# Annoyance Due to Noise from Tramlines in Hakodate, Japan

T. Sato[1]

[1] Department of Architecture, Hokkai Gakuen University, 1-1 Minami-26, Nishi-11, Chuo-ku, Sapporo 064-0926, JAPAN, sato@arc.hokkai-s-u.ac.jp

## ABSTRACT

A social survey was conducted to investigate the effects of tram noise on local residents in Hakodate, Japan. There are three tramlines in Hakodate, with the passage numbers 142, 142 and 287. The questionnaire was sent to people living in apartments and detached houses located along the tramlines. The questionnaire comprised 32 questions relating to environmental, housing, and personal factors. The key questions concerned annoyance and activity disturbance due to tram noise, and they were answered on a 5-point verbal scale and an 11-point numeric scale. There were 174 respondents, and the response rate was 49%. Following completion of the questionnaires, noise was measured at several points in order to calculate noise exposure levels for the residences investigated. The Hakodate residents' responses to the noise from tramlines were compared with the responses of Sapporo residents. Analysis of the dose-response relationships observed indicated that the Hakodate residents were more annoyed by tram noise than the Sapporo residents, but the extent of the annoyance reported was clearly lower than that caused by intercity railways at the same noise levels. Possible reasons for these findings were discussed in relation to non-noise factors such as frequency of use and participants' impressions of trams.

## INTRODUCTION

The development of public transportation is indispensable to the minimization of chronic traffic jams in urban areas. Trams operate in Hakodate, with several apartment buildings and detached houses located along the line.

Few studies have evaluated the annoyance caused by tram noise; however, Sandrock et al. compared the noise emitted by trams to that emitted by buses in a psycho-acoustical experiment. Noise emitted by a tram raised the same degree of annoyance as that emitted by a bus with a 3 dB lower noise level. In other words, noise emitted by a tram did not cause as much annoyance as that emitted by a bus at the same noise level (Sandrock et al. 2008).

A social survey was conducted in Sapporo, Japan in 2010, and the extent of annoyance caused by tramline noise was very low relative to that caused by noise emitted by intercity railways (Sato 2012). The current study was performed in Hakodate to compare the effects of tram noise between Hakodate and Sapporo residents.

This paper describes the differences observed in the effects of tram and intercity railway noise between the two cities. The reasons for the differences are discussed in relation to non-noise factors such as frequency of use and participants' impressions of trams.

## OUTLINE OF THE SURVEY

The survey was conducted from October to December 2012. The outline of the survey is summarized in Table 1. During the survey, residents of the area

surrounding the tramline were provided with a questionnaire, and the noise level in the area was measured. The questionnaire was sent via mail to people living along the tramline as a general survey regarding their living environment. The principal questionnaire items are 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 October 1. The key questions concerned annoyance and activity disturbance due to noise. The respondents were asked to answer these questions on a 5-point verbal scale and an 11-point numeric scale constructed using the International Commission on Biological Effects of Noise (ICBEN) method (Fields et al. 2001). One hundred thirty-seven and thirty-seven responses were collected from inhabitants of 286 detached houses and 68 apartments, respectively.

Figure 1 shows the relative response rates to questions concerning personal factors. The proportions of responses received were almost equal with respect to gender, whereas respondents aged over 60 years constituted a greater proportion than younger respondents did.

Following completion of the questionnaire, noise was measured in several points in order to calculate noise-exposure levels for the residences investigated. A microphone from a sound-level meter (RION NL-22) was placed at the edge of the sidewalk along the tramline to form a reference point, with measuring points set at a distance of 10 m, 20 m, and 40 m from the reference point. Noise levels were recorded every second for 60 minutes at each measuring point. As several events were recorded, the A-weighted single event noise exposure level ($L_{AE}$) of one event was calculated using the energy average of all events. The noise indices at the reference point were calculated using the one-event $L_{AE}$ and the timetable, and the noise exposure level for each residence was estimated using the distance reductions

**Table 1:** Outline of the survey

| Area | Hakodate, Japan | |
|---|---|---|
| Survey term | September to December, 2012 | |
| Questionnaire method | Postal method | |
| Housing type | Detached | Apartment |
| Sample size | 286 | 68 |
| Respondent | 137 | 37 |
| Response rate (%) | 47.9 | 54.4 |
| Number of scheduled passing tram | 142, 287 (Passing from 6:30 to 22:30) | |

