Economic valuation of sleep disturbance due to traffic noise: A questionnaire study applying CVM in Urayasu, Chiba, Japan

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ABSTRACT

In the present study, the economic value of sleep disturbance due to traffic noise was examined by means of the contingent valuation method (CVM). In 2009, we conducted a questionnaire study in an area in Urayasu, Chiba, Japan; residents of this area are expected to be affected by the expansion of the Tokyo International Airport, which is scheduled for 2010. Residents were asked about their willingness to accept compensation (WTA) per month for once-a-month and once-a-week sleep disturbance due to traffic noise. Although open-ended CVM was employed to gather residents' opinions on WTA, two choices ("I do not need compensation because it does not bother me" and "I need more than money, and do not accept the disturbance") were also offered. Two versions of the questionnaire, one asking about aircraft noise and the other asking about road traffic noise, were prepared. Each version of the questionnaire was sent to 1,600 residents in the study area. As a result, 1,947 responses with a signature on the consent form were collected and the number of valid responses obtained was 1,829 (906: aircraft noise, 923: road traffic noise). It was found that respondents' WTA did not seem to differ depending on whether the disturbance was due to aircraft noise or road traffic noise. It was also found that there were great differences between individual WTAs for sleep disturbance due to traffic noise. The median value of the WTA for once-a-month sleep disturbance was 26,000 JPY/month (25–75th percentile: 3,000–"More than money"). The median value of the WTA for once-a-week sleep disturbance was "More than money" (25–75th percentile: 15,000–"More than money"). Furthermore, it was revealed that respondents' WTA varied significantly according to their basic attributes, such as age, socio-economic status, and subjective noise sensitivity.

INTRODUCTION

Environmental valuation methods, both stated preference and revealed preference methods, have long been employed to estimate the economic value of traffic noise [1]. Recently, there has been increasing interest in utilizing stated preference methods to assess the economic value of traffic noise, such as the contingent valuation method (CVM) and the conjoint analysis.

Recent studies have suggested that sleep disturbance is associated with adverse health effects due to traffic noise [2]. Thus, it seems necessary to clarify the monetary value of sleep disturbance due to traffic noise, if we are to design effective noise policy. For instance, Riethmuller et al. [3] interviewed patients with obstructive sleep apnoea syndrome and discussed the monetary value of sleep undisturbed by noise. However, thus far, only a few studies have attempted to conduct an economic valuation of sleep disturbance due to traffic noise.

In this study, the economic value of sleep disturbance due to traffic noise was examined by means of the CVM. In 2009, we conducted a questionnaire study in an area in Urayasu, Chiba, Japan; residents of this area are expected to be affected by the expansion of the Tokyo International Airport, which is scheduled for 2010.

Residents were asked about their willingness to accept compensation (WTA) per month for once-a-month and once-a-week sleep disturbance due to traffic noise. Two versions of the questionnaire, one asking about aircraft noise and the other asking about road traffic noise, were prepared.

The results were then analysed to investigate individual diffrences in respondents' WTA in relation to various factors, including area (expected aircraft noise exposure), gender, age, socio-economic status, and subjective noise sensitivity.

METHODS

Study area and population

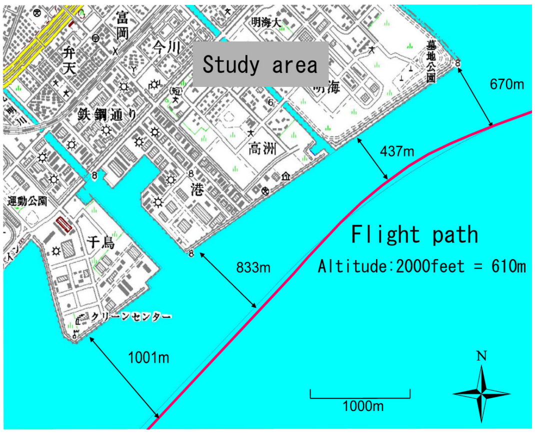
In 2009, we conducted the questionnaire study on residents of the area, to assess their WTA for sleep disturbance due to traffic noise.

