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Comparison of community response to transportation noise: Japanese results and annoyance scale

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The results of social surveys on transportation noise in Japan were summarized. They were compared with published data in foreign countries based on the Fidell's single value of L_{dn} in the annoyance function which corresponded to $1/e$ (37%) of highly annoyed. It was found that various kinds of response scales had been used in the past as listed in Appendix. The scales are expressed in some of different wordings. They are divided into 3 to 11 steps and the verbal descriptive labeling of steps are not always the same. Therefore, the selection of steps as highly annoyed is likely to affect the results of annoyance response. For comparison of social survey data, it seems necessary to use the standardized annoyance scale to avoid the ambiguity in the measuring procedure of annoyance. The expressions of an annoyance scale and steps in different languages and their translation are also important problems in the case of international comparison.

Keywords: Social survey on noise, Community response to noise, Transportation noise, Annoyance scale

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1. INTRODUCTION

Social surveys on transportation noise have been performed in many countries over the past 30 years. The published data up to 1978 were summarized by Schultz[1] and the recent surveys were reviewed and compared by Hall[2] and Fidell.[3] In Japan, lots of similar surveys have been carried out since 1965 for reflecting community response into environmental criteria on various noises. However, the results of these surveys had scarcely been referred in foreign papers, because they were issued mostly in Japanese publications. This paper summarizes results of social surveys on noise which have been published in the Journal of the Acoustical Society of Japan or in the reports of the special committees on environmental noise. In trying to compare the Japanese results with those in foreign reports, the author noticed that human response to noise had been measured using various kinds of scales, though noise exposure indices had generally been unified in L_{dn} after Schultz's synthetic work in 1978. For instance, the response scale was expressed in terms of a mono-polar scale; 'annoyed,' 'disturbed,' 'tolerable' or a bi-polar scale; 'agreeable-disagreeable' 'satisfied–dissatisfied.' The scale was divided into 3 to 11 steps and comparative labels were usually given to steps. For comparison of data obtained in different surveys, a category of 'highly annoyed' has been widely used, however, the labeling of each step and the selection of steps may affect the response expression to L_{dn}. The verbal description in different language is another problem to be considered.

2. SOCIAL SURVEYS PERFORMED IN JAPAN

2.1 Aircraft Noise

2.1.1 Ōsaka Airport study-1 (1965)[4]

Jet aircraft were introduced to Ōsaka Interna-

tional Airport in 1964, and a social survey on noise was conducted in 1965. The aircraft noise was measured at 27 points in 8 cities around the airport, and attitudes of people to aircraft noise were asked in parallel. A total of 2,700 samples were obtained. The aircraft noise measurement was made in a class room of a school at 1 meter from an open window which faced to flight paths of aircraft in most cases. A correction of 7 dB was added to the reported result in order to estimate the outdoor noise level. A noise exposure index NNI was used and it was converted to L_{dn} by,

$$L_{dn}=0.76\mathrm{NNI}+34.5\ .$$

The relation was derived in Schultz's report for the analysis of Heathrow Airport noise. The response scale had 7 steps and only upper 3 steps were named as 'noisy,' 'very noisy' and 'intolerable' (translation from Japanese). In this paper, the upper 2 steps are chosen as 'highly annoyed.' Figure 1 shows the linear and quadratic fitting functions of 27 data points for Ōsaka Airport Study-1. The Schultz's synthesis curve is also drawn in the figure. The difference of more than 10 dB is observed.

2.1.2 Ōsaka Airport study-2 (1973)[5]

The social survey was performed again in and in the neighbourhood of Itami City which is adjacent to the west of the airport. The area was divided into 416, and 2,333 samples were collected at random. As a noise exposure index, a modified WECPNL (Japanese aircraft noise index)[6] was used in the report and it was converted to L_{dn} by,

$$L_{dn}=\mathrm{WECPNL}-13-2$$

where, (1) (-13) is a correction from Perceived Noise Level to A-weighted sound pressure level.

(2) (-2) is a correction for L_{dn} from Japanese index which has an evening penalty.

(3) Duration correction for flyover noise is assumed to be 10 dB.

