Comparison of community response to railway noise before and after the opening of a new Shinkansen line

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ABSTRACT

Noise and vibration from Shinkansen lines has been a serious social problem in Japan since the opening of the Tokaido Shinkansen Line in 1964. Under the development of the Shinkansen network, the Kyushu Shinkansen Line was opened in 2011. The purpose of this study is to compare the community responses to railway noise and vibration before and after the opening of the Kyushu Shinkansen Line. Socio-acoustic surveys were carried out in areas of Kumamoto, where conventional railway and Shinkansen lines are close and parallel to each other, before the opening (2008-2010) and after the opening (2011-2012). After the opening, the limited express trains were retired and more super-express trains run. Though the noise and vibration exposures were almost the same before and after the opening, the annoyances were a little decreased after the opening. The annoyances and daily activities caused by conventional railway noise and vibration were greater than those of the Shinkansen line. When multiple logistic regression analysis was applied with highly annoyed (response to the top three categories on an 11-point numeric scale) or not as the dependent variable and Lden and a dummy variable of before or after the opening as independent variables, the coefficient of the dummy variable of before/after was not significant. However, in the case of annoyed (response to the top five categories on the 11-point numeric scale) or not the respondents were significantly less annoyed after the opening than before.

1.NTRODUCTION

Noise and vibration from Shinkansen Line has been a serious social problem in Japan since the opening of Tokaido Shinkansen Line in 1964. Noise, Vibration, and low frequency noise caused by running trains continue to annoy inhabitants along the railway. To deal with this problem, the Japanese government notified “Environmental Quality Standards for Shinkansen Superexpress Railway Noise” and “Measures for Vibration Caused by Shinkansen Trains Urgently Required to Preserve the Environment”. However, thirty years or more past after these environmental standards were established, and the noise and vibration environment along Shinkansen Line is changing by countermeasures for the noise and vibration.

Toida et al. [1] compiled survey data about the noise and vibration of the Tokaido Shinkansen which had been accumulated in Nagoya City for many years, and showed that the noise exposure decreased about 20dB in 1995 since the opening while the decrease of vibration exposure was only 2 to 3 dB. Nakanishi et al. [2] conducted a social survey and noise/vibration measurement along the Sanyo Shinkansen Line, and suggested that noise annoyance was increased by vibrations. This was based on the fact that the Shinkansen caused a higher level of vibration than the conventional line at the same noise levels. In Japan, Hokuriku and Hokkaido Shinkansen Lines are now under construction. So it is very important to accumulate

survey data on community response to noise and vibration from Shinkansen Line. On the other hand, the rapid transit railway is constructed in the European countries such as France, Spain and Germany and Asian countries such as China, Taiwan and Korea. It is expected that the rapid transit railway will expand worldwide led by rising nations such as Brazil or India in the future. Therefore, it is necessary to examine the influence on living environment by the rapid transit railway globally. The purpose of this study is to provide fundamental data for the future noise and vibration policy by comparing the community responses to railway noise and vibration between before and after the opening of Kyushu Shinkansen Line.

2.METHODS

2.1 Survey site

In March 2011, the Kyushu Shinkansen Line was opened. Shinkansen and conventional railway lines were closely paralleled in the area around Kumamoto Station as shown in Figure-1, and the elevated conventional railway line is now under construction in an area from about 5 km north to 1 km south of Kumamoto Station. The construction process is shown in Figure-2, namely changing from the first temporary line to the second one, and finally the elevated conventional railway over more than ten years. During the period, people living along the lines have been exposed to the railway noise and vibration in addition to the redundant noise and vibration from the construction of Shinkansen Line or elevated railway. A part of the conventional railway line was already elevated in another area from Kumamoto Station to about 12 km south.

The survey sites were selected in the area from about 5 km north (North area) to 12 km south (South area) of Kumamoto Station and 150 m east and west from the railways. The super-express trains run slowly in the North area and accelerate to the maximum speed in the South area.

