A new method of social survey on transportation noise using the Internet and GIS

Ichiro Yamada[1*], Jiro Kaku[2], Takatoshi Yokota[2], Seiichiro Namba[2], Seigou Ogata[3]

1 Aviation Environment Research Center, Airport Environment Improvement Foundation, K5 Bldg., 1-6-5 Haneda Kuhkou, Ohta-ku, Tokyo 144-0041, Japan

2 Kobayasi Institute of Physical Research, 3-20-41 Higashi-motomachi, Kokubunji, Tokyo, 185-0022

3 Traffic Safety and Environment Laboratory, 7-42-27 Jindaijihigashimachi, Chofu, Tokyo, 182-0012

*corresponding author: e-mail: i-yamada@center.aeif.or.jp

INTRODUCTION

This paper gives a brief summary of a research work which was performed over a period of two years (2006 and 2007) to develope a new method of social survey on the annoyance of transportation noise using the Internet and the geographic information system (GIS). It also discusses the effectiveness of the method through analysis of reults of a few preliminary surveys performed in regions along several arterial roads and railroads as well as around two airports: in the first year, surveys were conducted around airports and along conventional railroads, and in the second year arterial roads and high-speed railroads (Shinkansen). Finally, we examined the validity of the new method by comparing dose-response curves obtained by the new method with those obtained by conventional questionnaire surveys.

Up to now, two ways of fulfilling social survey have been mainly used in Japan; one is a face-to-face interview in which investigators visit individual households and the other a questionnaire survey by mail. In both cases, noise exposure levels at respondents' locations have been estimated using results of field measurements. Needless to say, such methods are in general expensive, and methodological limitation has prohibited us to collect a sufficient amount of survey data from much wider areas. Technical innovation has, however, made us possible to invent a new method of social survey, in which we perform questionnaire surveys through the Internet (we call it as web-based questionnaire survey in the following) and estimate noise exposure levels at locations of individual respondents by applying the GIS database and noise calculation models. Respondents to the web-based questionnaire survey were invited via several means including posting, handbill distribution and recruitment on the Internet. This method not only enables us straightforwardly to establish a dose-response relationship based on a large volume of human responses from a wide area or without ristriction of survey area, but also permits us to calculate the population exposed to certain levels of noise exposure by combining census data with the GIS information.

METHODS

The newly developed method of social survey consists of a web-based questionnaire survey and a noise exposure estimation using the GIS as is shown in Figure 1.

Web-based Questionnaire Survey

Web-based questionnaire survey is now performed in different fields, but in most applications target respondents are assumed to be unspecified internet users. When investigating adverse effects of noise on people, however, we need to identify addresses of respondents so as to estimate the level of noise exposure to which respondents are actually exposed. For that purpose, important issues are how to get respondents who are actually exposed to various levels of noise exposure, how to get their addresses and how to keep confidentiality of their personal information.