Figure 1 outlines the planned flight path of the new runway for night flights (2300–0600 hours) and the area in which we conducted this study.

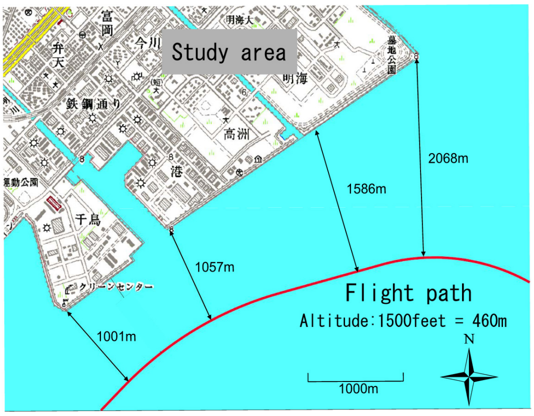
Figure 1(a) shows the planned flight path for night flights (as of September 2009). In February 2010, after this questionnaire study was carried out, the planned flight path was changed as shown in Figure 1(b) in order to mitigate adverse effects of aircraft noise on sleep.

Figure 1(c) shows the study area. In the figure, the study area is divided into three parts (Areas 1, 2, and 3). Area 1 falls closest to the planned flight path of the new runway.

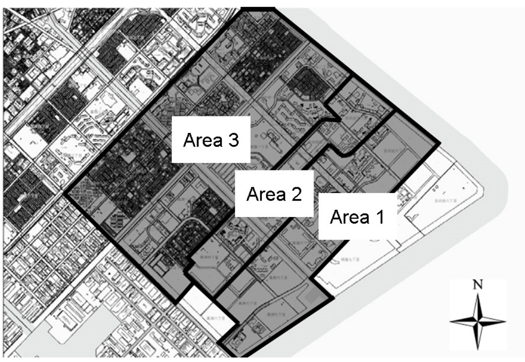
Three thousand two hundred residents aged 20 or over were sampled from the Basic Resident Register, by means of the stratified random sampling method with respect to the three areas.



(a) Planned flight path for night flights (as of Sept. 2009)



(b) Planned flight path for night flights (as of Feb. 2010)



(c) Study area

Figure 1. Map of study area

Questionnaire

After signing a consent form, the respondents were then asked to complete the questionnaire. They were also informed that we were planning to carry out a cohort follow-up study after the opening of the new runway.

The participants were asked about their WTA per month for once-a-month and once-a-week sleep disturbance due to traffic noise. Although open-ended CVM was employed to gather their opinions on WTA, two choices ("I do not need compensation because it does not bother me" and "I need more than money, and do not accept the disturbance") were also offered. Two versions of the questionnaire were prepared; one asking about aircraft noise and the other asking about road traffic noise.

The following items were also asked; subjective noise sensitivity, anxiety about the influence of the expansion of the airport, annoyance due to traffic noise (current state), disturbances of daily life due to aircraft noise (current state), tolerable disturbances due to aircraft noise, experience of noise disturbance, and habituation to noise disturbance.

The Weinstein's noise sensitivity scale (WNS) [4, 5] was included to measure subjective noise sensitivity. In this study, respondents' subjective noise sensitivity was evaluated according to their score of noise sensitivity scale WNS-6B, an improved WNS having been proposed by the present authors [6, 7]. The WNS-6B score can range from 0 (lowest noise sensitivity) to 6 (highest noise sensitivity).

In addition, the questionnaire investigated respondents' lifestyles and basic demographic attributes (e.g., gender, age, and occupation of the householder). The occupation of the householder was used as a measure of socio-economic status.

Statistical analysis

We calculated descriptive statistics from the data, in order to elucidate the features and trends in the data.

