 12 months,"[22] by selecting one of 11 categories ranging from 0 (not at all annoyed) to 10 (extremely annoyed). The 11-point numerical scale was chosen based on the assumption that respondents are more cognitively familiar with a 0 to 10 scaling than the shorter 7- or 9-point numeric scales.[23]

To avoid any bias in opinion, the surveys were not introduced to the interviewees in advance and respondents were randomly selected from residents near the survey sites based on simple random sampling method. Questionnaires were distributed in person and respondents completed the questionnaire independently while researchers waited. Each questionnaire took about 20 min to complete. They were administered concurrently with the noise measurements at each site. 61.7% of the randomly selected respondents participated in the surveys, resulting in a total of 724 respondents for the analysis of exposure-effect relationships between railway noise levels and annoyance responses.

III. RESULTS

The ages of respondents exhibit a wide range: younger than 20 years (4%), 20–40 (52%), 40–60 (32%), and older than 60 years (12%). Most of the respondents were female (76%) and were married (85%). These results were due to the nature of the Korean culture where most females become housewives after marriage. The duration of residency of the respondents was as follows: less than 1 year (8%), 1–3 years (24%), 3–10 years (41%), and 10–30 years (27%). Only the responses of respondents who had resided in the area for more than 1 year were analyzed for the purposes of this study.

Annoyance responses to railway noise were elicited by means of an 11-point numerical scale. Under the definition of the annoyance scale, the term "highly annoyed" was defined as the upper 27–28 % of the annoyance scale. Therefore, the "highly annoyed" variable of annoyance responses was calculated as a binary datum. This means, the equal variance assumption and the assumption that responses vary about the mean according to a normal distribution are not valid due to the binary nature of the data. In cases where the variable is binary, logistic regression analysis is more reliable.[24,25] The data, therefore, had to be dichotomized to conduct a logistic model. The numerical scale of annoyance response was dichotomized with the responses in the top three out of 11 categories (3/11) being defined as "highly annoyed" and the remaining are not. The responses were bounded between zero and one. The logistic model can be expressed as follows:

$$E(Y_i/X_i) = \frac{e^{(\beta_0+\beta_1 X_i)}}{1+e^{(\beta_0+\beta_1 X_i)}}, \tag{2}$$

where, β_0 and β_1 are the intercept and the slope of the logistic response function.

In the case of this study, maximum likelihood estimation (MLE) was used to dispose of the assumption problems mentioned earlier, and to estimate the parameters of a logistic model.[25,26]

When assessing the effects of noise on health, the percentage of respondents who felt highly annoyed (%HA) are recommended as the indicator of noise annoyance and the day-night average sound level (L_{dn}) is selected as the uniform metric for the description of noise in many countries, such as the European Union, North America, and Australia. Therefore, %HA and L_{dn} have been used to assess the effects of railway noise on health in terms of dose-response relationship between railway noise levels and annoyance responses.

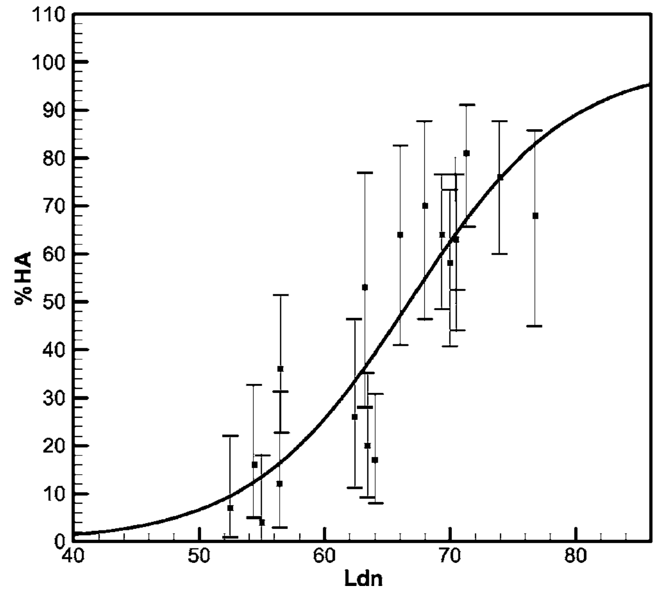

FIG. 2. Prediction curve for the percentage of highly annoyed respondents (%HA) based on noise exposure at the dwelling. Solid line is %HA prediction curve. Points are field survey data in 18 areas. Bars are 95% confidence intervals for the data point. $N=613$.

Figure 2 shows the %HA prediction curve of railway noise in this study. Square spots show the percentage of respondents who felt "highly annoyed" as a function of L_{dn}. Bars represent the 95% confidence intervals at each data point. The 95% confidence intervals were calculated to estimate the distribution of "highly annoyed" respondents at each field survey site. The levels of railway noise exposures

TABLE III. Estimated coefficients for the logistic equation using L_{dn} as the noise exposure metric.

