Annoyance due to railway noise before and after the elevation of the conventional railway

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ABSTRACT

The Kyushu Shinkansen Line was opened in 2011, the conventional railway line was moved under the Shinkansen Line (the second temporary line) in 2012, and a part of the conventional railway was elevated in 2015. The noise and vibration exposures are usually changed by opening a new line or elevating lines. The purpose of this study is to compare community response to railway noise and vibration between before and after the elevation of the conventional railway. A social survey on noise and vibration from the Shinkansen and the conventional railway was conducted along the railway where the Shinkansen and conventional railway lines ran close and parallel to each other. In this study, the annoyance responses obtained before and after the elevation was compared by applying multiple logistic regression analysis with highly annoyed/annoyed or not as dependent variable and day–evening–night sound level, sex, age, and a dummy variable of before or after as independent variables. The results show that the exposure–response relationships change slightly between before and after elevation, but there are no significant differences between them.

1. INTRODUCTION

Recently, noise problems are one of the global social problems. Transportation systems such as aircraft, road traffic, and railway, have been developed and people and goods have easily moved, whereas traffic noise has become a serious social problem in many countries. Social surveys on environmental noises have been conducted mainly in developed countries such as Europe and North America. Many survey data on community response to step changes in noise exposure have also been accumulated.

Brown and van Kamp [1] summarized 43 previous studies conducted over the past 30 years. They found excess response in which the change in the annoyance accompanying the change in the exposure was beyond what was predicted from the steady state and that the change in the exposure situation and the effect differs depending on the sound source. In addition, according to Huybregts [2] which is also referred to in Brown's paper, it is concluded that there are excess responses in railway as well as other traffic noise such as road traffic and aircraft, as a result of compiling the results of the seven surveys on the change in railway noise. In Japan few studies on changes in noise exposure have been conducted. However, Morihara conducted a social survey before opening the Hokuriku Shinkansen and emphasized the necessity of comparison before and after the opening of the Shinkansen Line.

Under such circumstances, the Kyushu Shinkansen Line opened all the way in 2011, although it was so far partially operated. In Kumamoto, JR Kagoshima Line (a conventional railway line) and the Shinkansen Line are operated adjacent to each other over 17 km between Uto station and Sojo Daigakumae station across Kumamoto station, and in the part of the railway line, three-dimensional crossing construction (elevated railroad construction) has been advanced. The areas between Sojo Daigakumae station and Kumamoto station and between Kumamoto station and Uto station are called here North and South areas, respectively. A special construction method was used, in which the conventional railway line was moved from the primary temporary line to the secondary temporary line. In 2015, the elevated construction from Sojo Daigakumae station to Kumamoto station was completed. Residents along the railway lines have thus been exposed to noise and vibration of conventional railway and Shinkansen lines depending on the time as shown in Figure 1.

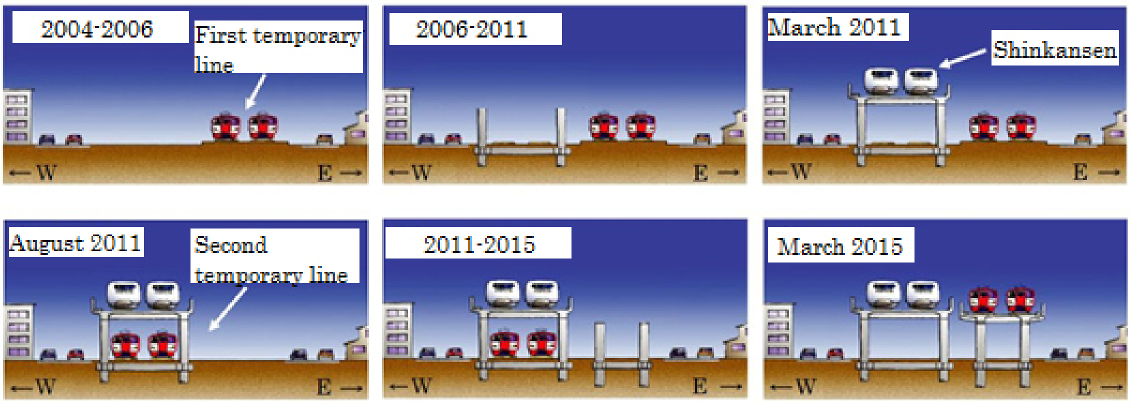

Figure 1: Process of constructing railways in North area

A series of social surveys on railway noise and vibration had been conducted from 2008 to 2012. Almost the same survey was conducted in the area from Sojo Daigakumae to Kumamoto station in 2016 after the elevation. This study aims to investigate the effects of the step change in the noise exposure before and after the conventional line elevation.