**Table 2:** Principal questionnaire items of the surveys

| | |
|---|---|
| Housing factors | House type; length of residence; main structure; number of glass layers of living rooms and bedroom windows; direction of doors and windows; Housing performance |
| Residential environment | Quality of residential environment; satisfaction with living area |
| Annoyance | Tram noise; road traffic noise; exhaust gas; bad smell |
| Activity disturbance caused by tram | Listening disturbance; sleeping disturbance; disturbance while resting, gardening; house vibration due to tram passage; etc. |
| Activity disturbance caused by car | Listening disturbance; sleeping disturbance; disturbance while resting, gardening; house vibration due to car passage; etc. |
| Sensitivities, attitudes, etc. | Attitudes to use of transportation system; frequency of use; impression of tram; sensitivity to environmental factors; etc. |
| Personal factors | Occupation; number of family members; age; gender |

from the noise source. To evaluate the distribution of noise levels in a vertical direction for apartment buildings, the noise levels that were measured in the outdoor corridor of each floor in a 2011 survey were utilized (Sato 2012). Figure 2 shows the formula for the horizontal distance reduction for near rail and far rail, and Figure 3 shows the vertical distance reduction.

**Figure 1:** Gender and age of respondents

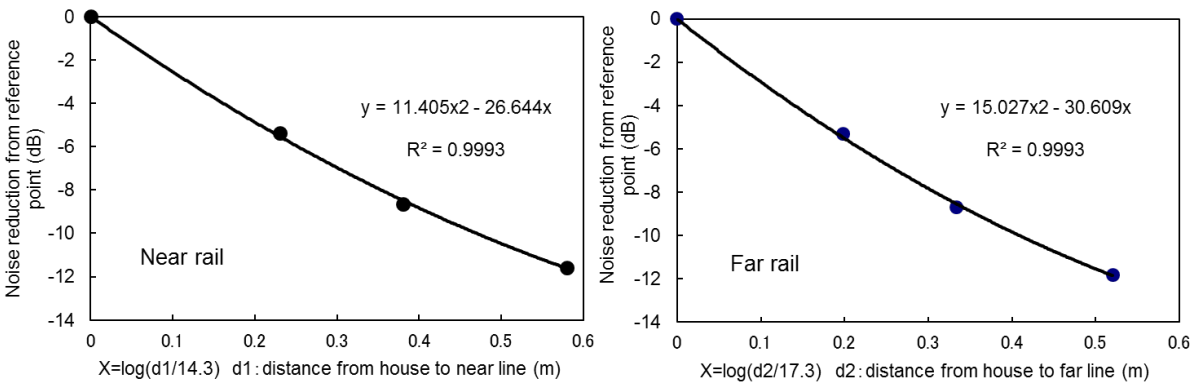



**Figure 2:** Horizontal distance reduction

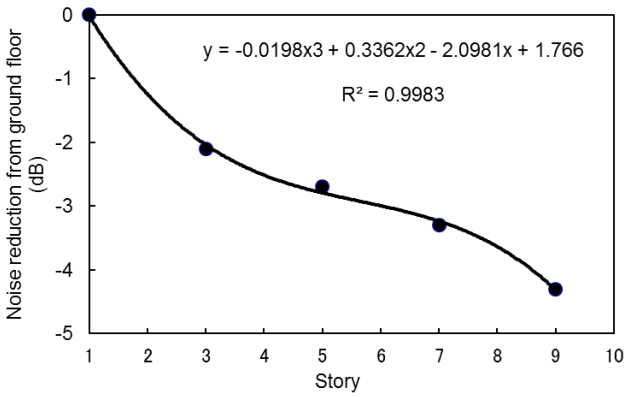



**Figure 3:** Vertical reduction

## RESULTS AND DISCUSSION

### Dose-response relationships

Figure 4 depicts the frequency of responses to the question regarding the use of trams. Over 60% of the respondents living in apartments and almost 50% of those living in detached houses replied “use it positively” or “use it if possible.” This indicated that they considered trams to be a convenient means of transportation. In

addition, Figure 5 portrays the frequency of responses with regard to respondents' impressions of trams. Over 70% of the respondents living in apartments and over 65% of those living in detached houses reported having "a very good impression" or "a good impression" of trams, implying that trams were supported by residents. Most of the respondents who reported having a good impression of trams considered them convenient, punctual, ecological, good for the environment, secure, tasteful, and symbolic of Hakodate.