Parameter	Estimate	Std. error	*P* Value
β_0	−10.547	1.028	<0.0001
β_1	0.158	.015	<0.0001

range from 52 to 76. The solid line is the %HA prediction curve that was determined by logistic fit procedure based on field survey data. The estimates of coefficients β_0, β_1 are presented in Table III with their estimated standard errors and significance levels. As shown in this table, the significance of p value is less than 0.01, meaning the parameters of this model are significantly effective.

A next step estimates the measure of fit of the established logistic model. As the criterion of an explanatory power, the coefficient of determination R^2 is used in linear regression models. Then again, the correct classification rate (CCR) is generally considered to estimate the measure of fit of logistic models. In this model, total CCR is 72.3. It shows a good relationship between railway noise levels and the percentages of respondents feeling "highly annoyed." As shown in Fig. 2, it is found that with an increase of L_{dn}, the percentage of respondents who felt highly annoyed also increased.

IV. DISCUSSION

In order to investigate the community response to railway noise, 18 areas were chosen and field surveys were carried out at each area. Then, the dose responses conducted in this study were compared with those of other countries to examine whether or not the annoyance responses to railway noise were equivalent among countries.

Figure 3 indicates comparison between the noise annoyance curve in this study and the one in the European survey.[8] Square spots are each field survey data showing %HA with respect to L_{dn}. The solid line is the %HA prediction curve of this study by logistic fit procedure. The dashed line is the one of Miedema and Vos by polynominal fit.[8] As shown in this figure, the results are different. Of course, we know that surveys can differ from one to another due to many factors, such as cultural differences, languages differences, different phrasings of the annoyance questions, and differences in climatic conditions.[16] The results of this study, however, are much more severe than those of European countries even after taking those external factors into account. A number of studies in foreign countries showed that noise annoyance from railway noise causes less annoyance than other transportation noise.[8,13–16] This is called a "railway bonus" in European countries. While there is no scientific evidence to suggest why respondents feel that railway noise is less annoying than other transportation noise, some researchers believe that some sentimental feelings about railways are influential.[17,27] Railways are often considered socially more acceptable than other types of transportation because of safety, economy, and convenience.[16] However, recent Japanese studies have produced different results.[17–20] Railway noise annoyance in Japan was much higher than in European countries. Figure 4 shows the comparisons of annoyance curves with respect to $L_{Aeq,24h}$ which was calculated from an average of A-weighted sound exposure level (L_{AE}) observed for every passing train in a Japanese study[28] and three European surveys.[29] The solid line is the %HA prediction curve of this study based on field survey data. Dash-dotted line (a) is the %HA prediction curve of conventional railways in Japanese survey. Dashed lines (b), (c), and (d) are the %HA prediction curves of French, Danish, and British surveys, respectively. Figure 4 shows that the result of this study is not only similar to that of the survey in Japan, but more severe when compared to those in European countries. The distance between the railway and the house may be an important

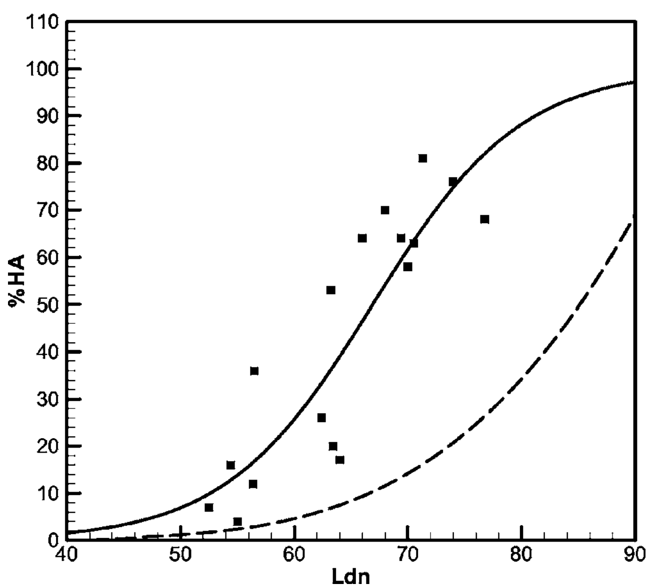

FIG. 3. Comparison between the %HA prediction curve of railway noise in this study and that in a European country. [■, field survey data with respect to L_{dn} in this study; ——, %HA prediction curve in this study; - -, the Miedema and Vos %HA prediction curve (Ref. 8).]

