Community response to noise and vibration caused by Nagano Shinkansen railway, Japan

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ABSTRACT

In Japan, about 50 years have passed since the Tokaido Shinkansen railway, it is first high-speed railway, opened in 1964. In recent years, the Shinkansen network has also been developed in Japan. The Nagano Shinkansen railway connects to Nagano from Takasaki Stations at the present time, it is expanded up to Kanazawa in 2015. The objective of the present study was to investigate the relationships between community response and L_{ASmax} (maximum A-weighted and S-weighted sound pressure level) or Lden caused by Nagano Shinkansen railway. Nagano Shinkansen railway has maximum 260 km/h, and operates 83 times per day. Four survey sites were selected in the range of up to 14 km from Nagano station. Target detached houses were selected in the range of up to 100m vertically from the rail of near side. A mail questionnaire method was carried out in June of 2013. The sample size was 294, and the response rate was 45%. The response of male was 60%, and about 80% were 50 years old or more. Noise exposure level for each house was estimated the prediction formula by Nagakura and results of field measurements in October. It was shown that respondents of about 16% responded “very” or “extremely” annoyed at 70dB (L_{ASmax}), this level is the value of the environmental standard for Shinkansen railway noise at 25m point from rail in Japan, using logistic analysis. The relationships between noise annoyance and L_{den} showed that response to Nagano Shinkansen railway noise higher than the Miedema’s curve of railway.

INTRODUCTION

Half a century has passed since the Tokaido Shinkansen railway opened in Japan. In 2015, the Hokuriku Shinkansen railway will open between Kanazawa and Tokyo, and in 2016, the Hokkaido Shinkansen railway will open between Hakodate and Aomori. The Shinkansen railway is a major means of transportation in Japan. Furthermore, Shinkansen technology was adopted in Taiwan, and in 2007, the Taiwan Shinkansen was opened. The Shinkansen is a high-speed railway and has the potential for future global development. Therefore, the impact of the noise and vibration caused by Shinkansen railway operations on the living environment will become an issue that should be understood in Japan and internationally. Sone et al. 1973 reported a mean annoyance score slightly greater than the third category on a 7-category scale at 70dB (power-averaged peak level). Tamura 1994 conducted a social survey in residential areas along the Tokaido Shinkansen and conventional railroads in 1985 and 1986, indicating a greater number of negative evaluation for the Shinkansen than

for conventional railroads. Yano et al. 2005 also identified greater noise annoyance for the Shinkansen than for conventional railways; however, for both noise sources, telephone listening disturbance and being awaken were not significant at the same noise levels ($L_{Aeq,24h}$). Using structure equation modeling, Yokoshima & Tamura 2006 identified synergetic effects between Shinkansen noise and vibration on annoyance. Moreover, Yokoshima et al. 2009 re-analyzed three sets of social survey data in Japan, reporting that L_{Amax} provided greater consistency than L_{Aeq} for noise assessment.

Currently, the Nagano Shinkansen railway connects to Nagano from Takasaki Stations. In 2015, it will be expanded to Kanazawa. Thus far, no social survey has been conducted on the Nagano Shinkansen railway. In addition, understanding the current impact of Shinkansen's noise and vibration on the living environment in the Nagano Station vicinity might enable us to predict the future impact on the living environment in the Kanazawa Station vicinity. This paper reports the results of a social survey on the Nagano Shinkansen railway.

