Effects of airplane and helicopter noise on people living around a small airport in Sapporo, Japan

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INTRODUCTION

Many field studies on aircraft noise have been conducted, but there have not been sufficient studies on noise around small airports. Rylander & Bjorkman (1997) carried out surveys in eight areas near three small and medium sized airports and concluded that noise levels are not of significant concern when the number of events is low. They cited a previous study covering similar sized airports in the US, which too found that the use of equal energy levels to express the noise exposure gave fewer precise relationships (Connor & Patterson 1976).

Okadama airport is a small airport in Sapporo, which lies in a residential area. It is used by commercial airplanes that connect local airports in Hokkaido prefecture and by helicopters of the Japan Self-Defense Forces. There are no jet runways, and night-time departures and arrivals are prohibited.

A survey was carried out around Okadama airport in 2007 to investigate the effects of aircraft noise on the local population, followed by a supplementary survey in 2008.

OUTLINE OF THE SURVEY

Okadama airport is located in north-east part of Sapporo. Five sites were selected around the airport as representative of the aircraft noise at various distances and directions from the airport. All the sites selected were such that they did not directly face any arterial road, so as to avoid the effects of road traffic noise. A social survey was carried out around Okadama airport from September to October 2007 and a supplementary survey from August to September 2008 (Table 1). The survey consisted of a questionnaire and noise measurements. The distribution-postal collection method was used in 2007 and the postal method was used in 2008. The questionnaire was delivered to the people living in detached houses as a general survey on the living environment. The content of the questionnaire is shown in Table 2. The respondents were selected on a one-person-per-family basis under the criteria that they were over 18 years of age, and that their birthday was close to September 1. The key questions concerned annoyance, activity disturbance, and related effects caused by aircraft. The questions were answered on a five-point verbal scale and an 11-point numeric scale, shown in Table 3. The modifiers in the Japanese language for the verbal scales were determined in a joint study conducted by the International Commission on Biological Effects of Noise (Fields et al. 2001). The English language modifiers that were determined in the same manner are also shown in Table 3 for comparison. The total number of respondents was 383, and the response rate was 44.6 %. Analysis of the data showed that the extent of annoyance was rather high in spite of the low noise exposure levels. The authors thought that one reason was the usage of the term "aircraft noise" in the questionnaire. The fact led us to perform a supplementary survey in 2008, in which the terms "airplane noise," "helicopter noise," and "combined noise" were used instead of "aircraft noise." In this survey, 291 responses were obtained, and the response rate was 76.0 %. Figure 1 shows the relative response rates to questions concerning personal and housing factors. The proportions are almost the same in gender and in length of residence, whereas in age, over fifty occupies the high proportion. Most of the respondents live in their own house constructed of wood with two layers of window glass.

Table 1: Outline of the surveys

	Survey in 2007	Supplementary survey in 2008
Area	Sapporo	
Housing type	Detached houses	
Survey site	Five sites around Okadama airport	
Method	Distribution-postal collection	Postal
Questionnaire term	September to October 2007	August to September 2008
Measurement term	October 2007	
Sample size	859	383 (same respondents as in 2007)
Respondent	383	291
Response rate (%)	44.6	76.0
Number of scheduled airplane flight	17 (Departure from 7:40 to 17:35) 17 (Arrival from 9:25 to 18:50)	
L_{Aeq},24h (dB)*	28-40(airplane), 38-49(helicopter), 39-50(combined)	
Observed noise event*	7.3-14.3(airplane), 13.8-40.5(helicopter)	

*average of four-day data

Table 2: Questionnaire items of the surveys

Survey in 2007		
Q1 - Q8	Housing factors	House type; length of residence; main structure; number of glass layers in living room and bedroom windows; direction of doors and windows; housing performance
Q9 - Q12	Residential environment	Quality of residential environment; satisfaction with living area
Q13 – Q17	Annoyance	Road traffic noise; aircraft noise; railway noise; exhaust gas; industrial noise; bad smell; industrial air pollution; neighborhood noise; electromagnetic waves; frequency of aircraft noise annoyance; annoyance at specific times and seasons, etc.
Q18	Activity disturbance and related effects caused by aircraft	Listening, sleeping disturbance; disturbance while resting, talking, gardening; house vibration due to aerial vibration; startle; fear of accident, etc.
Q19 – Q28	Sensitivities, attitudes, etc.	Sleeping with open window in certain seasons; time of going to bed and getting up on weekends and weekdays; sleeping condition; sensitivity to environmental factors; attitudes to the use of transportation vehicles; using frequency; comments on safety, etc.
Q29 - Q33	Socio-demographic variables	Occupation; length of period to stay at home; number of family members; age; gender
Supplementary survey in 2008		
Q1 - Q6	Annoyance	Airplane noise; helicopter noise; combined noise; frequency of helicopter noise annoyance; annoyance at specific times or seasons, etc.
Q7, Q8	Activity disturbance and related effects caused by helicopter	Listening, sleeping disturbance; disturbance while resting, talking, gardening; house vibration due to aerial vibration; startle; fear of accident, etc.