2. METHOD

2.1 Survey site

As shown in Figure 2, the three-dimensional crossing construction (elevated conventional railway construction) was implemented. In March 2015, the viaduct of the up and down lines over about 4 km north from Kumamoto Station and the up line over about 2 km south from Kumamoto Station was opened. The survey sites were located within about 150 m on either side of the railway lines in North area. The residents living in houses within 150m from the track were interviewed because the railway cannot be viewed directly from houses more than 150 m from the track and Yokoshima et al [4] showed that there is almost no influence of noises in houses 200m or more far from the track.

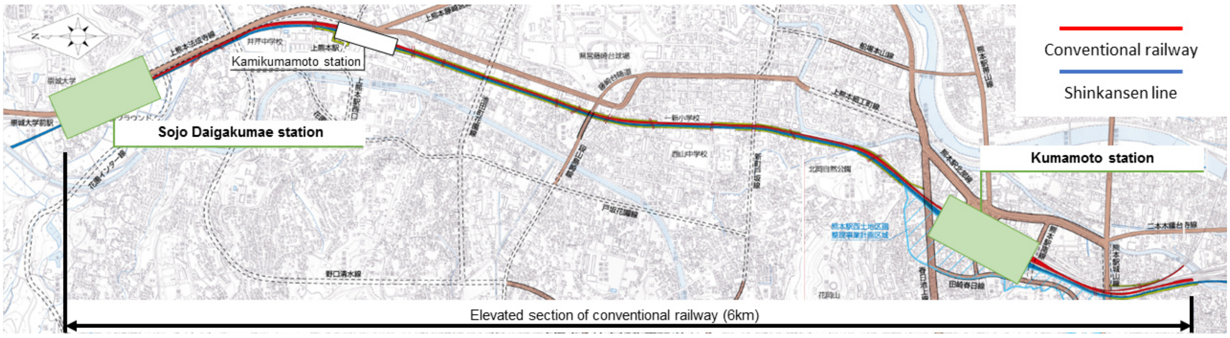

Figure 2: Elevation area for conventional railway

2.2 Survey plan

Social surveys and noise/vibration measurements were carried out for each railway operation situation according to the plan shown in Table 1. Community responses were compared between before the opening of the Shinkansen from 2008 to 2010 and after the opening of the Shinkansen in 2011 and 2012 [3]. In 2016, a survey was conducted in North area with the elevated conventional railway line to compare community response between before and after the elevation.

Table 1: Survey plan

ID	Year	Month	Area	Railway operation
Survey1	2009	Aug–Sep	North	First temporary line
	2010	Jul–Aug	South	Conventional railway
Survey2	2011	Apr–May	North	Shinkansen and conventional railway
		Aug–Sep	South	
Survey3	2012	Jul–Aug	North	Shinkansen and second temporary line
Survey4	2016	Nov–Dec	North	Shinkansen and elevated conventional railway
	2017		South	

2.3 Social survey

In principle, the distribute-collect method was used, but the mailing method was partially used for collection. In addition, reminder letters were sent when there was no reply after two weeks since the distribution. Respondents were 18 years of age or older, and were selected on a one person per family basis with the nearest birthday method to October 1. Also, in order to prevent psychological bias against railway noise, the survey was labeled as living environment survey.

The same survey items and the same scale were used for each survey. The questions addressed five factors: housing, residential environment, environmental pollution, daily activity disturbance, and demographic variables. As shown in Table 2, the noise and vibration annoyances were evaluated using the 5-point verbal (not at all, slightly, moderately, very, and extremely) and the 11-point numerical scale proposed by ICBEN (International Commission on Biologic-al Effects of Noise), and the daily activity disturbances were also evaluated using the 5-point verbal scale.

Table 2: Numerical annoyance scale and question wording in the survey

Thinking about the last 12 months or so, what number from 0 to 10 best shows how much you are bothered, disturbed, or annoyed by (…source…) noise?											
1) Conventional railway	0	1	2	3	4	5	6	7	8	9	10
2) Shinkansen	0	1	2	3	4	5	6	7	8	9	10
3) Total of conventional railway and Shinkansen	0	1	2	3	4	5	6	7	8	9	10
	Not at all										Extremely

2.4 Noise and vibration measurements

The levels of noise and vibration exposures at the houses were interpolated based on the distance to the reference points at which the noise and vibration levels were measured. First, levels of noise and vibration were measured at the reference points for 24 hours. All the noise and vibration events were identified and their sound exposure level (L_{AE}) and maximum vibration level (L_{Vmax}) values were calculated. The 24-hour noise indices and 24-hour mean value of L_{Vmax} were obtained from these values.