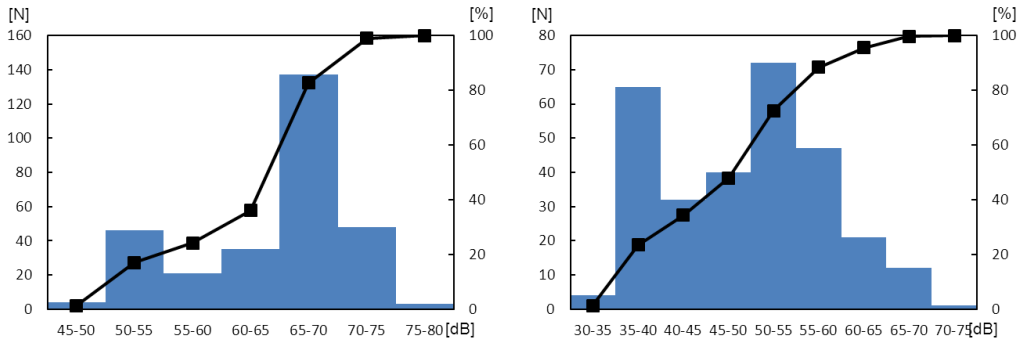
METHODS

Social survey

A social survey was conducted in 2013 in Nagano prefecture, Japan. Nagano prefecture, with a population of approximately 2.11 million, is located in central Japan. We selected four survey sites in residential areas along the Nagano Shinkansen railway between Nagano and Takasaki. Target houses were detached houses located within 100 m of the Nagano Shinkansen track. The questionnaire comprised five sections focusing on housing, the residential area, evaluation of noise and vibration caused by the Shinkansen railway, attitude to transportation, and demographic factors. The questionnaire was distributed and collected through the mail. With regard to respondents, one person per family was selected based on the nearest birthday principle. In total, 648 people were selected in target houses, of which 294 responded, a response rate of 45.4%. The primary questions for noise and vibration annoyance and activity disturbance were measured using the ICBEN scale (Fields et al. 2001).

Estimation of noise and vibration level

Selected target residents living along the Nagano Shinkansen railway were located within 14 km of the Nagano station. Furthermore, the average speed of the Shinkansen ranged from 100 to 250 km/h. The train operates 83 times per day, and most of the rail structure is elevated. The noise exposure levels of each house were estimated at a maximum A-weighted and S-weighted sound pressure level using the estimation method for the Shinkansen railway noise (Nagakura et al. 2000) and noise measurements at the four sites. Vibration levels were estimated through a distance reduction estimation equation using field survey data. These coefficients ranged from 0.888 to 0.999. Figure 1 shows the distribution of noise and vibration levels. The maximum noise level ranged from 45 to 75 dB, and 17% of the respondents in this study were exposed to 70 dB or more (L_{Amax}). The environmental quality standard for Shinkansen railway noise in residential areas is 70 dB (L_{Amax}). In the vertical axis, the vibration level ranged from 34 to 76, and one respondent was estimated to have been exposed to more than 70 dB. This value is the guideline value recommended by the Ministry of the Environment for Shinkansen railway vibration.



(a) Maxmum noise level (b) Vibration level of vertical axis

Figure 1: Distribution of noise and vibration levels.

RESULTS

Demographic characteristics of social survey data

Table 1 shows the demographic characteristics of respondents participating in this social survey. About 60% of respondents were male, and many were aged in their 60s, 70s, or older. As such, more elderly persons participated in this survey than in a previous survey at Ishikawa (Morihara 2009). In Japan, a recent trend indicates that many of those living in detached houses are elderly persons or those with small families. The rate of respondents indicating high noise sensitivity was similar for residential areas measuring less than 70 dB (L_{Asmax}) and those measuring more than 70 dB. On the other hand, higher house satisfaction and residential preference were indicated in low noise level areas than in high noise level areas.

Table 1: Demographic characteristics

Variables	L_{ASmax}: <70 N*(%)	L_{ASmax}: 70≦ N*(%)	Total N*(%)
Gender			
Male	138(62.4)	26(57.8)	164(61.7)
Female	83(37.6)	19(42.2)	102(38.3)
Age			
20s	4(1.7)	4(8)	8(2.7)
30s	10(4.1)	2(4)	12(4.1)
40s	21(8.7)	6(12)	27(9.3)
50s	43(17.8)	5(10)	48(16.5)
60s	80(33.2)	17(34)	97(33.3)
70s or more	83(34.4)	16(32)	99(34)
Noise sensitivity (5-point scale)			
High (4-5)	44(18.3)	10(20.4)	54(18.6)
Low (1-3)	197(81.7)	39(79.6)	236(81.4)
House satisfaction			
High (1-2)	119(49.8)	20(39.2)	139(47.9)
Low (3-5)	120(50.2)	31(60.8)	151(52.1)
Residential preference			
High (1-2)	183(76.6)	33(66)	216(74.7)
Low (3-5)	56(23.4)	17(34)	73(25.3)

*Totals may differ due to missing data

Dose-response relationships

Figure 2 shows dose-response relationships caused by the Shinkansen railway. This study applied logistic regression analysis. The survey's top 3 categories on an 11-point numerical scale were located between the top 2 and top 1 categories of a 5-point noise annoyance verbal scale. The results indicate 26% of the top 2 categories on the 5-point verbal scale and 16% of the top 3 categories on the 11-point numerical scale at 70 dB $L_{Asmax.}$ About 67% of the sample responded within the top 2 categories of the 5-point verbal scale at 70 dB L_{vz}. For the logistic regression analysis, responses for activity disturbances in the top 2 categories of the 5-point verbal scale were further classified into three categories. Reported disturbance regarding television or listening to the radio was higher than that reported for other types of listening disturbance. Increased disturbance regarding reading regarding or thinking and sleep was indicated at at 70 dB L_{ASmax}. The disturbance curves for not being able to open a window and rattling increased above the L_{ASmax} level of 65 dB.