The response scale had 5 steps, and the upper 2 steps were named as 'annoyed' and 'very annoyed'. In Fig. 2, 1/5 ('very annoyed') and 2/5 ('very annoyed' and 'annoyed') to L_{dn} are shown. The similar result was obtained as that of 1965 survey when the top step (1/5) of annoyance scale was chosen.

2.2 Road Traffic Noise.

2.2.1 Nagoya road traffic (1984)[7]

The community response to road traffic noise was measured in Nagoya City. A noise index, $L_{eq,24}$ was used and it was converted to L_{dn} by,

$$L_{dn}=L_{eq,24}+3$$

The response scale was a 4-step scale.

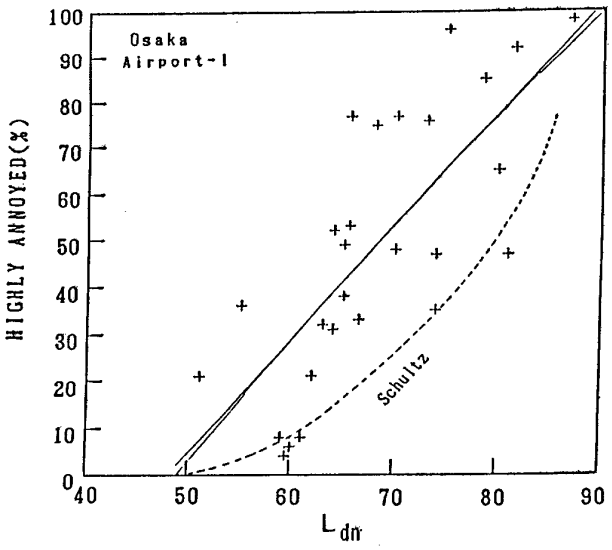

Fig. 1 Dose-response curves of Osaka Airport study-1. Linear and quadratic fitting functions for 27 data points. 2/7 of annoyance scale is shown as highly annoyed to L_{dn}.

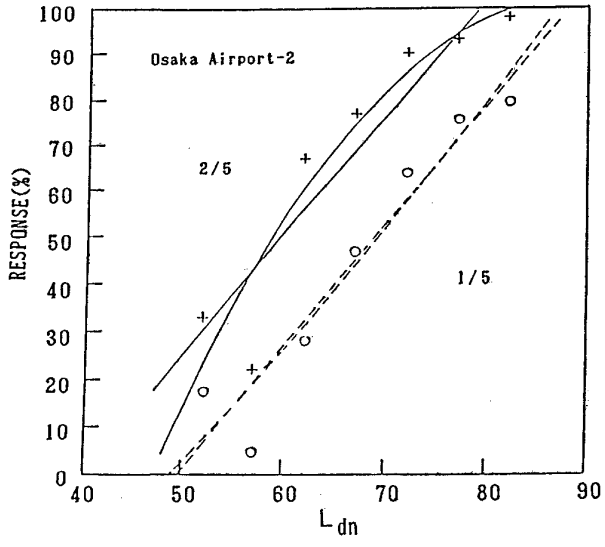

Fig. 2 Dose-response curves of Osaka Airport study-2. Linear and quadratic fitting functions for data points. 1/5 (broken lines) and 2/5 (full lines) of annoyance scale to L_{dn}.

1. not annoyed. 2. a little annoyed. 3. annoyed. 4. very annoyed.

In Fig. 3, a half of 3 plus 4 (1.5/4) and 1/4 of the response scale to L_{dn} are shown. Among two curves, (1.5/4) of the response scale agrees fairly well with the Schultz's synthesis curve.

2.2.2 Fukuoka road traffic (1986)[8]

The similar study to Nagoya city was carried out in Fukuoka City. A 7 step response scale and L_{dn} were used, the upper 2 steps were named as 'annoyed' and 'very annoyed.' A total of 1,381 samples were collected. An average response curve, 2/7 of the response scale to L_{dn} was reported as 'highly annoyed' which is shown in Fig. 4. The result is almost the same as that of Nagoya City, when 1.5/4 and 2/7 of the respective response scales are chosen.