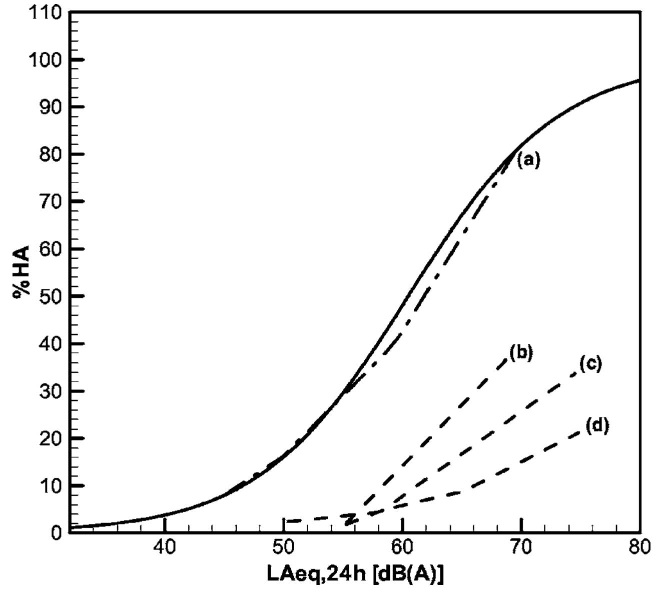

FIG. 4. Comparison between the %HA prediction curve of railway noise in this study and those in other country surveys. [——, %HA prediction curve in this study; (a) Japan 1992 (Ref. 28); (b) France 1988 (Ref. 29); (c) Denmark 1988 (Ref. 29); (d) U.K. 1984 (Ref. 29).]

TABLE IV. Measurement data at sites within 50 m of railway lines when a train passes by.

Measurement point	$L_{A\max}$	Measurement point	$L_{A\max}$
Point 1	93.1	Point 6	100.5
Point 2	93.7	Point 7	99.9
Point 3	97.6	Point 8	92.8
Point 4	94.1	Point 9	96.1
Point 5	91.6		

cause of the difference in annoyance responses between Korea and European countries. A number of houses in Korea are situated closer to railway lines than those in European countries due to high population density. Therefore, noise and vibration levels caused by train passages are usually higher than those of European countries. For example, Table IV shows the maximum noise level ($L_{A\max}$) at sites within about 50 m of railway lines when trains pass by. As shown in this table, all of them exceed 90 dB(A) and Point 6 even exceeds 100 dB(A). These values are too high to lead a peaceful life, especially when nighttime exposure to heavy freight trains occurs.

The position of the balcony also has a significant effect on general annoyance responses. Respondents who lived in apartments with balcony windows facing a railway may be more annoyed by the noise than those having balcony windows not facing in the railway direction.[20] In Korea, many apartments have balconies that face the railway.

Attitudes toward railway noise could also have an influence on annoyance responses since the noise could cause social and economic costs, such as property value depreciation. In Korea, the price of apartments in areas close to railway lines is lower than those in noise free areas. The increase of 1 dB noise affects the price of an apartment by about 0.3%.[30]

For these reasons, Korean people living close to railways in this study may feel more annoyed than European people. There is a similarity between the results of the Japanese survey and those of this study because conditions, such as high population density in metropolitan areas and distances from railways to houses, in Japan are similar to those in Korea.

Another factor contributing to our findings may be the inconsistent nature of railway noise. About 15% of the respondents said that they have been surprised by very loud and unexpected railway noise every day. They also considered the railway noise as having negative effects on their health, and complained that the exposure to railway noise caused insomnia, nervousness, and indigestion.

V. CONCLUSIONS

Environmental noise pollution due to transportation noise continues to grow and has become a serious problem in many countries. This problem is difficult to regulate because it involves direct and cumulative adverse effects of noise on health. In recent years, therefore, the percentage of respondents who felt "highly annoyed" has become a critical component of environmental impact analyses to support environmental decisions regarding transportation noise. The World Health Organization (WHO) has recommended annoyance as one of the environmental health indicators to support environmental noise policy-making activity in many countries. However, WHO does not recommend an international consensus on how to predict annoyance from transportation noise sources. Therefore, this study of community annoyance caused by railway noise exposures was carried out to accumulate social survey data and to assess the relationship between railway noise levels and annoyance responses in Korea. Noise measurements were carried out in 18 areas along Gyungbu and Honam railway lines in Korea. Social surveys were administered to residents living within 50 m of the noise measurement sites. The total number of respondents for the social surveys was 726.

It can be concluded that the community annoyance of railway noise in this study is similar to that found in Japan but more severe than that found in European countries. The cause of the difference can be ascribed to the distance between railways and houses, the position of the balcony, and attitudes of the residents toward the source of the noise. Based on these results, we claim that a railway bonus should not be applied to railway noise guidelines in Korea.

ACKNOWLEDGMENT

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