The difference in WTA for sleep disturbance was also examined between the two noise sources: aircraft noise and road traffic noise (Wilcoxon rank sum test).

A comparison between the two WTAs (once-a-month and once-a-week sleep disturbance) was carried out by means of cross-tabulation.

How respondents' area, gender, age, socio-economic status, and subjective noise sensitivity related their WTA was also investigated (Wilcoxon rank sum test, Kruskal Wallis test, and Jonckheere-Terpstra test).

Furthermore, in order to investigate the factors causing individual differences in WTA, categorical regression analysis with optimal scaling was applied to the WTA; respondents' area, gender, age, socio-economic status, and subjective noise sensitivity were included as explanatory variables.

All statistical analyses were performed with SPSS, version 15.0.

RESULTS AND DISCUSSION

Sample

Each version of the questionnaire was sent to 1,600 residents in the study area. One hundred and eighty-three questionnaires were returned unfilled because the addresses were unknown. Thus, the final number of questionnaires that were distributed was 3,017, 2,094 of which were returned completed (response rate: 69%). Those questionnaires that were returned without a signed consent were regarded as invalid. As a result, 1,947 valid responses with a signature on the consent form were collected.

Moreover, responses were only deemed valid when they fulfilled the following conditions: (1) the answer contained the respondent's age; (2) the respondent's age was 20-79 years; (3) the respondent answered all the questions about the WTA for sleep disturbance; and (4) the WTA for once-a-week sleep disturbance was the same or more than the WTA for once-a-month sleep disturbance.

There were nine respondents who answered that their WTA for once-a-week sleep disturbance was less than their WTA for once-a-month sleep disturbance. On authors' judgement that they tended to make more or less false answers, they were exclued from the analyses.

Table 1. Distribution of the attributes of the respondents stratified by the three areas

	Area 1	Area 2	Area 3	Total
Gender				
Male	311 (41.9)	201 (37.9)	234 (42.1)	746 (40.8)
Female	400 (53.8)	315 (59.4)	300 (54.0)	1015 (55.5)
Unknown	32 (4.3)	14 (2.6)	22 (4.0)	68 (3.7)
Age				
20–39	266 (35.8)	184 (34.7)	163 (29.3)	613 (33.5)
40–59	388 (52.2)	283 (53.4)	222 (39.9)	893 (48.8)
60–79	89 (12.0)	63 (11.9)	171 (30.8)	323 (17.7)
Socio-economic Status				
Executive	297 (40.0)	202 (38.1)	196 (35.3)	695 (38.0)
White-collar	354 (47.6)	250 (47.2)	231 (41.5)	835 (45.7)
Blue-collar	81 (10.9)	72 (13.6)	122 (21.9)	275 (15.0)
Unknown	11 (1.5)	6 (1.1)	7 (1.3)	24 (1.3)
Subjective noise sensitivity (WNS-6B score)				
6 points high-sensitive	274 (36.9)	181 (34.2)	221 (39.7)	676 (37.0)
5 points mid-sensitive	176 (23.7)	126 (23.8)	138 (24.8)	440 (24.1)
0–4 points low-sensitive	291 (39.2)	222 (41.9)	195 (35.1)	708 (38.7)
Unknown	2 (0.3)	1 (0.2)	2 (0.4)	5 (0.3)
Total	743 (100)	530 (100)	556 (100)	1,829 (100)

Frequecny and percentage distributions are shown.

Thus, after these exclusions, the number of valid responses obtained was 1,829 (906: aircraft noise, 923: road traffic noise). Table 1 lists the respondents' attributes for each area.

As shown in the table, age was significantly correlated with the three areas (Chi-square test: $p<0.001$). Among the respondents living in Area 3, the percentage of those in their 60s and 70s was 30.8%, which was higher compared with the other areas. Socio-economic status was also significantly correlated with the three areas (Chi-square test: $p<0.001$). Among the respondents living in Area 3, the percentage of blue-collar was 21.9%, which was higher compared with the other areas. On the other hand, gender and subjective noise sensitivity evaluated by the WNS-6B were not significantly correlated with the three areas.