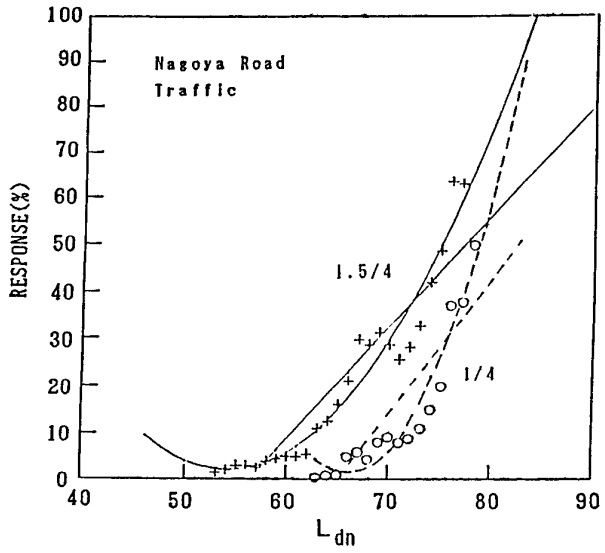

Fig. 3 Dose-response curves of Nagoya road traffic noise study. Linear and quadratic fitting functions for data points. 1/4 (broken lines) and 1.5/4 (full lines) of annoyance scale to L_{dn}.

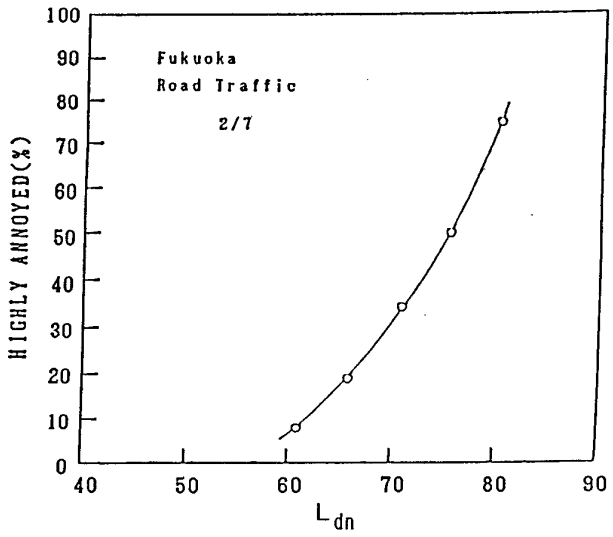

Fig. 4 Dose-response curve of Fukuoka road traffic noise, 2/7 of annoyance scale to L_{dn}.

2.3 High-speed Railway (Shinkansen) Noise[9-11]

Several studies have been performed on railway noise, but only three reports on high-speed railway (Shinkansen) noise have been published. Shinkansen is a special name of a high-speed railway in Japan. It was constructed from Tōkyō to Ōsaka (Tōkaidō line) in 1964, Ōsaka to Fukuoka (Sanyō line) in 1971, extending over 1,000 km.

There were remarkable complaints against unfamiliar noise from Shinkansen train (200 km/h and about 200 operations per day). A couple of surveys were performed in 1973. The average level of L_{max}'s for passing trains is an index to evaluate the Shinkansen noise (based on the procedure of the environmental criterion for Shinkansen noise), and it is converted to L_{dn} by,

$$L_{dn}=L_{max}+a+10_{10}\log N+b-49.4$$

where, a: Duration correction for a train passing noise (a mean duration time of Shinkansen is 6 seconds and $a=8$)

b: Time of day correction for L_{dn} ($b=2$ from a time table)

N: Number of train operations.

The annoyance response was measured by a 7 step scale, and only both ends were named as, 'not at all annoyed' and 'very annoyed.' The first survey, Shinkansen-1, was carried out by Tōhoku University and the second, Shinkansen-2, by Environment Agency of Japan. The dose response curves were expressed by 3/7 of the annoyance scale in both reports as 'positive reaction,' and a 2/7 curve was also drawn in the second report, as 'highly annoyed.' These are shown in Fig. 5. The difference of one step between 2/7 and 3/7 is about 8 dB in L_{dn}. In the Schultz's report,[1] the result of Japanese high-speed railway noise (Shinkansen-1) was referred. Schultz pointed out that the Japanese response to railway noise was extremely high, and he attributed it to the difference of Japanese house attenuation. But as the author mentioned above, the Japanese response curve in Shinkansen-1 was reported based