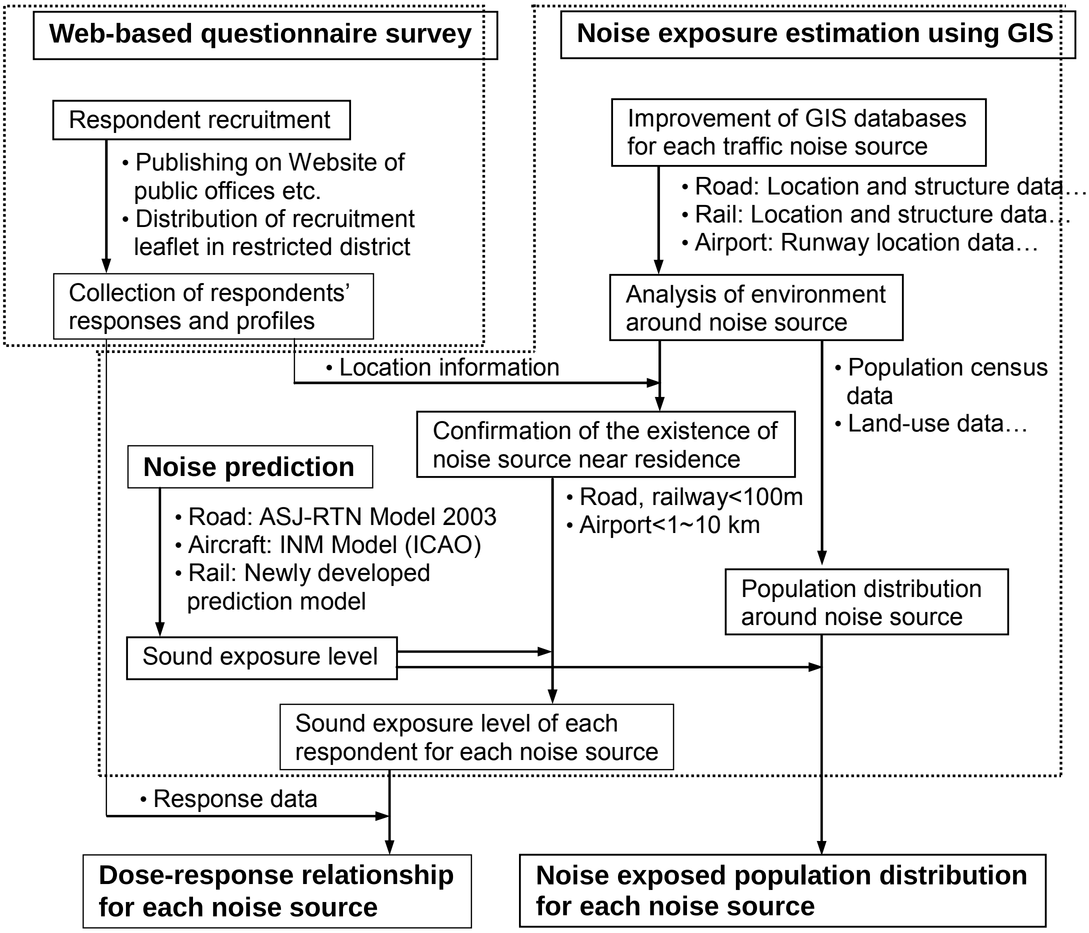

Figure 1: Research flow of the newly developed social survey method

Recruitment of applicants to the web-based questionnair survey: A typical way of recruiting applicants could be putting a want ad on a web-site hosted by a well-known organization such as the Ministry of the Environment or local governments. It is, however, not admissible for every one, nor is it easy to pick up applicants that suit our purpose. In other words, it is difficult to pick up only those who live in areas just near to a specific target noise source such as a road, railroad or airport. To avoid such difficulty and to put a want ad only in targeted areas without specifying survey purpose, we decided to take a way of distributing a recruitment handbill or leaflet as an insert of a life information journal. It is common that distribution of such leaflets is controled separately in each finely divided block. Note that items mentioned on the leaflet which we distributed include:

- Purpose of the survey, which focuses on the living environment,
- Reward for an answer (1,000 yen),
- How to access a website dedicated to the survey (URL),
- Consideration for keeping confidentiality of personal information.

The leaflet also included an area code which was specified depending on the distributed area. We asked respondents to answer the code when replying to the questionnaire in order to avoid respondents from areas other than the targeted.

Collecting survey responses and respondents' profiles: Applicants to the survey are requested to access the questionnaire server system on the URL either from a personal computer or from a cell phone equipped with a function of internet access. When applicants key in the area code provided in the recruitment leaflet in response to the request from the server, our policy for keeping confidentiality of personal information appears on the display of the PC or the cell phone of the applicants. Only applicants who agree to this policy can answer the following questionnaire. Note that the time necessary to complete answering all questions is about 10 minutes on the average. Note also that the location (latitude & longitude) of a respondent was estimated from the address, which the respondent filled in, using a freeware "Geocoding" offered by Google.

The form of questionnaire was made up, following the format of "*Questionnaire on Living Environment* (INCE/J-SSM-03)" which was established by the INCE/J under the request from the Ministry of the Environment, as reported by Kaku et al. (2002). In the main question, respondents are asked to reply whether they hear noises from five noise sources (road traffic, aircraft and helicopter, railroad, factory and construction site) and in case they hear those noise they are also asked to reply how much annoyed with those noises in a five-step scale from "not at all annoyed" to "very annoyed".

Noise Exposure Estimation using GIS

Noise exposure at locations of individual respondents was estimated using the GIS database and noise calculation models. We have built an integrated calculation model that estimates sound exposure level at locations of respondents by integrating noise maps calculated using noise prediction models and respondents' location data calculated using the GIS database. The following are summary accounts of noise exposure estimation procedures for road traffic noise, aircraft noise and railroad noise.