WTA for sleep disturbance due to traffic noise

As a result of the questionnaire study, individual WTA was obtained.

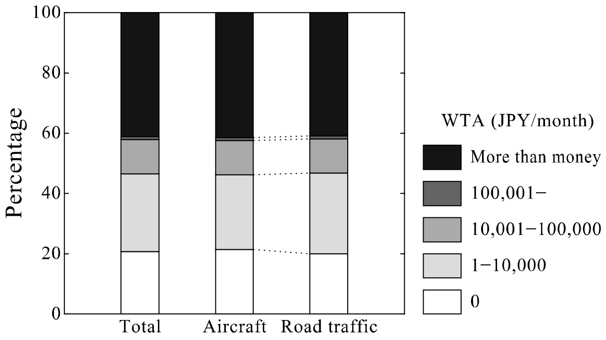
Figure 2 presents a comparison of the WTAs for sleep disturbance between the two noise sources: aircraft noise and road traffic noise. Figure 2(a) presents the WTA for once-a-month sleep disturbance and Figure 2(b) presents the WTA for once-a-week sleep disturbance. In the figures, "More than money" means the WTA of those respondents who chose the item "I need more than money, and do not accept the disturbance." In April 2010, 10,000 JPY was equivalent to approximately 79 EUR.

No significant differences between the two noise sources were observed in terms of their WTA (Wilcoxon rank sum test: $p=0.917$ and $p=0.665$ for once-a-month and once-a-week sleep disturbance, respectively).

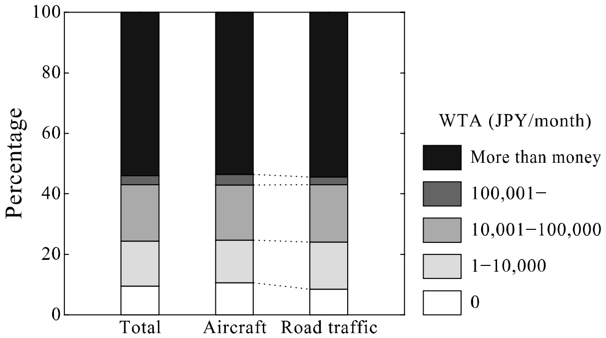
The issue of whether the economic value of noise differs depending on the transport mode that causes it (whether rail, road, or air) is still debated [1]. Since most of the existing studies estimate the economic value of noise per dB, it is difficult to compare the results of the present study with the results of previous studies. However, our results suggest that there is no difference between the economic value of the two noise sources in regard to sleep disturbance. Therefore, in the following, we discuss economic value of sleep disturbance due to traffic noise without distinction of the two noise sources.

The results regarding the WTA for once-a-month sleep disturbance were as follows. The median value was 26,000 JPY/month (25–75th percentile: 3,000–"More than money"). About 41% of the respondents reported that they would need more than money. On the other hand, about 21% of the respondents reported that they would not need compensation; for these participants, their WTA is zero. When excluding the respondents whose WTA was "More than money," the maximum value was 10,000,000 JPY/month, the median value was 5,000 JPY/month (25–75th percentile: 0–10,000), and the mean value was 29,779 JPY/month.

The results regarding the WTA for once-a-week sleep disturbance were as follows. The median value was "More than money" (25–75th percentile: 15,000–"More than money"). About 54% of the respondents reported that they would need more than money. On the other hand, about 9.6% of the respondents reported that they would not need compensation. When excluding the respondents whose WTA was "More than money", the maximum value was 40,000,000 JPY/month, the median value was 10,000 JPY/month (25–75th percentile: 3,000–50,000), and the mean value was 132,002 JPY/month.