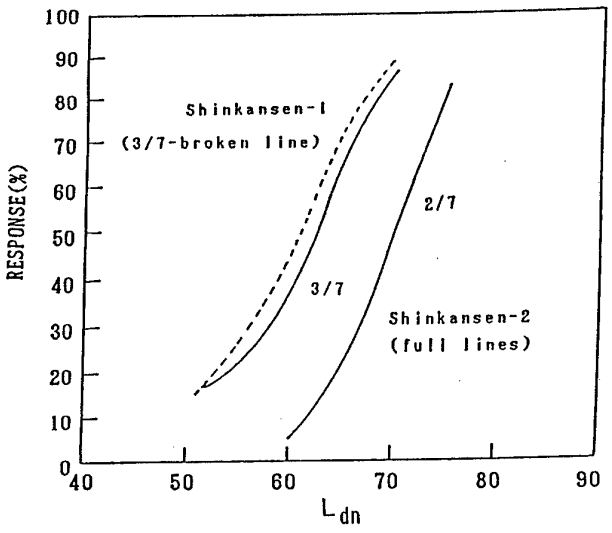

Fig. 5 Dose-response curves of Shinkansen noise. Shinkansen-1 (3/7-broken line) and Shinkansen-2. (3/7-full line), (2/7-full line).

Table 1 Partial correlation coefficients between (1) annoyance, (2) disturbance to conversation and personal characteristics of individuals (Shinkansen-2).

Personal characteristics	(1) Annoyance	(2) Conversation
Living years	0.00	0.05
Age	0.05	0.11
Occupation	0.08	0.20
Structure of dwelling	0.10	0.09
Environmental feature of one's area	0.18	0.10
Frequency of Shinkansen utilization	0.04	0.11
Noise exposure level by Shinkansen	0.44	0.39

on 3/7 of the response scale, and if 2/7 was adopted instead of 3/7, the difference would become smaller, though the response was still too high. In Shinkansen-2, the partial correlation coefficients between annoyance and several factors of the respondents were calculated. The noise level of the Shinkansen has the maximum correlation coefficient, 0.44 to annoyance as shown in Table 1. In the Table, the correlation coefficients between disturbance to conversation and personal factors are also shown.

In 1982, other two new lines were constructed from Tōkyō to the northern parts of Japan, Sendai (Tōhoku line) and Niigata (Jōetsu line). And the third social survey, Shinkansen-3 was carried out

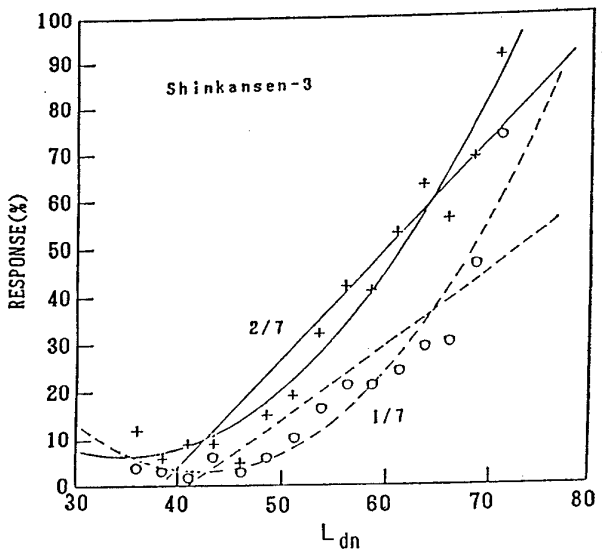

Fig. 6 Dose-response curves of Shinkansen-3. Linear and quadratic fitting functions for data points. 2/7 (full lines) and 1/7 (broken lines) of annoyance scale to L_{dn}.

in 1989 by selecting 7 areas along new and old lines, 3 areas of old lines, and 4 areas of new lines. For each area, 200 samples were obtained. The dose response relation, 'highly annoyed' (2/7) averaged 7 areas to L_{dn} is shown in Fig. 6. In the figure, 1/7 of the annoyance scale is also shown. The difference of one step in this study is 7.5 dB from the quadratic curves.