After the questionnaires were completed, noise measurements were performed on each site, in a garden or open space next to the house. Noise exposure levels were recorded every 1 second for five successive days using a sound level meter (RION NL-22). Data could not be obtained on the last day because of heavy rain; therefore, four-day data were adopted for calculating the noise index values. Airplane and helicopter noise events were identified from the waveforms, as shown in Figure 2.

Table 3: Rating scale

(a) Verbal scale

Category	Japanese	English
5	hijoni	extremely
4	daibu	very
3	tasho	moderately
2	sorehodo...nai	slightly
1	mattaku...nai	not at all

(b) Numeric scale

0 1 2 3 4 5 6 7 8 9 10

Mattaku ...nai — Hijoni

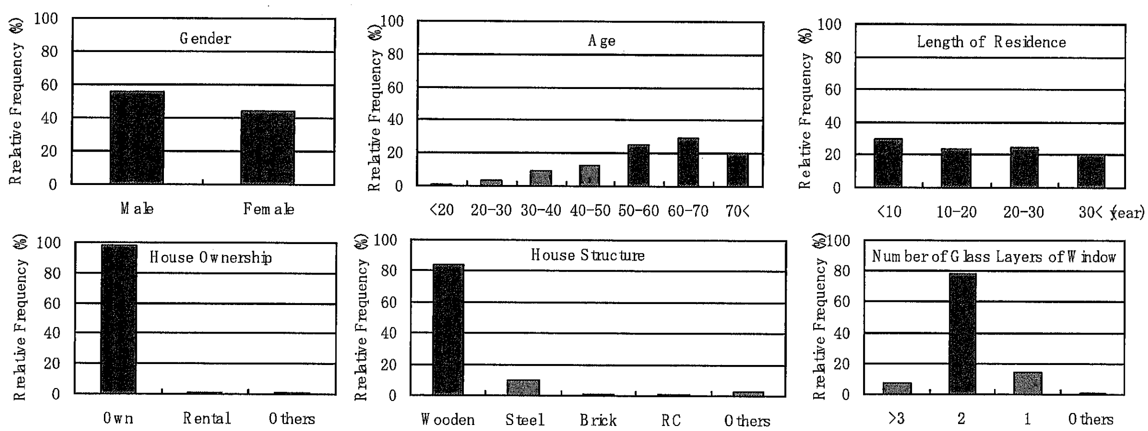


Figure 1: Personal and housing factors of respondents

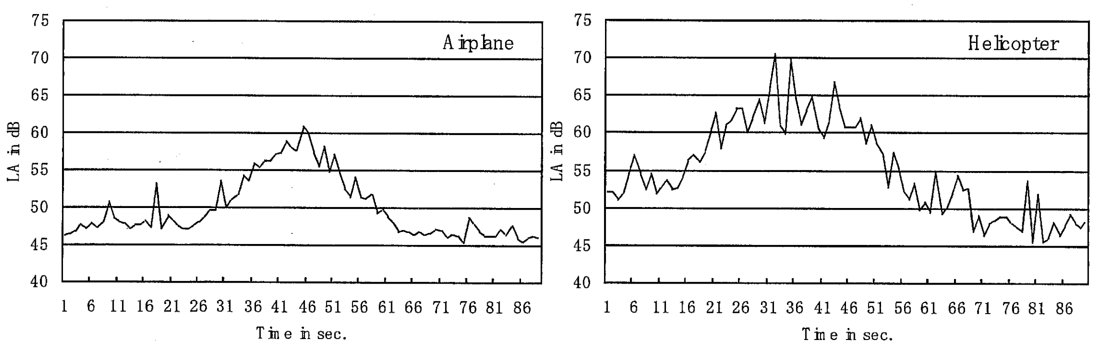


Figure 2: Typical waveforms of airplane and helicopter

Table 4: Noise exposure level, L_{Aeq},24h in dB

Site	1	2	3	4	5
Airplane	36	31	39	28	40
Helicopter	47	38	48	43	49
Combined	47	39	48	43	50