Road traffic noise: Inquiry focused on several residential areas along heavily traveled roads, which were specified as targets of road traffic census investigation. Geographic information necessary for the estimation of the geometrical relationship between respondent's residences and target roads was constructed from a digital road map with a scale of 1 to 25,000, together with an additional information derived from detailed maps (scale; 1/2,500). This geographic information as well as the result of road traffic census investigation at the year of 2005 formed a GIS database, which covered an area of 100 m on both sides of the target road. The noise exposure at locations of respondents was estimated using a spatial distribution of daytime and nighttime average sound levels calculated using ASJ RTN-Model 2003. Necessary input data for the calculation such as the volume of traffic for each type of vehicle and time period and conditions of road structures etc. were derived from the result of road traffic census investigation. Excess attenuation of sound levels due to sound diffraction through houses was calculated using various parameters (line-of-sight angle from the observer to the road, average height of buildings, house density, the rate of open space at the façard of buildings facing the road, etc.), together with an adjustment for respondent's home height and distance from the road.

Aircraft noise: The GIS database was improved to incorporate information on the location and length of runway, the location of respondent's residence, the population distribution obtained from the census data, etc. The estimation of noise exposure levels at locations of residents were calculated using INM Ver.6.2 developed by FAA. Input data (flight path, operational conditions of aircrafts and aircraft movements for each type of aircraft and engine) necessary for calculation were obtained from flight log information and field measurements open to the public. Note that some unusual aircraft were replaced to certain typical category of aircraft and that altitude profiles were unified to use ICAO/A, which is similar to the standard flight profile usually used in Japan. Noise exposure levels at locations of respondents and the population exposed to certain levels of noise exposure were finally determined using overlays of noise contours with GIS objects and census.

Railroad noise: The GIS database was improved to incorporate information on the location, height and structure of the railroad track, the height of sound-proofing barriers, the location of respondent's residence, the population distribution along the railroad lines within an area of 100 m on both sides using the census data, etc. The estimation of noise exposure at locations of respondents was carried out from spatial distributions of daytime and nighttime average sound levels, which were calculated using equations derived by Nagakura et al. (2002) for high-speed railroads (Shinkansen) as well as using equations derived by Kitagawa et al. (1999) with some modifications for conventional railroads, on the cross section at various distances along each railroad line. Necessary input data including train speed, number of cars per train, operation schedule, etc. for each type of train were obtained from documents open to the public, information on the internet, pay data, field measurements and so on. Excess attenuation of sound levels due to sound diffraction through houses for conventional railroads was estimated, following the process for road traffic noise, together with an adjustment for respondent's home height and distance from the track. Note that a little modified equation, shown in Nagakura et al. (2002), was applied to Shinkansen.

RESULTS

Result of the questionnaire survey

The inquiry was carried out over two years, resulting in collection of 5,405 responses in total from residents dwelling in 4 areas along roads, two areas around airports, five areas along conventional railroads and 8 areas along the Shinkansen, as shown in Table 1. We selected densely populated areas where we confirmed usual distribution of a life information journal. Note that we also performed small supplemental surveys by conventional means, i.e., by mail and using face-to-face interview.

Rate of applications: The method of accessing the dedicated URL was modified twice as the inquiry advanced; initially, we asked applicants to directly access the URL via PC and soon added another way to access the URL using cell phones. The rate of applications was at most 1 %, which means a distribution of ten thousand copies of a recruitment leaflet brought us only a hundred successful applications to the questionnaire survey. We guessed that applicants might have taken precaution against phishing is a cause of the lower application of cell phones. Thus, we added a third way to access the URL via Web-site of Kobayasi Institute of Physical Research so that applicants could trust the survey in advance, e.g., by making sure of the credibility of the institute on the Internet using a serch engine such as Google. Inclusion of the third way caused the rate of application to increase to 1.8 % on the average. As a result, the ratio of applications via cell phones re. those via PCs became about 1 to 3, as is shown in Table 2. It is suggested that fear of suffering phishing is so high for cell phones, compared with PCs, considering the difference of the diffusion rate between the two. Anyway, one of the most important issues we must overcome is to sweep away such distrust of applicants in order to attain a high rate of application. Note that the cost for the distribution of recruitment leaflets was ¥2.5-3.0 per copy.