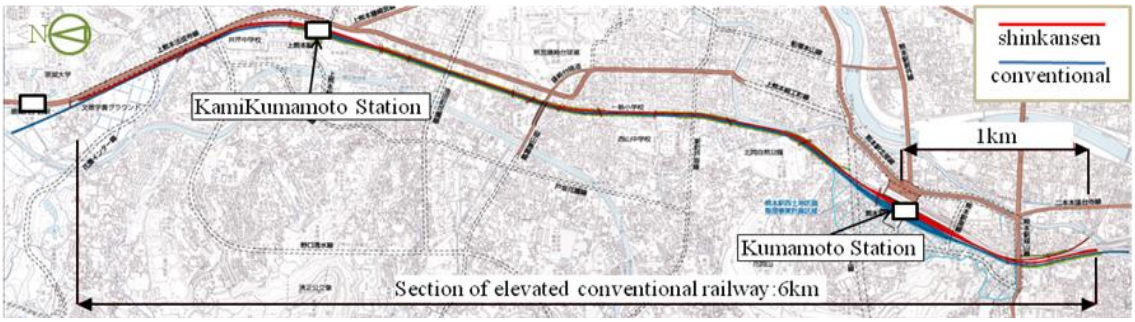


Figure-1 – North survey area for Shinkansen and conventional railway noise and vibration

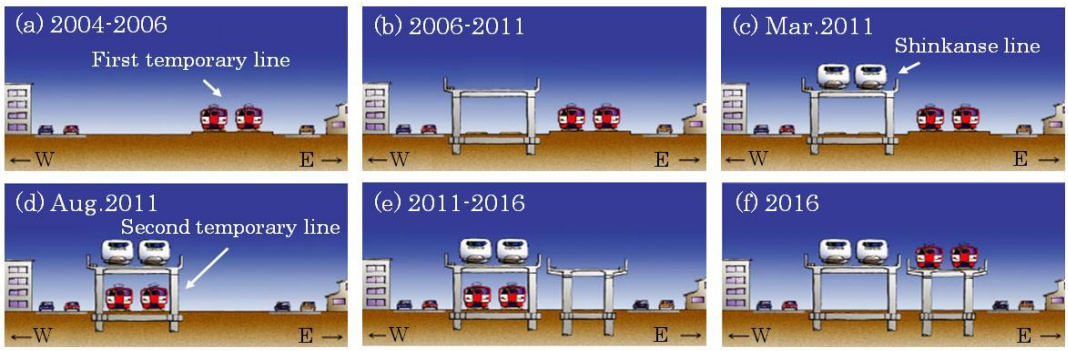


Figure- 2 – Process of step-change of noise and vibration exposures from railways

2.2 Social survey

Social survey and measurements have been conducted at every stage of railway operation as shown in Table 1. These surveys were conducted before the opening of Kyushu Shinkansen Line (2008-2010) and after the opening (2011-2012). The target houses for the surveys were uniformly classified into four groups (N1 to N4) in the North area with approximately 3,500 houses in total and three groups (S1 to S3) in the South area with approximately 3,800 houses in total. The surveys were conducted in accordance with the plan shown in Table 1. The questionnaires used in every survey contained a common set of core questions. The inquiry items described in Table 2 are composed of five factors.

The annoyances due to noise and vibration from conventional railway, Shinkansen Line and the total of the both were rated by 11-point numeric and 5-point verbal scales which were proposed by ICBEN (International Commission on Biological Effects of Noise). In addition, disturbances of daily activities were similarly rated by the 5-point verbal scale. These scales were shown in Figure-3.

Table 1 – Survey plan

Years	Survey areas	Groups	Railway operations
2008	North	preliminary	First temporary line of conventional railway
2009	North	N1	First temporary line of conventional railway
2010	South	S1	Conventional railway
2011	North and South	N2,S2	Shinkansen and conventional railway
2012	North	N3	Shinkansen and conventional railway (secondary temporary line of conventional railway)
2020	North and South	N4,S3	Shinkansen and elevated conventional railway

Table 2 – Inquiry items in the questionnaire

Factors	Items
Housing	Types of house ownership, Total floor area, Site area, House structure, Number of glass panes, Direction of opening, Area of dwelling unit and garden, Comfort of housing unit in summer and winter etc.
Residential environment	Satisfaction with residential area, Comfort in four seasons, Natural environment, Townscape, Scenery views, Quietness, Convenience in access to workplace, shopping, post office and bank etc.
Environmental pollution	Railway noise, Aircraft noise, Road traffic noise, Streetcar noise, Construction noise, Exhaust gas, Odor, Dust from factories etc.
Daily activity disturbance	Conversation, Telephone conversation, TV/radio listening, Reading and thinking, Resting and relaxing ,Falling asleep, Awakening, Difficulty to open windows, Disturbance due to vibration etc.
Personal	Length of residence and living in residential area, Frequency of window openings, Relation with neighbors, Sleep quality, Sensitivity, Attitude to transportation, Employment, Number of family members, Sex, Age etc.