Next, by comparing above Shinkansen studies, it is noteworthy that the response curves of the recent Shinkansen-3 shift nearly one step to the left from the former surveys. On the other hand, Shinkansen-3 shows that people in rural areas (mostly along new lines) are less sensitive than those in urban areas by 5 dB in L_{dn}. The old lines were constructed along densely populated districts in Japan over 20 years ago, accordingly, the change of degree of annoyance could be attributable to the change of attitudes of people along the old lines by an influence of some non-acoustical factors. The response to Shinkansen noise shows extremely high annoyance. It might be caused not only by the unfamiliar high-speed train noise but also by a special factor of non-step operation of Shinkansen, because the residents have no benefit from it in most areas along the lines. It was also found out that residents living in the south side area to a railway were less sensitive to noise than those in the north side as shown in Fig. 7. It is because, most of

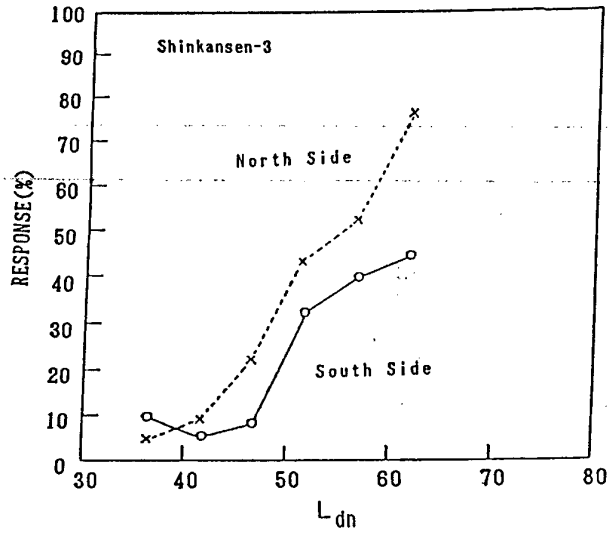

Fig. 7 Comparison of response of people living in the north side and south side areas of railway.

living rooms of Japanese house (in the northern hemisphere) locate in the south part of a house. The noise exposure level reported in Shinkansen-3 was $L_{eq,24}$ and only a time of day correction was added calculated from a time table of Shinkansen.

3. ANNOYANCE SCALE USED FOR SOCIAL SURVEY

Except road traffic noise, the Japanese studies show that the response curves shift more than 10 dB to the left relative to the Schultz's synthesis curve. However, for comparison of the annoyance responses obtained in different studies, the response scales have to be examined. In the Appendix, various response scales are listed which have been used in the social surveys. Most of scales in foreign studies were quoted from the reports of Schultz[1] and Fidell.[8] As a category of 'highly annoyed,' Schultz recommended to select 27–29% of a response scale, but in his analysis, different percentages of the response scale were chosen depending on the verbal description of each step and a number of steps. For instance, in the case of 5 step scale, Schultz adopted 1/5 (20%) or 2/5 (40%) of the scale as 'highly annoyed' by taking into account of the adjectival expression of the top step.

In the Appendix, a percentage of the scale selected by Schultz and Fidell as 'highly annoyed' in each report is also indicated. For Japanese results, dual selection of steps was tried in order to compare with the data of foreign countries.

4. COMPARISON OF DIFFERENT SURVEYS

Fidell[12] reported the theoretical interpretation of the dose response relationship on noise. He indicated that a dose-response curve could be identified by a decibel unit criterion D^* (Response index in L_{dn}) which corresponded to $1/e$ (37%) of 'highly annoyed.' It will be convenient if this single value is used to compare the Japanese results with those obtained in other countries. Tables 2–4 show the D^* value of each survey listed in the APPENDIX. Table 2 is the data for aircraft noise, Table 3 for road traffic noise and Table 4 for railway noise. In the second column, the response indices (D^*) were determined by the author from the response curves in the Schultz's report,[1] the D^* values in the third column were quoted from Fidell's paper[18] in which Schultz's data were corrected slightly by Fidell, in addition, he calculated D^* values from the survey results obtained recently. In the fourth column, Japanese data are shown, most of which are determined from the quadratic fitting curves of data points to L_{dn}. It can be seen from the Tables that D^* values vary widely in different studies. Among them, Japanese results of social surveys show particularly sensitive response, except for road traffic noise. Concerning to railway noise, it has been pointed out in the foreign studies that people are less sensitive to it than to road traffic noise. On the contrary, Japanese people are more sensitive to high-speed railway noise than to road traffic noise.