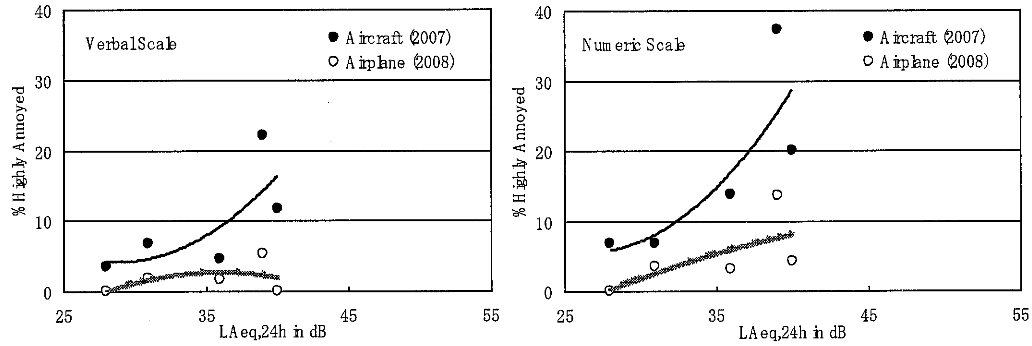
L_{Aeq},24h values in Table 4 were calculated from those noise events. It was found that helicopters are the dominant noise source around Okadama airport.

RESULTS AND DISCUSSION

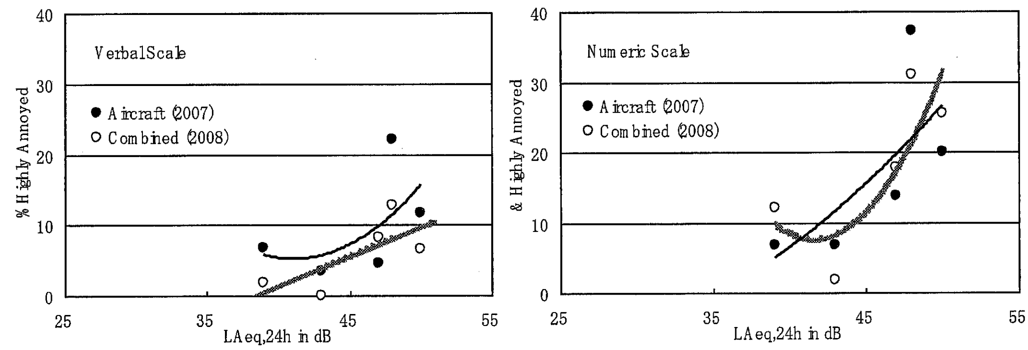
Dose-response relationships

Figure 3 (a) compares the annoyance responses to “aircraft noise (2007)” with the responses to “airplane noise (2008)” on the airplane noise exposure levels, and (b) compares with “combined noise (2008)” on the combined noise exposure levels. The percentage of highly annoyed respondents is defined here as the rate of the number of people who responded to the top category on the verbal scale and the top three categories on the numeric scale. For most Japanese people, the term “aircraft” has the same meaning as “airplane” when used in daily conversation. It is seen that both lines are close together in (b). This indicates that people seem to respond to the annoyance of both airplane and helicopter noises, even if they are asked about the annoyance due to “aircraft” noise.

Figure 4 (a) compares the annoyance responses to aircraft noise (2007) with those obtained from the survey around Kumamoto airport (Henmi et al. 2007) on the airplane noise exposure levels, and (b) compares the combined noise exposure levels. It is seen that both lines are close together in (b). This also indicates that people seem to respond to the annoyance of both airplane and helicopter noises, even if they are asked about “aircraft” noise annoyance.

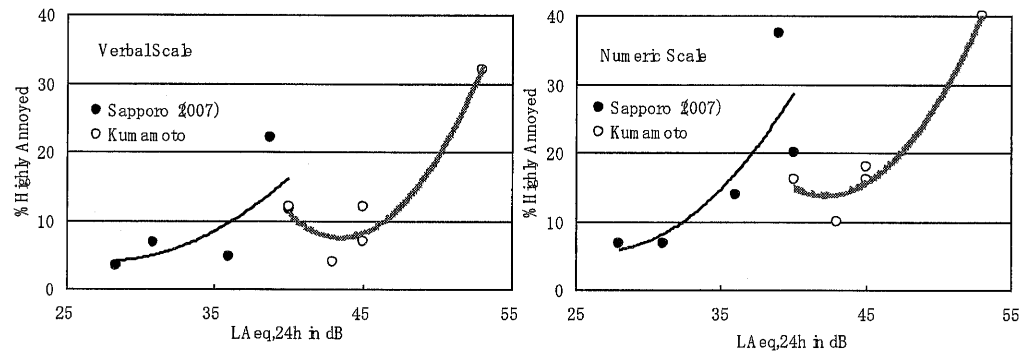


(a) Relationships between annoyance responses to aircraft noise (2007) and airplane noise (2008) with respect to airplane noise exposure level