Since the sound propagation is different depending on the type of railway and the surrounding environment such as the density of the housing, the surveyed area was divided into several areas. Distance reduction measurements were performed simultaneously at reference points and several other points and distance attenuation equations were formulated by logarithmic regression.

3. RESULTS AND DISCUSSION

3.1 Basic data of social survey

Table 3 summarizes the number of respondents, the response rate, and the distribution of demographic variables. The response rate is relatively low, 33-34%.

Pearson's chi-square test was applied to test the independence of housing type, sex and age distribution. There was significant differences in house type ($p=7.76\times10^{-14}$) and age ($p=0.02$) but no significant difference in sex ($p=0.08$) between before and after the elevation.

The significant difference in house type, that the number of detached houses was increased and that of apartment houses was decreased in 2016, seems to be due to the fact that the questionnaires were distributed again to the detached houses recovered in the past surveys, and that the responses from apartment houses could not be sufficiently collected by the effects of the Kumamoto earthquake in April 2016.

In addition, while many students lived alone in the apartment houses, older people lived in the detached houses before the elevation. That is why young people in their 20s of age were quite many before the elevation and older people of their 60s or more are the majority after the elevation.

Table 3: Number of respondents, response rate, and demographic variables
N: Number of respondents, D: Detached house, A: Apartment house, R: Response rate

Elevation	Year	N	D	A	R (%)	Sex (%)		Age (%)					
						Male	Female	-20s	30s	40s	50s	60s	70s
Before	2012	336	144	192	32.7	56.7	43.3	18.6	8.7	14.7	16.8	19.2	21.9
After	2016	399	279	120	34.2	44.5	55.5	5.3	6.6	9.6	14.5	29.9	34

3.2 Number of passing trains and noise exposures

Table 4 shows the frequency of passing trains before and after the elevation. The total numbers of conventional railway and freight trains were almost the same between before and after the elevation. However the number of Shinkansen trains decreased slightly after the elevation with the change of train schedule.

Table 4: The number of passing trains before and after the elevation

Elevation	Train type			
	Conventional	Shinkansen	Freight	Total
Before	84	135	12	231
After	82	125	11	218

Table 5 compares the mean and standard deviation (S.D.) of noise exposures for conventional railway, Shinkansen, and the total before and after the elevation to each house. After the elevation, L_{den} was reduced by 6 to 7dB.

Table 5: Comparison of the mean value and S.D. of noise exposures for conventional railway, Shinkansen, and the total between before (n=336) and after the elevation (n=399) (dB)

	Elevation	Conventional		Shinkansen		Total	
		Mean	S.D	Mean	S.D	Mean	S.D
$L_{Aeq,24h}$	Before	43.6	10.1	44.5	10.3	48.3	9.9
	After	35.7	7.6	36.0	5.0	40.0	5.9
$L_{Aeq,d}$	Before	44.8	10.1	46.3	10.3	50.2	9.9
	After	36.0	7.5	38.8	5.0	41.0	5.7
$L_{Aeq,e}$	Before	44.2	10.1	43.5	10.0	48.1	9.8
	After	37.4	7.7	39.0	4.9	41.7	5.9
$L_{Aeq,n}$	Before	40.3	10.2	35.8	10.2	42.7	9.9
	After	34.7	7.6	31.1	5.0	36.9	6.4
L_{den}	Before	48.2	10.1	46.7	10.2	51.8	9.9
	After	41.8	7.6	40.7	5	44.9	6.2

Table 6: Comparison of the mean noise exposure values between west and east sides and between before and after the elevation (dB)
(Before & West: n=123, After & East: n=213, Before & West: n=187, After & East: n=212)

	Elevation	Conventional		Shinkansen		Total	
		West	East	West	East	West	East
$L_{Aeq,24h}$	Before	42	44.6	45.2	44.1	48.2	48.4
	After	28.9	41.7	32.8	38.7	35.5	43.9
$L_{Aeq,d}$	Before	43.3	45.9	47.5	46.4	50.1	50.2
	After	29.3	41.8	35.8	41.5	36.7	44.7
$L_{Aeq,e}$	Before	42.5	45.2	44.3	43	48	48.2
	After	30.4	43.5	36.1	41.5	37.1	45.6
$L_{Aeq,n}$	Before	38.7	41.3	36.5	35.3	42.2	43
	After	27.8	40.7	28	33.8	31.6	41.5
L_{den}	Before	46.6	49.2	47.5	46.3	51.5	51.9
	After	34.9	47.8	37.7	43.3	39.9	49.2

Table 6 compare the mean noise exposure values between west and east sides and between before and after the elevation. After the elevation the conventional railway noise largely decreased in the west side and Shinkansen noise decreased in the east side

3.3 Annoyance score

To compare the value of annoyance score before and after the elevation, mean value and standard deviation were calculated. The results are shown in the Table 7. It was found that the mean value of annoyance score decreased 0.31 for conventional railway, 0.5 for Shinkansen and 0.54 for the total after the elevation. Annoyance score for conventional railway decreased more than that for Shinkansen.