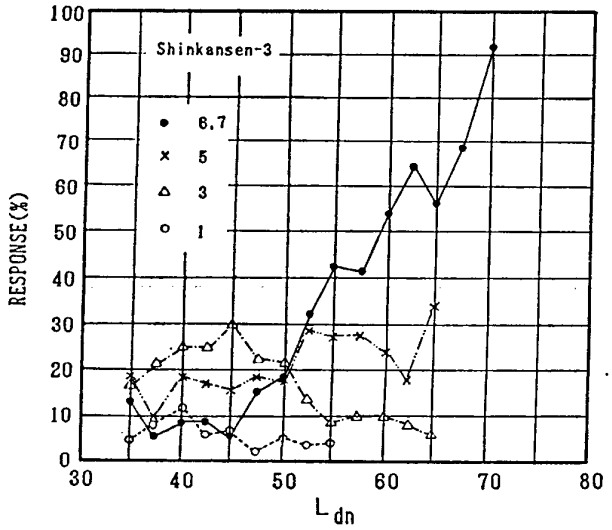

Fig. 8 Response distribution of annoyance score in each step. Shinkansen-3.

Table 2 Comparison of dose-response to aircraft noise by $1/e$ (37%) of highly annoyed: response index (D^*).

Survey report	Response index, D^*		
	Schultz	Fidell	Japan
London A/C (1) (McKennell, '63)	(2/7) 74 dB	(2/7) 70.0	
London A/C (2) (MIL Rep., '71)	(2/7) 81	(2/7) 74.8	
Munich A/C (Rohrman, '72)	(2/5) 75	(2/5) 72.1	
Swiss A/C (Grandjan, '73)	(3/11) 74	(3/11) 67.6	
Sweden A/C (Rylander, '72)	(1/5) 77	(1/5) 72.7	
French A/C (Alexabder, '70)	self 74	self 74.0	
(Average)	(76.7)	(72.5)	
Schultz synthesis curve,	**75**		
Canada A/C (Hall, '77)		(2/9) 63.3	
Australia A/C (Hede, '82)		(1/5) 74.5	
US Airbase (Borsky, '85)		(3/10) 71.8	
Burbank A/C (Fidell, '85)		(2/5) 58.0	
Orange Country (Fidell, '85)		(2/5) 58.6	
Dectur A/C (Fidell, '85)		(2/5) 74.0	
Westchester A/C (Fidell, '85)		(2/5) 65.5	
(Average)		(70.1)	
Osaka A/C-1 ('66)			(2/7) 63
Osaka A/C-2 ('73)			(1/5) 64 (2/5) 55

Table 3 Response index to road traffic noise.

Survey report	Response index, D^*		
	Schultz	Fidell	Japan
London traffic (Langdon, '76)	(2/7) 73	(2/7) 71.8	
French exp. way (Lamure, '76)	(2/4) 65	(2/4) 61.0	
Paris st. (Aubree, '71)	(1/10) 75	(1/10) 74.2	
Swiss road (Grandjan, '73)	(3/11) 77	(3/11) 75.8	
Vienna st. (Bruckmayer, '65)	(2/5) 65	(2/5) 65.8	
Danish st. (Relster, '75)	(1/3) 77.5	(1/3) 71.3	
Sweden traffic (Rylander, '77)	—	(1/3) 83.2	
(Average)	(76.5)	(74.6)	
Canada road (Hall, '77)		(2/9) 81.8	
Antwerp st. (Mynke, '77)		(3/10) 80.3	
Brussels st. (Mynke, '77)		(3/10) 77.9	
Nagoya st. ('84)			(1.5/4) 72 (1/4) 78
Fukuoka st. ('86)			(2/7) 72

Furthermore, the recent Shinkansen study reveals nearly one step difference (high annoyance) compared with the former study. In trying to check the data in the Shinkansen-3[11] report, I found a table in which a number of people in each step of annoyance scale was listed (Fig. 8). Corresponding to these data, the similar table of response distribution for 7 steps are included in the Heathrow aircraft noise survey.[14] The data of Heathrow study in Fig. 9 show a reasonable distribution, on the other hand, the lower and upper steps of Shinkansen study in Fig. 8 show different responses and they shift more than 10 dB to the lower level in L_{dn}.

In order to compare the Japanese response to

Table 4 Response index to railway noise.