Thinking about the last 12 months or so, what number from zero to ten best shows how much you are bothered, disturbed or annoyed by (…source…) noise?

0 **1** **2** **3** **4** **5** **6** **7** **8** **9** **10**

Not at all Extremely

In daily life, how disturbed are you when (…transportation…) passes by in the following cases?

1. Not at all **2.** Slightly **3**. Moderately **4**. Very **5**. Extremely

Figure- 3 – Question wordings and scales

2.3 Noise and vibration measurements

Respondents' exposures of noise and vibration were calculated from 24-hour noise and vibration measurement values at the reference points and the distance reduction for each house. All noise databases for this study were compiled using field measurements and calculations.

First, noise and vibration were measured at reference points for 24 hours. All the noise and vibration events were identified and their L_{AE} and L_{Vmax} were calculated. 24-hour noise indices and mean L_{Vmax} over 24 hours were obtained from these values.

To obtain the distance reduction from the reference points, the survey area was divided into several sub-areas because sound propagation characteristic varies according to the structure of railway or the density of houses and buildings. The measurements for distance reduction were conducted at reference point and several points from the reference point simultaneously. The distance reduction equations were formulated by logarithmic regression. Then, distance between railway lines and each house were measured by using housing map.

In order to accurately estimate the noise exposures at apartment houses, it is essential to consider the influence of diffraction by elevated railway and the sound insulation wall. Therefore, the exposure on the first and the third or upper floors of the same apartment house were calculated by the equations formulating Maekawa's Chart proposed by Yamamoto et al. [3].

3. RESULTS AND DISCUSSION

3.1 Social survey

Table 3 summarizes the sample sizes and the response rates. The overall response rate was approximately 30%, and that of detached house residents (approximately 45%) was higher than that of apartment house residents (approximately 20%).

Table 3 – Sample size and response rate

Types	Before the opening			After the opening		
	Detached	Apartment	Total	Detached	Apartment	Total
No. of distributed questionnaire	1017	1400	2417	988	1534	2522
No. of recovered questionnaire	466	301	767	427	319	746
Response rate (%)	46	22	32	43	21	30

After the opening of the Shinkansen Line (A1), the respondents were asked to compare the impressions of vibro-acousitc environment. Figure-5 (a) shows the most annoying source. About 60% of respondents answered not disturbed, while 20 to 30% of respondents answered noise from conventional railway as the most annoying source. After the changing of conventional railway from the first temporary line to second one (A2), the respondents who answered not disturbed increased. Figure-5 (b)-(d) compares the evaluations of the railway noise, vibration and viewing landscape between before and after the opening. Twenty to thirty% of respondents answered that not only noise environment but also vibration environment became better than before. This may be because the noise and vibration exposure levels from Shinkansen Line are lower than respondents expected. About 20 to 40% of detached house residents responded that viewing landscape turned worse. This might be due to the elevated railway.