Table 1: Summary of responses in the inquiry over two years

year	sound source	survey area	No. of responses
2006	airport	Kyushu	252
		Kansai	331
	conventional railroad	Kanto	508
		Kansai	903
2007	road	Kyushu	813
		Kansai	667
		Chubu	439
		Kanto	453
	Shinkansen	Chugoku	114
		Kansai	324
		Chubu	428
		Tohoku	201

Table 2: Summary of access means in the inquiry over two years

survey area	access via PC	access via cell phone	total
Kyushu	655	410	1,065
Chugoku	69	45	114
Kansai	1,564	661	2,225
Chubu	532	335	867
Kanto	694	239	933
Tohoku	109	92	201
Total	3,623	1,782	5,405

Age and sex of respondents: Table 3 shows a distribution of age and sex of the respondents. Male and female of the overall respondents were at a ratio of 1 to 2, but it seems that the ratio of male respondents increases with the age. The number of respondents was the highest in thirties and forties, i.e., in the range of age from 30 through 49, but we might say that the distribution is flat across the age compared with those of conventional survey methods in which respondents of 50 years or older account for 65 % of the overall responses.

Valid responses: Almost all responses for the survey around airports were valid, whereas many responses for the surveys along roads and railroads were invalid because of responses from applicants living outside the target areas, which were specified as regions within 100 m from roads and/or railroads. The percent rates of valid responses for each of the three means of transportation were as follows;

- Road traffic 62 %,
- Conventional railroad traffic 63 %,
- Shinkansen raillroad traffic 22 %.

One of the main causes of such a low response rate for Shinkansen was a difficulty to find a sufficient amount of suitable survey areas satisfying conditions. There are different patterns of train operations, and as a result trains often run at a relatively low speed near densely populated areas for a stop at the station.

Table 3: Distribution of age and sex of respondents in the inquiry over two years

age	Web-based survey			conventional surveys		
	male	female	total	male	female	total
18 - 19	34	59	93	8	2	10
20 - 29	180	700	880	22	26	48
30 - 39	454	1,525	1,979	19	39	58
40 - 49	414	866	1,280	10	19	29
50 - 59	242	407	649	25	40	65
60 -69	187	135	322	32	35	67
> 70	116	39	155	49	42	91
reply without age	12	30	42	0	1	1
reply without sex	0	0	5	0	0	2
Total	1,639	3,761	5,405	165	204	371

Accuracy of noise exposure estimation: The accuracy of noise exposure estimation is dependent on the validity of noise prediction models we used. We have examined it by comparing calculations with measurements at several locations in the surveyed areas for each of road, airport and railroads. As a result, we confirmed that, roughly speaking, the difference of calculations with measurements remained within ±2 ~ ±3 dB.

Dose-response Relationships: Figures 2 and 3 show dose-response relationships on noise annoyance for individual sound sources, i.e., road traffic noise, airport noise, conventional and Shinkansen railroad noises. The horizontal axis means $L_{Aeq,day}$, which is defined as time average sound level in the daytime (6:00 – 22:00), while the vertical axis means the percentage of human responses; mark ● means results for the highest step of five-step scales (5/5), and mark ▲ means results for the highest two steps ((4+5)/5). From the figures you can see that noise annoyance increases as noise dose increases, which implies that both questionnaire surveys and noise exposure investigation were appropriately performed, although the rate of response is clearly different among sound sources. That is, the response rate for road traffic noise is unexpectedly low, whereas those for airport noise and railroad noise are rather high.

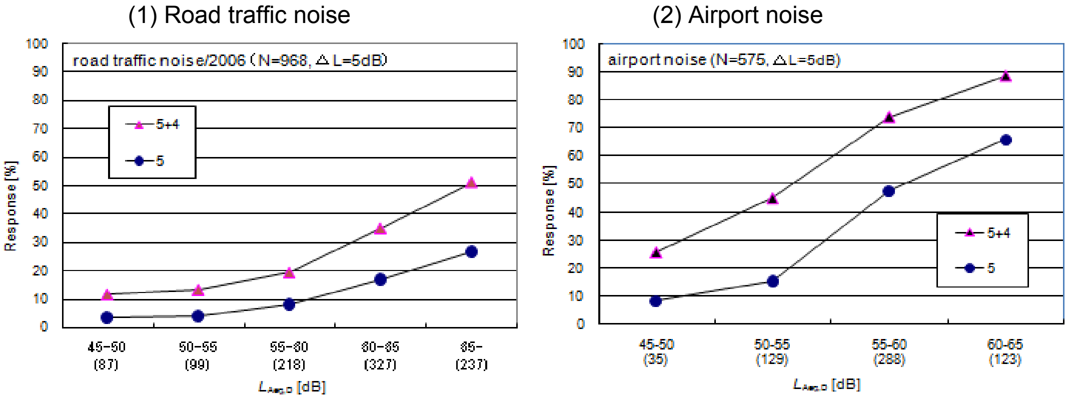

Figure 2: Dose-response relationships ($L_{Aeq,D}$ vs %responses): (1) road traffic noise and (2) airport noise. N means the total number of samples and ΔL class bin