Survey report	Response index, D^*		
	Schultz	Fidell	Japan
British rail (Fields, '82)		(1/4) 73.8	
French rail (Lamure, '76)	(2/7) 80	(2/7) 78.1	
Tramway Sweden (Rylander, '77)		(1/3) 79.7	
Swedish rail (Sorensen, '77)		(1/4) 74.6	
Danish rail (Anderson, '82)		(1/5) 74.3	
(Average)		(76.8)	
J. ex. rail ('73)			(3/7) 58
J. ex. rail ('73)			(3/7) 60 (2/7) 68
J. ex. rail ('90)			(2/7) 57.5 (1/7) 65

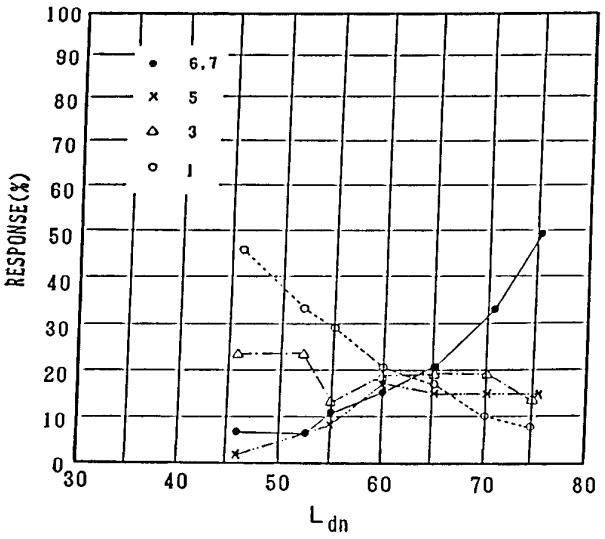

Fig. 9 Response distribution of annoyance score in each step. London Heathrow study (Original step numbers (0–6) were changed to (1–7) for comparison with Fig. 8).

railway noise with that of foreign study, results for ordinary railway lines in Japan have to be reported. Several social surveys were performed in the past, but unfortunately, I could not find the detailed results in official papers.

5. DISCUSSION

Attitudes of people to transportation noise have been measured using various kinds of response scales. The dose responses of different social surveys were compared by converting to the same category of 'highly annoyed' to L_{dn}. However, the data of social surveys in the past show widely diverse results. It has been pointed out by many researchers that the degree of annoyance to various noises depends not only on noise levels but also on non-acoustical factors, such as area characteristics and individual attitudes to the sound sources. However, as I mentioned in the previous section, the degree of response has been determined in various ways. The relation between percent highly annoyed and L_{dn} depends on the number of steps corresponding to 'highly annoyed' and the verbal labeling of each step in the measuring procedure of each study. This is another factor which makes a comparison of different studies difficult. In most Japanese results, the response curves of 'highly annoyed' shift to the left compared with the foreign studies. It might be caused partly by the difference of labeling of steps, that is, in the foreign study, the upper two steps are labeled as, 'extremely or strongly annoyed' and the next, 'very annoyed,' but in the Japanese study, the upper two steps are labeled as 'very annoyed' and the next, 'annoyed' (Japanese to English). In both cases, usually the upper two steps are chosen as 'highly annoyed.'

In conclusion, the results of social surveys show that the attitudes of people to transportation noise vary depending on various factors other than noise, and the dose response curves observed in different studies might exhibit diverse results, but if the same kind of response scale is used, that is, the same number of steps (the scale of 5 or 7 steps is preferable), and the same verbal labeling of steps, the difference of results will become smaller. However,

the language problem will still exist for further study when we compare the response data obtained in different countries.