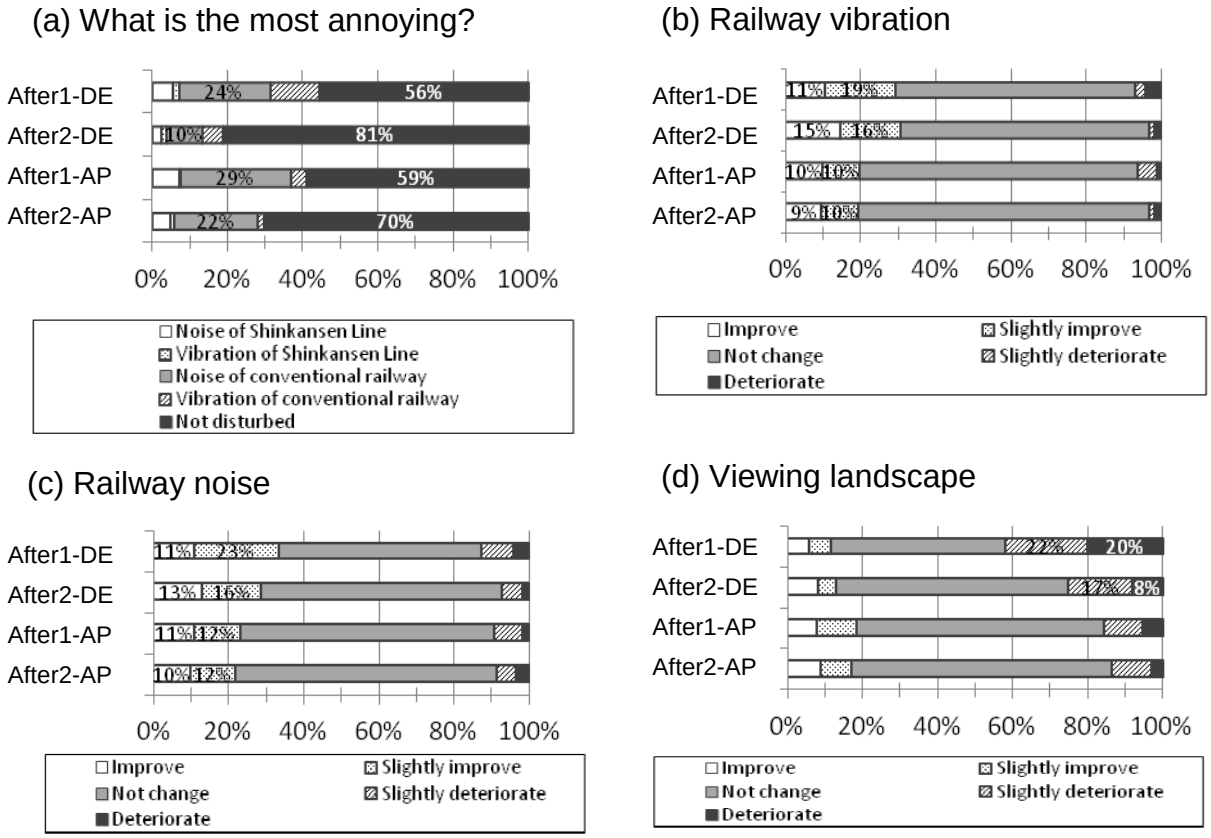


Figure-5 – Relative frequencies of the most annoying source, change of impressions of noise, vibration and viewing landscape before and after the opening of Shinkansen Line-
(Upper figure: Northern area, Lower figure: Southern area)
DE: Detached, AP: Apartment

After1: After the opening of Shinkansen Line, After2: After the changing of conventional railway

3.2 Exposures and annoyance of noise and vibration

Tables 4 and 5 show the frequency of railway transportation before and after the opening of Shinkansen Line. The number of railway transportation was about 50 more in the South area than in the North area both before and after the opening. After the opening of the Shinkansen Line, the limited express trains were retired and about 25% more super express trains run.

Table 4 – Frequency of railway transportation before the opening of Shinkansen line

	Local	Limited express	Freight	Total
North	80 (55, 12, 13)	92 (67, 15, 10)	11 (3, 2, 6)	183 (125, 32, 29)
South	138 (93, 25, 20)	84 (60, 13, 11)	9 (3, 3, 3)	231 (156, 41, 34)

Table 5 – Frequency of railway transportation after the opening of Shinkansen line

	Local	Shinkansen	Freight	Total
North	82 (56, 13, 13)	133 95, 33,	12 (4, 2, 6)	227 (155, 38, 34)
South	141 (94, 24, 23)	122 (71, 21,	12 (4, 2, 6)	275 (169, 47, 59)

*A parenthesis shows the number of railway transportation of daytime (from 7:00 to 19:00), evening (from 19:00 to 22:00) and night (from 22:00 to 7:00)

Table 6 compares the exposures and annoyance of railway noise and vibration between before and after the opening. The medians of individual exposures were used as the representative noise and vibration levels because there were houses where the measured background noise and vibration levels were more than the estimated noise and vibration levels from trains. On the other hand, the annoyance scores are the means of individual ones. The total exposure levels were the arithmetic mean value of conventional train's and Shinkansen's exposures. Analysis of variance and chi-square test were used to test differences in noise/vibration exposures and annoyance, respectively. The exposures after the opening were the combined ones from Shinkansen and conventional railway. The annoyance after the opening was the total annoyance from Shinkansen and conventional railway.

Table 6 shows the results of testing the significant difference in exposure and annoyance between conventional railway before the opening of Shinkansen Line and the total of both sources after the opening and between conventional railway and Shinkansen Line after the opening. In north area, noise and vibration exposures were almost the same before and after the opening, though the annoyances were decreased after the opening. Comparing the annoyance between before and after the opening, both the noise and vibration annoyances of Shinkansen Line were smaller than those of conventional railway. The decrease might have to do with noise and vibration abatement measures undertaken when the sound insulation wall and elevated railway were built. Thus, it may influence the decrease of total annoyance that annoyance of Shinkansen Line was not so high. On the other hand, noise and vibration exposures and noise annoyance were significantly decreased after the opening in south area.