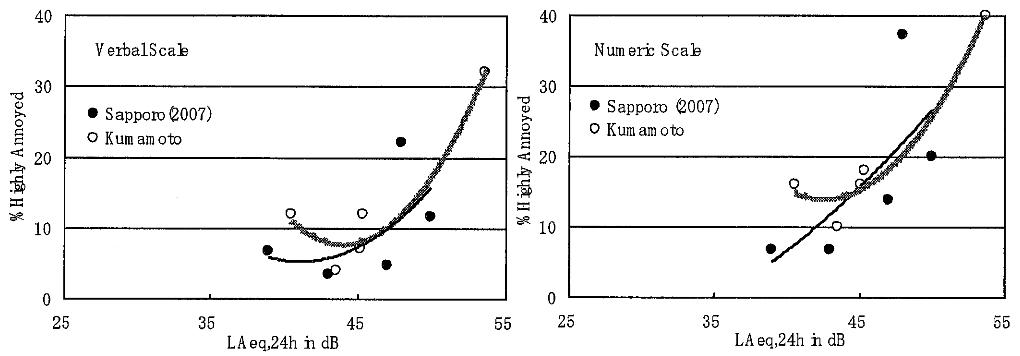


(b) relationships between annoyance responses to aircraft noise (2007) and combined noise (2008) with respect to combined noise exposure level

Figure 3: Relationships between annoyance responses in the 2007 and 2008 surveys



(a) Relationships between annoyance responses to aircraft noise around two airports with respect to airplane noise exposure level



(b) Relationships between annoyance responses to aircraft noise around two airports with respect to combined noise exposure level

Figure 4: Relationships between annoyance responses around Sapporo Okadama and Kumamoto airports

Figure 5 shows the relationship between the annoyance responses to combined noise and airplane noise compared with Miedema's curve (Miedema & Vos 1998). This is evaluated by the percentage of highly annoyed respondents and the day-night average sound level (L_{dn}). Following Miedema's paper, in which the cut-off point for the highly annoyed was defined as the top 28 %, the authors prorate the relevant data in both scales to be 28 %. The data of the present study exceed Miedema's line. It suggests the existence of some factors, which do not reduce the annoyance at the low noise exposure levels. Fidell & Silvati (2004) proposed a modified curve in which the extent of annoyance is higher at the low noise exposure levels. Rylander & Bjorkman (1997) also suggested that noise levels are less important when the number of events is low. The results obtained here might be explained by a comparison with those studies.

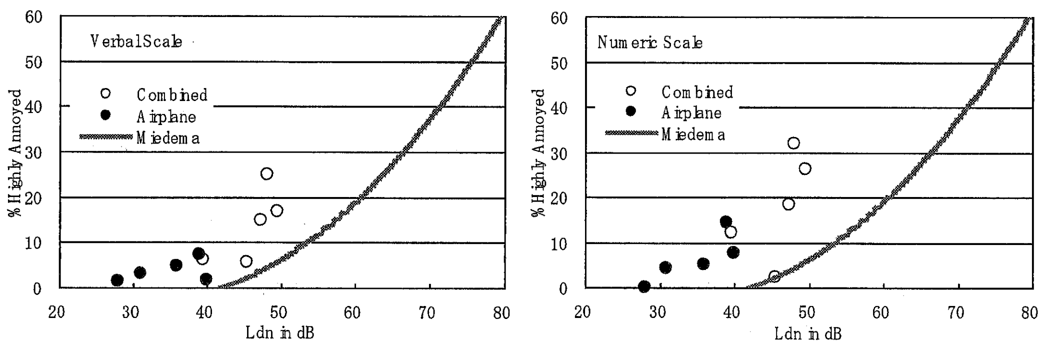


Figure 5: Comparison of annoyance responses with Miedema's curve

Structural equation modeling

Considering the causal relations among the variables, covariance structure analysis was performed on the aircraft noise annoyance. Covariance structure analysis is one of the general methods of investigating the hypothetical causal linkages between variables, and has been successfully used in noise evaluation studies by Morihara et al. (2004), Lam et al. (2009), and others.