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APPENDIX LIST OF RESPONSE SCALES USED IN SOCIAL SURVEYS

1) *3 step scale*
   a) Danish road traffic study (referred to Schultz)[1)]
   1-not at all annoyed, 2- a little annoyed, 3-very annoyed. Highly Annoyed: 1/3 (33%)
   b) Swedish tramway (referred to Fidell)[8)]
   1-a little annoyed, 2-rather annoyed, 3-very annoyed. H.A.: 1/3 (33%)
2) *4 step scale*
   a) French expressway (Schultz: French to English)[1)]
   1-not at all annoyed, 2-a little, 3-moderately, 4-extremely annoyed. H.A.: 1/4 (25%)
   b) Australian railroad (Fields and Walker, 1982)[15)]
   1-not at all, 2-a little, 3-moderately 4-very annoyed. H.A.: 1/4 (25%)
   c) Swedish railroad (Sorensen, 1983)[16)]
   1-not annoyed, 2-a little, 3-rather, 4-very annoyed. H.A.: 1/4 (25%)
   d) Dectur Airport (Fidell, 1985)[8)]
   1-a little annoyed, 2-moderately, 3-very, 4-extremely annoyed. H.A.: 2/4 (50%)
   e) Nagoya road traffic (Kuno, 1984)[7)]
   1-not annoyed, 2-a little, 3-annoyed, 4-very annoyed. 1/4 (25%) & 1.5/4 (37.5%)
3) *5 step scale*
   a) Munich A/C (Schultz: German to English)[1)]

1-not at all disturbed, 2-slightly, 3-average, 4-very, 5-strongly disturbed. H.A.: 2/5 (40%)

b) Swedish A/C (Rylander, 1972)[17]
1-don't notice, 2-notice, but not annoyed, 3-a little annoyed, 4-rather annoyed, 5-highly annoyed. H.A.: 1/5 (20%)

c) USA street (Schultz)[1]

d) Orange County Airport (Fidell, 1985)[8]

e) Westchester Airport (Fidell, 1985)[8]
1-not at all annoyed, 2-a little (or slightly), 3-moderately, 4-very, 5-extremely annoyed. H.A.: 2/5 (40%)

f) Vienna road traffic (Schultz; German to English)[1]
1-not at all disturbed, 2-slightly, 3-disturbed, 4-very, 5-unbearably disturbed. H.A.: 2/5 (40%)

g) Ōsaka Airport-2 (Maekawa, 1973)[5]
1-not at all annoyed, 2-a little, 3-annoyed, 4-fairly, 5-very annoyed. 1/5 (20%) & 2/5 (40%)

4) *7 step scale*

a) London (Heathrow) A/C (Wilson Report, 1963)[18]
Q: Does the noise of aircraft disturb you not at all, a little or very much? (0–6)
0-not at all disturbed, 2-a little, 3-moderately, 4-very disturbed, 1, 5, 6 not named.
Schultz selected 2/7 as highly annoyed, but in the Wilson Report, Step 4 was named as "very disturbed." Schultz figured out 3/7 of scale in his report, but he classified it as a non-clustered one. H.A.: 2/7 (27%) (Schultz, Clustered) 3/7 (43%) (Non-clustered)

b) French railroad (Schultz: French to English)[1]
1-quite tolerable,—7-intolerable. H.A.: 2/7 (29%)

c) London street (Schultz)[1]
1-definitely satisfied, —7-definitely dissatisfied. H.A.: 1.5/7 (21.5%)

d) Sweden A/C (B. Berglund, 1976)[19]
1-not at all annoying, 2-slightly, 3-somewhat, 4-annoying, 5-quite, 6-very annoying, 7-unbearable. H.A.: 2/7 (29%)

e) Japan, Ōsaka Airport-1 (Committee on Noise, 1966)[4]
1–4 not named, 5-noisy, 6-very noisy, 7-intolerable. H.A.: 2/7 (29%)

f) Shinkansen (Tōhoku Univ. Environ. Agency of Japan, Committee of Shinkansen Noise)[9-11]
1-not at all annoyed, —7-very annoyed. 2/7 (29%) & 1/7 (14%)

5) *9 step scale*

a) Canada Toronto A/C (Hall, 1982)[2]

b) Canada road traffic (Hall, 1982)[2]
1-extremely agreeable, 2-considerably, 3-moderately, 4-slightly agreeable, 5-neutral, 6-slightly disturbing, 7-moderately, 8-considerably, 9-extremely disturbing. H.A.: 2/9 (22%)

6) *10 step scale*

US Airbase (Borsky, 1983)[20]
Not at all—0, 1, 2, 3, 4, 5, 6, 7, 8, 9—extremely. H.A.: 3/10 (30%)

7) *11 step scale*

Swiss street, Swiss A/C (Schultz)[1]
Non-named, self rating annoyance scale. H.A.: 3/11 (27%)