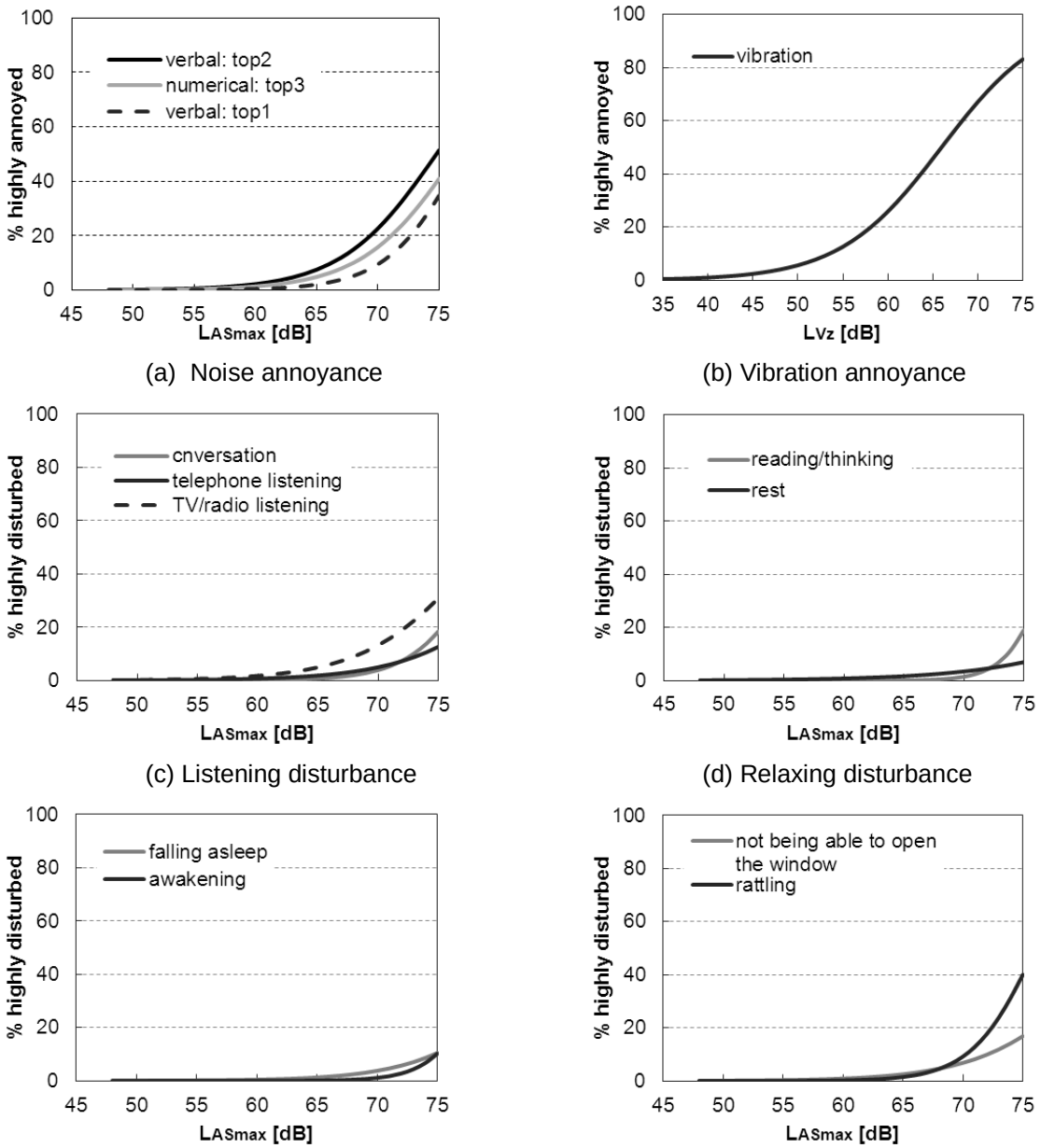
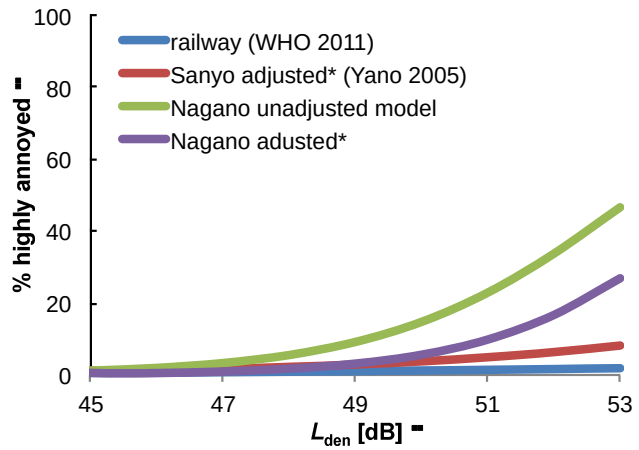