(a) Respondents' WTA for once-a-month sleep disturbance



(b) Respondents' WTA for once-a-week sleep disturbance

Figure 2. Comparison of respondent's WTAs for sleep disturbance between the two noise sources

Many previous studies have used environmental valuation methods such as the CVM to estimate the economic value of traffic noise [1]. Often, one of the major objectives of these studies is to use the results to help conduct a cost-benefit analysis. For example, the results can be analysed in order to answer questions about whether the social benefits of a reduced noise and sleep disturbance justify the high costs of implementing it. Data garnered by the CVM can be also used to estimate the appropriate level of compensation that should be offered to recompense those who have been adversely affected by traffic noise.

In most of the previous studies, median and mean values have been reported as representative values. However, our results strongly suggest that there are great differences among individual WTAs for sleep disturbance due to traffic noise; this implies that there are great differences between these representative values and individual WTA. Needless to say, using the median value of WTA means that half of the residents are not satisfied with the compensateion. Therefore, it seems reasonable to conclude that the median and mean values of WTA for sleep disturbance do not give us useful information to help conduct a cost-benefit analysis.

Table 2 shows the relationship between the two WTAs (once-a-month and once-a-week sleep disturbance). As shown in the table, the ratio of the WTA for once-a-week sleep disturbance to the WTA for once-a-month sleep disturbance varied with each individual. For example, among the respondents whose WTA for once-a-month sleep disturbance was zero, their WTA for once-a-week sleep disturbance varied from zero to "More than money."

It was also noted that some respondents also gave details about how they had made their basic calculation as well as giving their WTA. An example of this can be seen in the response of one respondent who wrote, "One month consists of about four weeks. That is why I have multiplied this by four." and so on. In this connection, about 11% of the respondents reported that their ratio of the WTA for once-a-week sleep disturbance to the WTA for once-a-month sleep disturbance was 4 to 5.

Table 2. Relationship between the two WTAs (once-a-month and once-a-week sleep disturbance)

Once-a-month	Once-a-week					Total
	0	1-	10,001-	100,001-	More than money	
0	175 (9.6)	109 (6.0)	28 (1.5)	0 (0.0)	67 (3.7)	379 (20.7)
1-		162 (8.9)	214 (11.7)	1 (0.1)	95 (5.2)	472 (25.8)
10,001-			98 (5.4)	42 (2.3)	68 (3.7)	208 (11.4)
100,001-				13 (0.7)	5 (0.3)	18 (1.0)
More than money					752 (41.1)	752 (41.1)
Total	175 (9.6)	271 (14.8)	340 (18.6)	56 (3.1)	987 (54.0)	1,829 (100)

Frequecny and percentage distributions are shown.

Factors causing individual differences in WTA for sleep disturbance due to traffic noise

We also investigated individual differences in respondents' WTA in relation to their area, gender, age, socio-economic status, and subjective noise sensitivity. Since there was little difference between the results of the two WTAs, the following figures only represent the results of the WTA for once-a-month sleep disturbance.

Figure 3 illustrates respondents' WTA for once-a-month sleep disturbance in relation to the three areas. No significant relationship was observed between respondents' WTA and the three areas (Kruskal Wallis test: p=0.277, Jonckheere-Terpstra test: p=0.147).

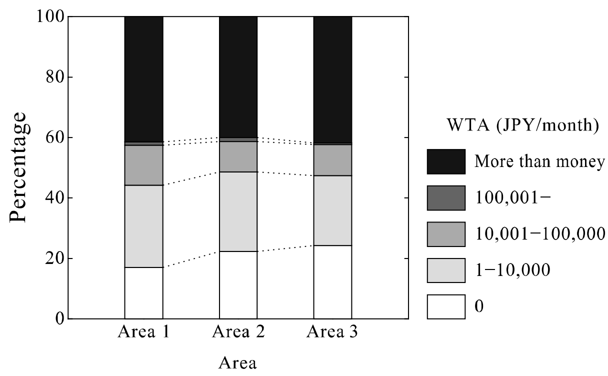


Figure 3. Respondents' WTA for once-a-month sleep disturbance in relation to the three areas

Figure 4 shows respondents' WTA for once-a-month sleep disturbance in relation to their gender. No significant relationship was observed between respondents' WTA and their gender (Wilcoxon rank sum test: p=0.522).