Figures 6 and 7 depict the distribution of the extent of respondents' annoyance caused by noise and vibration. The majority of respondents replied that the noise and vibration were "not annoying at all," "slightly annoying," or "moderately annoying"

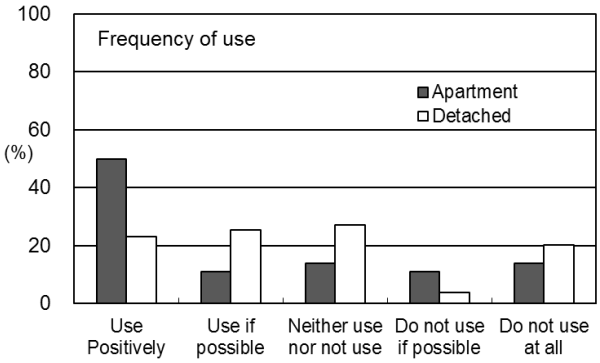



**Figure 4:** Response to the question on frequency of use of tram

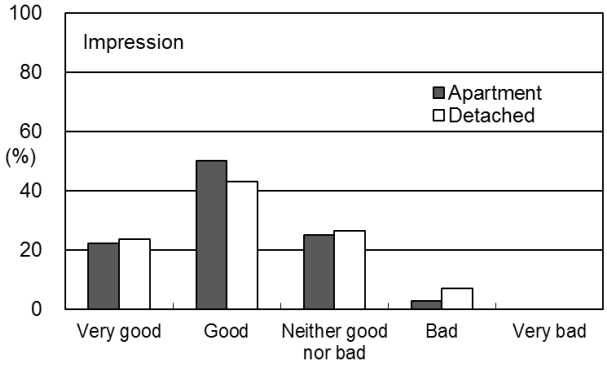



**Figure 5:** Response to the question on impression of tram

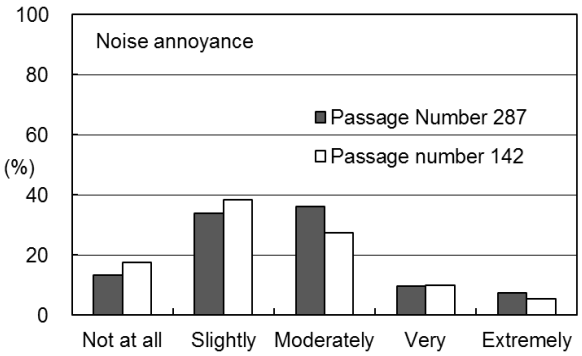



**Figure 6:** Response to the question on tram noise annoyance

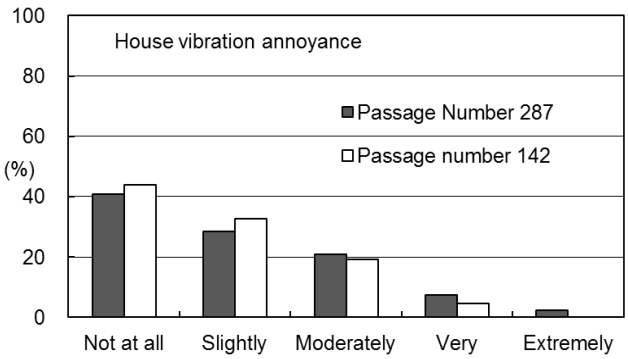



**Figure 7:** Response to the question on house vibration annoyance

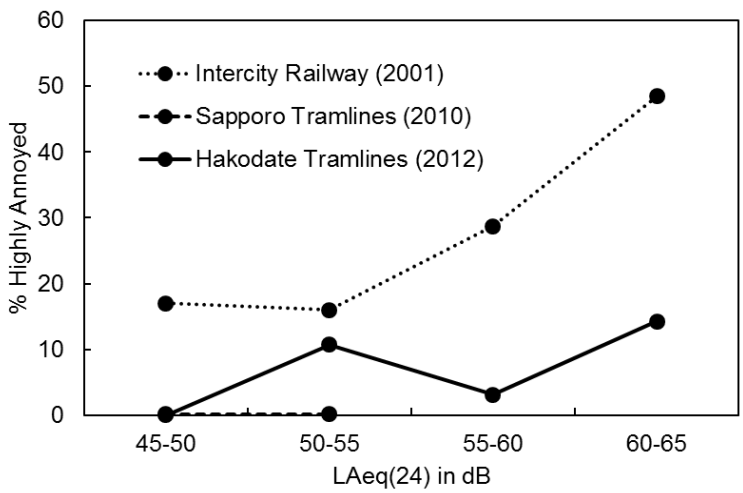



**Figure 8:** Comparison of dose-response relationships between tramlines and intercity railways

annoying." Figure 8 shows the comparisons between the dose-response relationships for noise from tramlines in the two cities and those for noise from intercity railways (Sato 2004). The trains considered in the survey included intercity express and freight trains. The percentage of highly annoyed respondents is defined here as the rate of the number of people who answered "extremely annoying" on a 5-point verbal scale. Analysis of the dose-response relationships observed indicates that the Hakodate residents are more annoyed by tram noise than the Sapporo residents, but the extent of the annoyance reported is clearly lower than that caused by intercity railways at the same noise levels. As described earlier, the majority of the respondents reported having "a very good impression" or "a good impression" of tramlines.

In addition, regarding frequency of the use of trams, many respondents felt that it could be used "positively" or "if possible." According to these replies, trams appear to be convenient for residents living along the tramline. With respect to intercity railways, direct comparisons are impossible because the questions concerning respondents' impressions and frequency of use were not included in the questionnaire. However, the express trains do not necessarily stop at the residents' nearest station, and the freight trains can pass at midnight. Considering these points, the intercity railways appear inferior to tramlines with respect to frequency of use and respondents' impressions. Hence, non-noise factors greatly affected annoyance in response to noise, and the extent of annoyance experienced consequently decreased when the noise was emitted from a more favorable source.