Table 7: Compare the mean value and standard deviation of annoyance score

	Elevation	Conventional		Shinkansen		Total	
		Mean	S.D	Mean	S.D	Mean	S.D
Annoyance score	Before	2.25	2.59	2.64	2.81	2.78	2.93
	After	1.94	2.26	2.14	2.38	2.24	2.57

3.4 Logistic regression analysis

To draw exposure–response relationships for annoyance by the railway noise, the logistic regression analysis was applied with “Highly Annoyed/Annoyed or not” as dependent variables and L_{den} as independent variable. “%HA” is the rate of people who responded to any of the top three categories on the 0–10 numerical scale and "%A" is the rate of people who responded to any of the top five categories on the 0–10 numerical scale in Table 2. Figures 3 to 8, compares the exposure–response relationships for conventional railway, Shinkansen, and the total of conventional railway and Shinkansen between before and after the elevation.

There seems to be little difference in exposure-response relationships between before and after the elevation in all figures. To investigate the differences in the exposure–response relationships between before and after the elevation systematically, multiple logistic regression analysis was applied with highly annoyed/annoyed or not as dependent variables and L_{den}, sex, age, and a dummy variable of before or after the elevation as independent variables.

The results are shown in Tables 8 and 9. There is no significant difference in the dummy variable for high and moderate annoyance. This indicates that there was no change effect with the elevation of conventional railway.

Table 8: Parameter estimates for sex–age-adjusted logistic regression models of high annoyance before and after the elevation

HA	Conventional			Shinkansen			Total		
Parameter	Estimate	SE	*p*	Estimate	SE	*p*	Estimate	SE	*p*
Intercept	-8.917	1.473	<0.0001	-5.961	1.406	<0.0001	-6.042	1.388	<0.0001
L_{den}	0.13	0.026	<0.0001	0.07	0.018	0	0.087	0.019	<0.0001
Before/after	-0.159	0.195	0.414	0.33	0.487	0.5	0.052	0.209	0.8

Table 9: Parameter estimates for sex–age-adjusted logistic regression models of moderate annoyance before and after the elevation

A	Conventional			Shinkansen			Total		
Parameter	Estimate	SE	*p*	Estimate	SE	*p*	Estimate	SE	*P*
Intercept	-5.585	0.868	<0.0001	-4.411	0.803	<0.0001	-5.418	0.863	<0.0001
L_{den}	0.084	0.015	<0.0001	0.055	0.014	<0.0001	0.074	0.015	<0.0001
Before/after	-0.091	0.126	0.469	0.025	0.144	0.864	-0.018	0.02	0.9

4. CONCLUSIONS

A socio-acoustic survey was conducted after the conventional railway elevation in the area where conventional railway and Shinkansen are parallel and close each other and the results were compared with those before the elevation. The main findings are summarized as follows:

(1) Noise exposures decreased considerably after the elevation.

(2) Annoyance was also decreased after the elevation.

(3) The exposure-response relationships were almost the same between before and after the elevation and multiple logistic regression analysis showed no significant between them.

(4) This implies no change effect with the elevation of conventional railway.