The structural equation model was constructed using the data from the 2007 survey, based on knowledge from previous studies and the values of the fit indices.

To construct the causal relationships between noise annoyance and other factors such as noise levels, personal sensitivity, etc., the following hypotheses were made:

1) Aircraft noise exposure level causes not only noise annoyance but also daily activity disturbances such as listening disturbance.
2) The length of residence in the area affects the annoyance/activity disturbances.
3) Personal sensitivity to noise/vibration affects the annoyance/activity disturbances.
4) Activity disturbances increase the aversion to noise source.
5) Satisfaction with the living area/house affects the level of aversion to the noise source.
6) Aircraft flight causes fear of accident/crash and startle.
7) Aversion to the noise source comprises of noise annoyance and house vibration annoyance due to aerial vibration.

Fit indices were used for judging whether the models could express the character of the data well. The fit indices used in this study are GFI (Goodness of Fit Index), CFI (Comparative Fit Index), and RMSEA (Root Mean Square Error of Approximation). The model is good if the value of GFI or CFI is over 0.9 (close to 1) or if the value of RMSEA is under 0.05 (close to 0). If the RMSEA ranges from 0.05 to 0.1, it is considered to be in the gray zone.

Covariance structure analysis can build models using a latent variable such as "listening disturbance," which is treated as a comprehensive concept constituting the three observed variables of listening disturbance.

Figure 6 shows a primary structural equation model of annoyance caused by aircraft noise. The variables in the squares are the observed variables and those in the ovals are the latent variables. The arrows show the causal relations between the variables. Error variables are shown in circles.

Among the paths in this model, some were statistically proved to be not significant. The first revised model was made by excluding non-significant paths; consequently, the sleeping disturbance variables were deleted. In the same manner, the second revised model was made by excluding the non-significant paths of the first revised model and the variables for activity disturbance in the garden were deleted. Finally, the path with the largest probability value ($p = 0.035$), from the residential environment to aversion to noise source, was deleted to increase the fit indices' values. The final revised model is shown in Figure 7, and the values of the fit indices are shown in Table 5. Considering the values of the fit indices, the model is not exceptionally good, but it is acceptable. The standardized total effects of the independent variables on aircraft noise annoyance were calculated by the maximum likelihood method, and summarized in Figure 8. "Standardized total effects" means the degree of the contribution of each variable to aircraft noise annoyance. Aircraft noise annoyance is mainly affected by aversion to the noise source, sensitivity to noise, and fear, whereas the noise exposure level and length of residence in the area have a little effect. Regarding the variable "fear," Janssen et al. (2010) mentioned that fear is a very important factor in the response to aircraft noise, reflecting the important function of fear in the regulation of behavior. This corresponds to the findings of the present study.