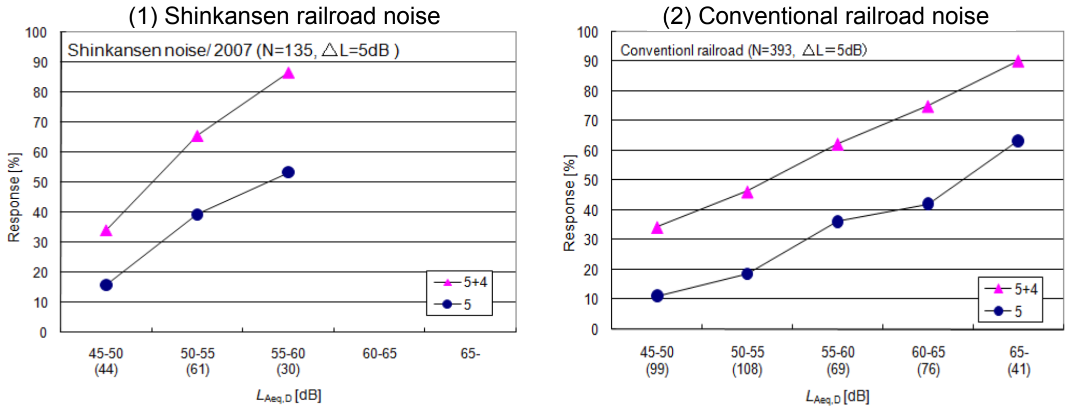

Figure 3: Dose-response relationships: (1) Shinkansen and (2) conventional railroad noises

Thus, we examined whether the dose-response relationships obtained from the web-based surveys around two airports (Osaka and Fukuoka) in 2006 are consistent with those derived from the conventional interview and mail surveys in 2007. Both surveys were carried out in areas close to each other. The survey area of the latter was carefully selected so that people were not asked to reply doubly. Noise exposure at respondents' locations was estimated using the same noise model and input data. Figure 4 compares two dose-response curves obtained by the two surveys for each airport. You can identify that the two response curves are consistent with each other, although the response rate is a little different between the two airports.

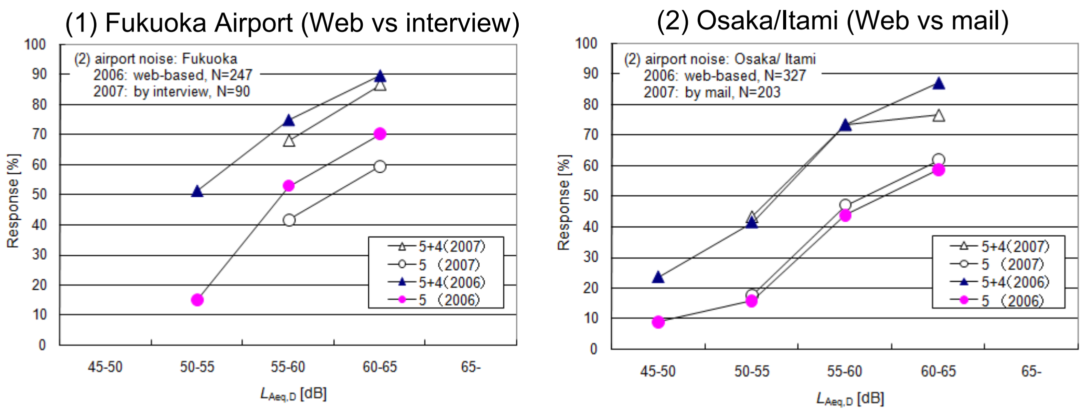

Figure 4: Comparison of dose - response relationships between web-based surveys and conventional surveys on airport noise (1) at Fukuoka Airport (by interview) and (2) at Osaka/Itami Airport (by mail)

By the way, as you see from Figures 2 and 3, the percentage of highly annoyed for road traffic noise was unexpectedly low compared with those for airport noise and railroad noise. One cause is guessed that respondents were asked to evaluate their annoyance due to exposure to road traffic noise exclusively from the targeted arterial road. It might be different if they were asked to answer their annoyance due to general road traffic noise including that from nearby alleys.