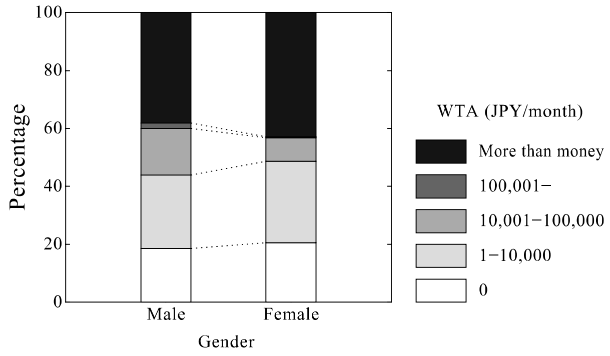


Figure 4. Respondents' WTA for once-a-month sleep disturbance in relation to their gender

Figure 5 illustrates respondents' WTA for once-a-month sleep disturbance in relation to their age. A significant relationship was observed between respondents' WTA and their age (Kruskal Wallis test: $p<0.001$, Jonckheere-Terpstra test: $p=0.006$). As Figure 5 makes clear, respondents in older age groups (40s-50s and 60s-70s) had a higher WTA than those in younger age group (20s-30s) did.

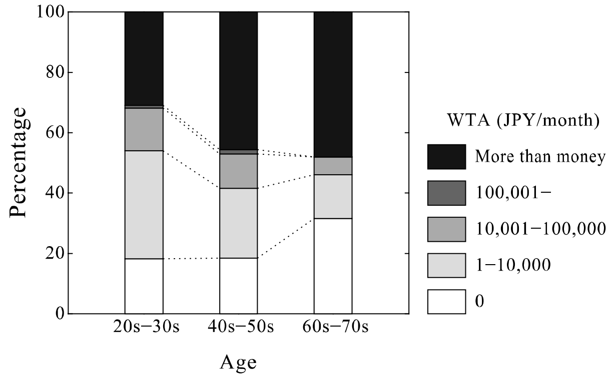


Figure 5. Respondents' WTA for once-a-month sleep disturbance in relation to their age

Figure 6 shows respondents' WTA for once-a-month sleep disturbance in relation to their socio-economic status. A significant relationship was observed between respondents' WTA and their socio-economic status (Kruskal Wallis test: $p=0.002$). Respondents in the executive group and those in the white-collar group indicated a higher WTA than the blue-collar group did.

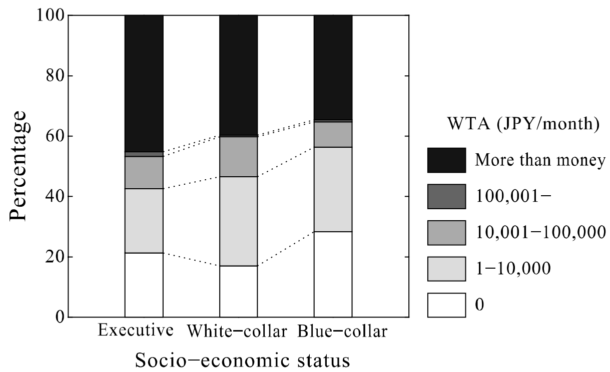


Figure 6. Respondents' WTA for once-a-month sleep disturbance in relation to their socio-economic status

Figure 7 illustrates respondents' WTA for once-a-month sleep disturbance in relation to their subjective noise sensitivity. The respondents were classified into the three groups on the basis of their WNS-6B score. As Figure 7 shows, a significant correlation was observed between respondents' WTA and their subjective noise sensitivity (Kruskal Wallis test: $p<0.001$ and Jonckheere-Terpstra test: $p<0.001$). Those respondents who had a high sensitivity to noise reported a higher WTA than those with a low sensitivity to noise did.