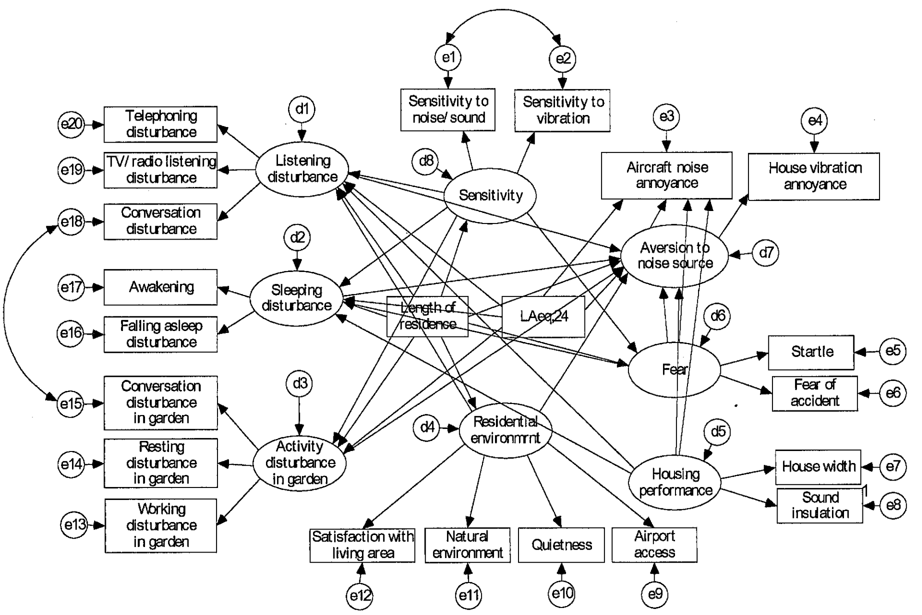


Figure 6: Primary structural equation model

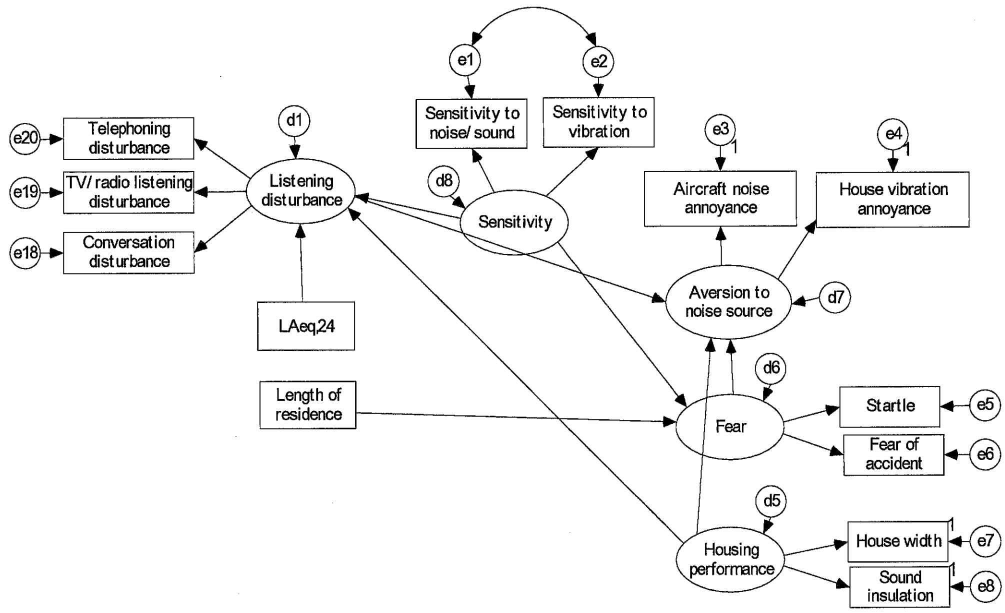


Figure 7: Revised model

Table 5: Values of fit indices

GFI	CFI	RMSEA
0.945	0.967	0.058

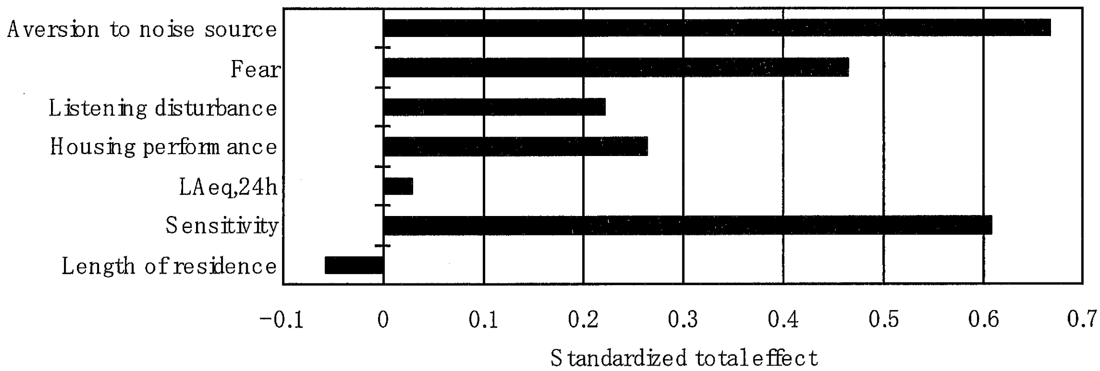


Figure 8: Standardized total effects of independent variables on aircraft noise annoyance

SUMMARY

A social survey was carried out around Okadama airport in Sapporo, Japan, for over two years to investigate the effects of aircraft noise on the local residents. The findings obtained and discussions on dose-response relationships and structural equation modeling are summarized as follows: 1) Helicopters are the dominant noise source around Okadama airport. 2) People seem to respond to the annoyance of both airplane and helicopter noises, even if they are asked about the annoyance due to aircraft noise. 3) The existence of some factors that do not reduce the annoyance in low noise exposure level was suggested. 4) Aircraft noise annoyance is mainly affected by aversion to the noise source, sensitivity to noise, and fear, whereas the noise exposure level and length of residence in the area have only a small effect.

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