Table 6 – Noise and vibration exposure levels and noise annoyance before and after the opening

		North area						South area					
		Before	After 1					Before	After 1				
		CV	Total		CV	SK		CV	Total		CV	SK	
DE + AP	*L*den	51	50	–	52	49	*	52	48	**	50	45	**
	Noise annoyance (5point scale)	2.6	2.2	**	2.5	2.2	**	2.7	2.3	*	2.6	2.2	**
	Noise annoyance (11point scale)	3.2	2.7	*	3.2	2.3	**	3.4	3.0	–	3.3	2.3	**
	L Vmax	47	47	–	47	48	–	47	48	–	51	45	**
	Vibration annoyance (5point scale)	1.9	-	–	1.6	1.3	**	1.7	-	–	1.7	1.4	*

DE: Detached, AP: Apartment, CV: Conventional railway, SK: Shinkansen Line

Before: Before the opening of Shinkansen Line, After1: After the opening of Shinkansen Line,

*p<0.05, **p<0.01 - Not conducted

3.3 Exposure-response relationships

The rate of people who responded to any of top three categories from the 11-point numeric scale was defined as percent highly annoyed (%HA), while the rate of people who responded to any of top five categories from the 11-point numeric scale was defined as percent annoyed (%A).

In order to verify the change in noise exposure-response relationships between before and after the opening of Shinkansen Line and the changing of conventional railway, multiple logistic regression analysis was applied with highly annoyed or not and annoyed or not as the dependent variable and L_{den} and a dummy variable of

before or after the opening as independent variables (Table7, 8). Both total and dominant annoyances were used for the analysis. Here, the dominant annoyance was greater one of the Shinkansen and conventional railway noises and the total noise exposure were the energy summation of both conventional train's and Shinkansen's ones.

Table 7 – Noise annoyance before and after the opening of Shinkansen and the changing of conventional railway

		Total		Dominant	
		Before	After	Before	After
Opening of Shinkansen Line	%HA	11.97	10.05	11.97	15.77
2009-2010,2011（North and South area）	%A	35.73	26.80	35.73	33.02
Changing of conventional railway	%HA	9.02	8.43	13.93	10.57
2011,2012（North area）	%A	25.68	25.60	33.61	28.10

Table 8 – Results of multiple logistic regression analysis

		Total			Dominant		
		Lden	D(0/1)	Intercept	Lden	D(0/1)	Intercept
Opening of Shinkansen Line	%HA	**		**	**		**
	%A	**	**	**	**	**	**
Changing of conventional railway	%HA	**		**	**	*	**
	%A	**		**	**	*	**

**:p<0.01, *:p<0.05

Figure-5 compares noise exposure-response relationships between conventional railway before the opening and the combined sources after the opening in north and south areas. The noise exposure-response relationships for %A were significantly decreased, even though those for %HA were not significantly different