**Structural Equation Modeling**

Considering the causal relationships between the variables, structural equation modeling (SEM) was performed to examine the annoyance caused by tram noise. SEM is widely used to investigate hypothetical causal links between variables and has been employed successfully in noise evaluation studies (e.g., Morihara et al. 2004; Lam et al. 2009; and Sato et al. 2011).

The structural equation model was constructed using data from the tram noise surveys conducted in Sapporo and Hakodate, based on knowledge from previous studies and the values of the fit indices.

To construct the causal relationships between noise annoyance and other factors, including noise levels, activity disturbances and so on, the following hypotheses were made:

1) Tram noise exposure level causes both noise annoyance and daily activity disturbance such as listening disturbance.

2) The length of residence in the area affects the degree of annoyance and activity disturbance experienced.

3) Personal sensitivity to noise and vibration affects the degree of annoyance and activity disturbance experienced.

4) Activity disturbance increases aversion to the source of noise.

5) Satisfaction with the living area or residence affects the degree of aversion felt toward the source of noise.

6) The likability of trams reduces aversion to the source of noise.

7) Aversion to the source of noise comprises of noise annoyance and house vibration annoyance.

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

Structural equation modeling can be used to 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 9 shows a primary structural equation model of annoyance caused by tram noise. The variables depicted in the squares are the observed variables and those in the ovals are the latent variables. The arrows depict the causal relationships between the variables. Error variables are shown in circles.

Among the paths included this model, some were statistically non-significant with respect to the Hakodate data. The first revised model was formed by excluding non-significant paths; consequently, some important variables, such as sleep disturbance, were deleted. In the same manner, the second revised model was formed by excluding the non-significant paths identified in the first revised model, and the noise exposure level ($L_{Aeq24}$) was deleted. The third revised model was formed by excluding $L_{Aeq24}$, and the path from residential environment to public transportation access, with the largest probability value (p = 0.034), was deleted. Finally, the path from residential environment to listening disturbance, with the second-largest probability value (p = 0.028), was deleted to increase the fit indices' values. The final revised model and the values of the fit indices are shown in Figure 10. In the same