Figure 2 Dose-response relationships for annoyance and activity disturbances

Comparison with other research for noise annoyance

Figure 3 compares the results for dose-response relationships in this study with those of the WHO 2011 report, and Yano et al. 2005 by using logistic regression analysis. In this analysis, the top 3 categories of the 11-point numerical scale were used to indicate the percentage of those who reported being annoyed. In the Nagano survey, Lden ranged from 45 to 53 dB. The response curves for the Nagano and Sanyo Shinkansen railways were higher than that for the railway in the WHO reports 2011. Ota et al. (2013) determined that the Shinkansen railway caused higher noise annoyance than conventional railways. This is possibly because high-speed railways cause greater noise annoyance than conventional railways.

Figure 4 shows the dose-response relationship between L_{ASmax} and % highly annoyed (top 2 categories of the 5-point verbal scale) divided by vibration level at 50 dB L_{vz}. Respondents indicated significantly higher noise annoyance in residential areas at a vibration level of 50 dB or more than that for less than 50 dB L_{vz} (p<0.05). Öhrström et al. (2006) and Gidlöf-Gunnarsson et al. (2012) reported that responses indicated greater noise annoyance in higher vibration areas than in small or no vibration areas. In Japan, Yano et al. (2006) showed that the possibility of vibration affects noise annoyance. In addition, using structural equation modeling, Yokoshima et al. (2011) identified synergetic effects between the Shinkansen noise and vibration on annoyance.



*Gender, age, noise sensitivity

Figure 3 Comparisons between Nagano, WHO 2011 and Sanyo (Yano 2005)

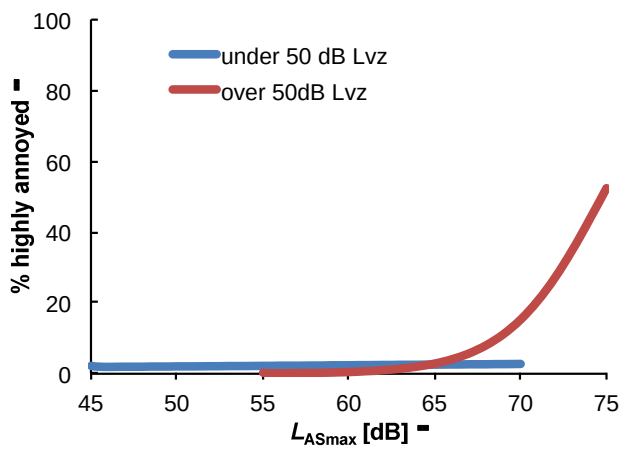


Figure 4 Dose-response relationships by vibration division

CONCLUSIONS

This paper reported community response to the noise and vibration caused by the Nagano Shinkansen railway. It indicated that 16% of respondents were highly annoyed by noise at 70 dB L_{ASmax}, and 67% were highly annoyed by vibration at 70 dB L_{vz}, furthermore, the noise annoyance caused by the Shinkansen railway in residential areas with higher vibration (over 50 dB L_{vz}) was significantly more than that in low vibration areas (less than 50 dB L_{vz}). Less than 70 dB L_{ASmax} caused low activity disturbances. The cause of low evaluation of sleeping disturbances could be attributed to the fact that the Shinkansen railway operated seven times at night (22:00-07:00).

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