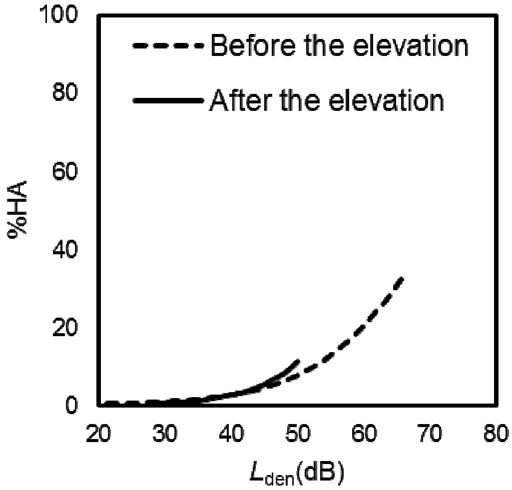

Figure 3: L_{den}-%HA relationship for conventional railway

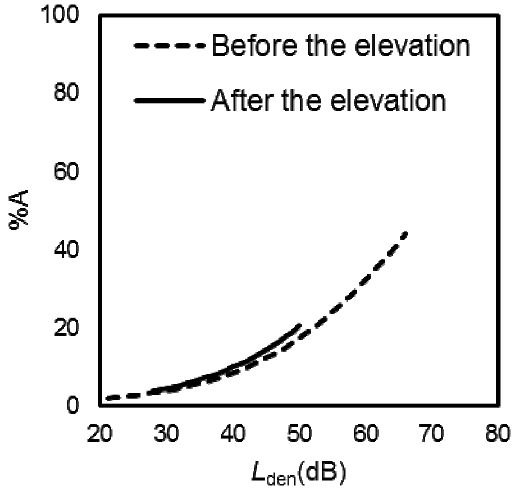

Figure 6: L_{den}-%A relationship for conventional railway

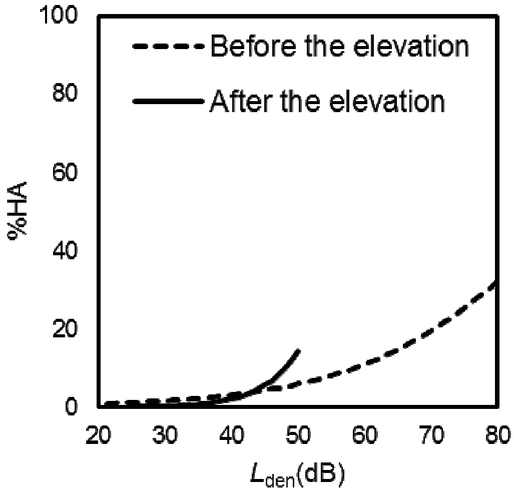

Figure 4: L_{den}-%HA relationship for Shinkansen

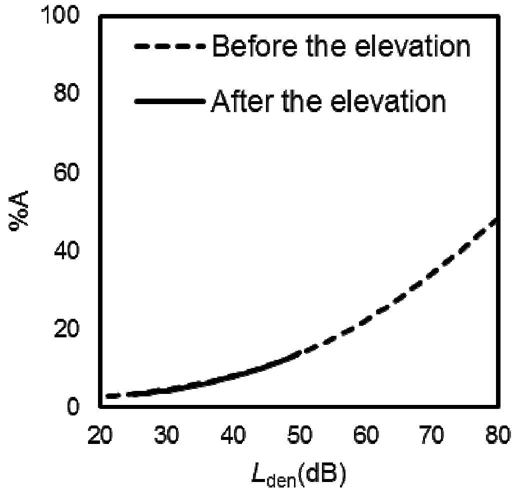

Figure 7: L_{den}-%A relationship for Shinkansen

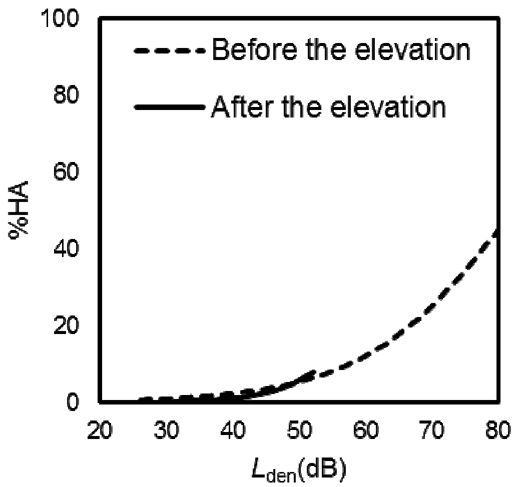

Figure 5: L_{den}-%HA relationship for the total of conventional railway and Shinkansen

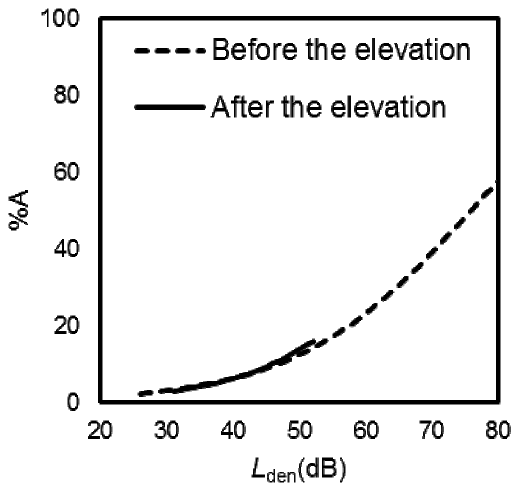

Figure 8: L_{den}-%A relationship for the total of conventional railway and Shinkansen

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