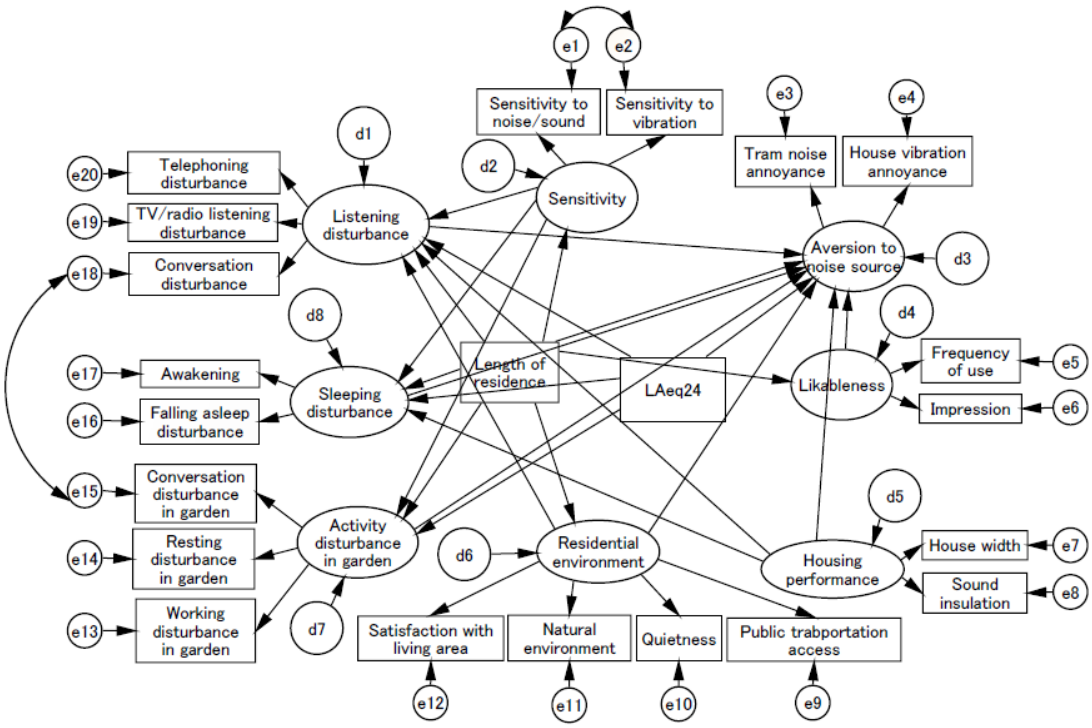
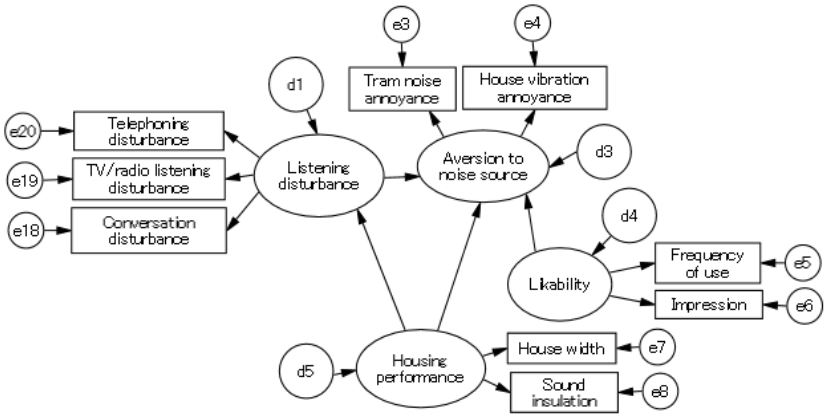