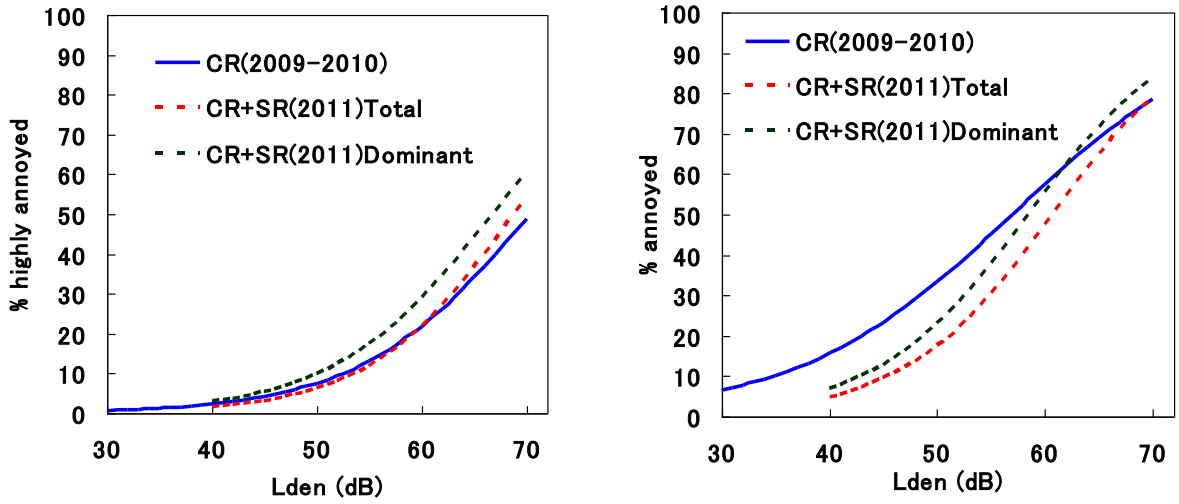
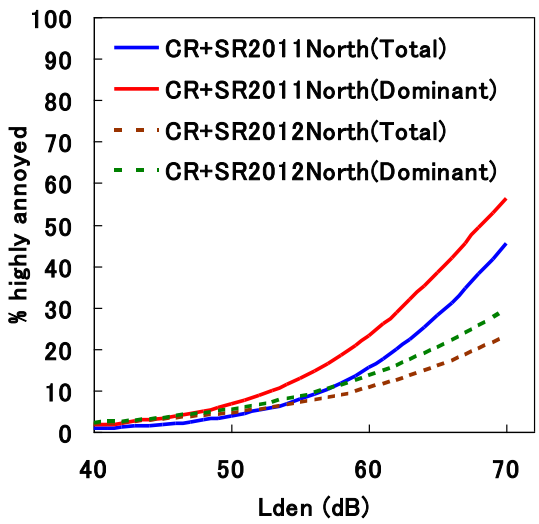
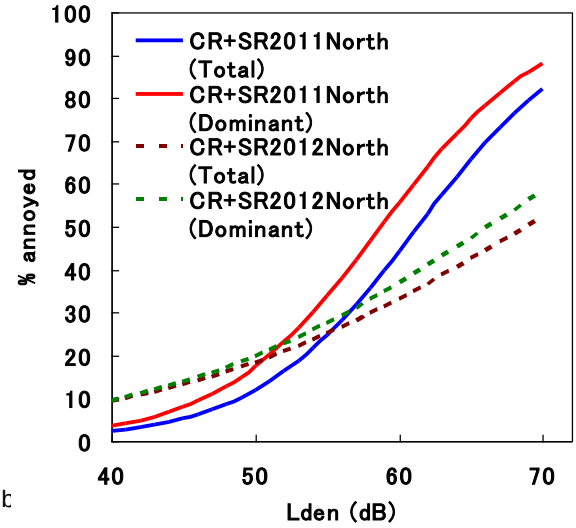


Figure-5- Exposure-response curves for railway noise before and after the opening of Shinkansen Line

Figure-6 compares noise exposure-response relationships between the combined sources before and after the changing of conventional railway in north area. The noise exposure-response relationships of dominant annoyance were significantly decreased, even though the ones of total annoyance were not significantly different. That might be because conventional railway noise which was dominantly annoying for most of respondents in north area decreased after the changing of conventional railway.





4. CONCLUSIONS

This study is concluded as follows:

(1)The noise and vibration exposures were slightly decreased after the opening, and the annoyances were significantly decreased.

(2)The annoyance caused by conventional railway noise and vibration was larger than those of Shinkansen Line.

(3)The noise exposure from conventional railway to apartment house increased by about 3dB after the changing of temporal conventional railway. On the other hand, the vibration exposures of conventional railway and Shinkansen Line were significantly decreased after the changing.

(4) The noise exposure-response relationships between before and after the opening of Shinkansen Line and the changing of temporal conventional railway seemed to decrease significantly.

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REFERENCES

[1] M. Toida, M. Omiya and K. Kuno, “Report of noise and vibration from the Tokaido Shinkansen in Nagoya city”, Proc. of Annual Meeting of Architectural Institute of Japan, 103-104, (2005)

[2] T. Nakanishi, Y. Nakashima, T. Morihara and T. Yano, “Measurements of vibration from Shinkansen and conventional railway; Effects of vibration on community response to noise Part1”, Proc. of Annual Meeting of Architectural Institute of Japan, 103-104, (2005)

[3] K. Yamamoto and K. Takagi, “Expressions of Maekawa’s Chart for Computation”, Proc. of Institute of Noise Control Engineering of Japan, Vol.15, No.4, (1991)

[4] S.Yokoshima, T.Yano, K.Kawai, M.Morinaga, A.Ota, “Representative dose-response curves for individual transportation noise in Japan”, Internoise2012, CD-ROM, August 2012

[5] Henk M. E. Miedema and Henk Vos, Exposure-response relationships for transportation noise, J. Acoust. Soc. Am. 104 (6), pp.3432-3445, December 1998