Finally, Figure 5 shows dose-response relationships for airport noise via the Web-based survey after a correction for effects of differences in the age distribution from the census was applied to the response data. The result of a statistical test on the difference from Figure 4 was not significant at statistical level of significance of 5 %.

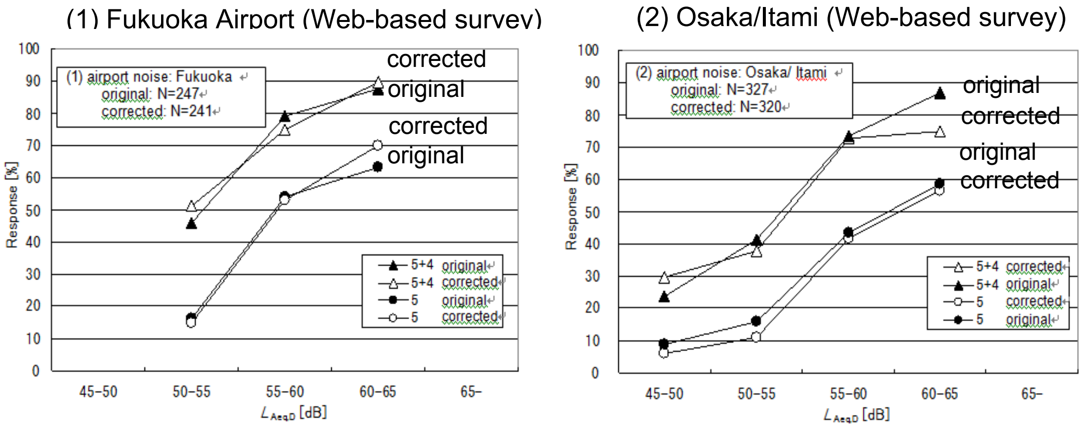

Figure 5: Dose-response relationships for airport noise via the Web-based survey after an adjustment was applied to correct differences in the age distribution from the census: (1) at Fukuoka Airport and (2) at Osaka/Itami Airport

CONCLUDING REMARKS

This paper reported the outline of a new method of social survey on traffic noise using the Internet and the GIS, which was established based on a research work performed over two years. The effectiveness of the method was examined through analysis of results of a few preliminary surveys performed in areas along several arterial roads, conventional railroads, Shinkansen and around two airports. It was also confirmed that dose-response relationships are consistent with each other between the new web-based method and conventional questionnaire surveys by interview and/or by mail.

This study was supported by a grant for the promotion of environmental technological development from the Ministry of the Environment. The authors are also greatful to K. Nagakura, Y. Abe and Y. Ogata (Railway Technical Reserach Institute), S. Wake, Y. Kimura and R. Haga (Hao Technical Consultant Office), M. Nakazawa (Knowledge Vanguard), K. Goto (Aviation Env. Res. Center) and M. Morinaga (Defense Facilities Improvement Environment Assosiation).

REFERENCES

Acoustical Society of Japan (2003). ASJ RTN-Model 2003.

INCE/J Committee on comprehensive research on the evaluation of noise effects (2004). Report of the research sponsored by the Ministry of the Environment of Japan (in Japanese).

Kaku J, Yamamoto K, Yamashita M, Kabuto M, Kageyama T, Kuno K, Kuwano S, Namba S, Sueoka S, Tachibana H, Kamigawara K (2002). Standardization of social survey method in Japan. In: Proceedings of INTER-NOISE 2002.

Kaku J, Yokota T, Namba S, Ogata S, Yamada I (2007). Availability of a newly developed social survey method on noise using the Internet and the geographic information system (GIS). In: INTER-NOISE 2007, Istanbul, Turkey.

Kitagawa T et al. (1999). Estimation of prediction method for narrow-gauge railroads. In: Proceedings of the Meeting of ASJ 99 (in Japanese).

Nagakura K et al. (2002). Prediction method of noise from Shinkansen high-speed railroad. In: Report of the Meeting of ASJ Noise and Vibration Committee, N-2000-01 (in Japanese).