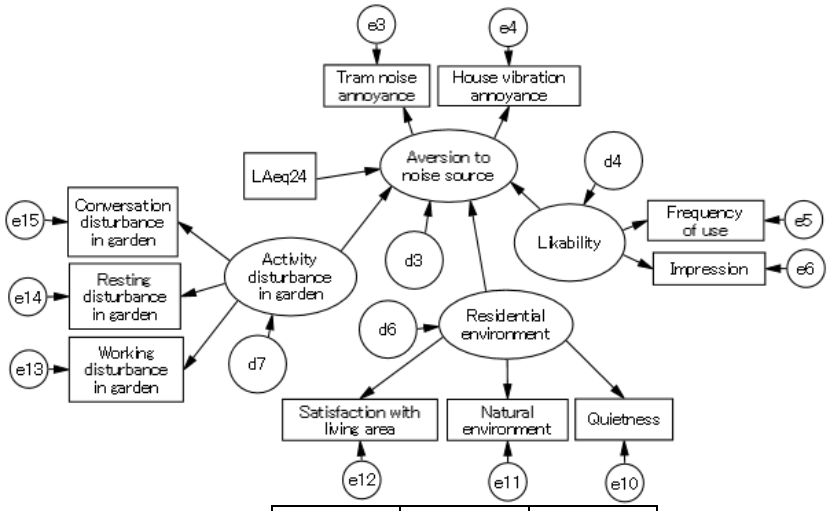

**Figure 9:** Primary structural equation model

manner, a revised model was formed for the Sapporo data, as shown in Figure 11. Considering the values of the fit indices, two models are not exceptionally good, but they are acceptable. The standardized total effects (the degree of the contribution of each variable to tram noise annoyance) of the independent variables on tram noise annoyance were calculated using the maximum likelihood method and are summarized in Figure 12. Tram noise annoyance is mainly affected by aversion to the source of the noise for both the Hakodate and the Sapporo models. Aversion to the source of the noise was followed by listening disturbance and housing performance in the Hakodate model and by activity disturbance in garden/balcony,




| GFI | CFI | RMSEA |
|---|---|---|
| 0.911 | 0.97 | 0.068 |

**Figure 9:** Revised mode (Hakodate)




| GFI | CFI | RMSEA |
|---|---|---|
| 0.9 | 0.954 | 0.065 |

**Figure 10:** Revised model (Sapporo)

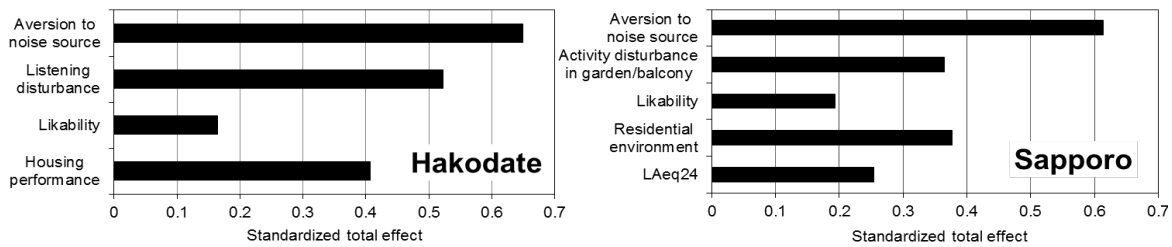



**Figure 11:** Standardized total effects of independent variables on tram noise annoyance

residential environment, and $L_{Aeq24}$ in the Sapporo model. Likability of trams did not exert a strong influence on tram noise annoyance, but it was significant. This emphasizes the dose-response relationship findings.

## SUMMARY

A social survey was conducted along tramlines in Hakodate, Japan, to investigate the effects of noise on the local residents. Community responses to noise from tramlines in Hakodate were compared to those from tramlines and intercity railways in Sapporo. A discussion on dose-response relationships showed that people were less annoyed by noise from tramlines than they were by noise from intercity railways at the same noise levels. The reasons were discussed in relation to non-noise factors, and it was found that likability of trams due to frequency of use and the respondents' impressions significantly reduced tram noise annoyance.

## REFERENCES

Sato T (2012). Community response to noise from inner-city railway transportation in Sapporo, Japan. Proc Inter-noise 2012 CD-ROM.

Sandrock S, Griefahn B, Kaczmarek T, Hafke H, Preis A, Gjestland T (2008). Experimental studies on annoyance caused by noises from trams and buses. J Sound Vib 313: 908–919.

Fields JM, De Jong RG, Gjestland T, Flindell IH, Job RFS, Kurra S, Lercher P, Vallet M, Yano T, Guski R, Felscher-Suhr U, Schumer R (2001). Standardized general-purpose noise reaction questions for community noise surveys: research and a recommendation, J Sound Vib 242: 641–679.

Sato T (2004). Relationships between rating scales, question stem wording, and community responses to railway noise J Sound Vib 277: 609–616.

Morihara T, Sato T, Yano T (2004). Comparison of community responses to railway and road traffic noises using structural equation model. Proc. Inter-noise 2004: CD-ROM.

Lam K-C, Chan P-K, Chan T-C, Au W-H, Hui W-C (2009). Annoyance response to mixed transportation noise in Hong Kong. Applied Acoustics 70: 1-10.

Sato T, Yano T (2011). Effects of airplane and helicopter noise on people living around a small airport in Sapporo, Japan. Proc. ICBEN 2011: CD-ROM.