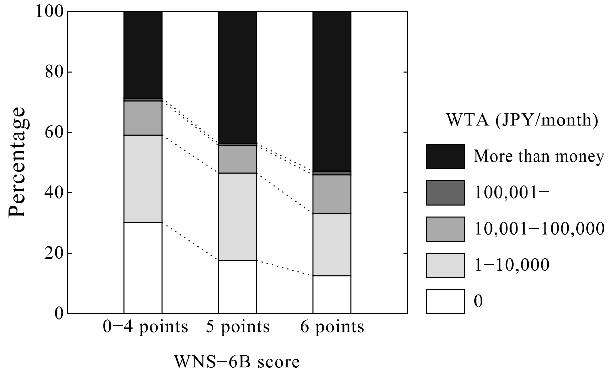


Figure 7. Respondents' WTA for once-a-month sleep disturbance in relation to their subjective noise sensitivity evaluated by the WNS-6B

A categorical regression analysis with optimal scaling was conducted on respondents' WTA for once-a-month sleep disturbance. Their WTA was classified into 5 categories, as shown in Figure 2. The categories were then included in the categorical regression model as an ordinal variable. The following two analyses were conducted. In Analysis 1, only objective measures—that is, respondents' area, gender, age, and socio-economic status—were included as explanatory variables. In Analysis 2, subjective noise sensitivity and objective measures were included as explanatory variables. When we developed a categorical regression model, all the explanatory variables were included as a nominal scale.

Figure 8 shows the results of the categorical regression analysis on respondents' WTA for once-a-month sleep disturbance. The ANOVA that was conducted to test the significance of the categorical regression model overall revealed that the model was significant ($p<0.001$); despite this, the explanatory variables only accounted for 2.7% (Analysis 1) and 7.0% (Analysis 2) of the variance in the WTA, respectively.

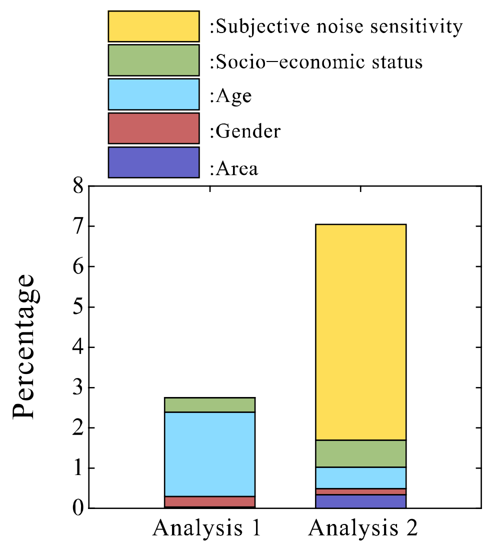


Figure 8. Results of the categorical regression analysis regarding respondents' WTA for once-a-month sleep disturbance. R squares of each variable were shown in both analyses

Table 3 shows the importance—that is, each explanatory variable's contribution to the explained variance—obtained in Analysis 2. Although respondents' WTA was significantly correlated with their area, age, socio-economic status, and subjective noise sensitivity; these explanatory variables only explained 7.0% of the variance in the WTA. The factor that had the highest importance in terms of respondents' WTA was subjective noise sensitivity (76%). The second most important factor was socio-economic status (9.5%), which was followed by age (7.6%).

Table 3. The importance of each explanatory variable, as obtained in Analysis 2

Explanartory variables	p value	Importance
Area	0.008	0.048
Gender	0.079	0.022
Age	<0.001	0.076
Socio-economic status	<0.001	0.095
Subjective noise sensitivity	<0.001	0.759

This study revealed that respondents' WTA for sleep disturbance varied significantly depending on their basic attributes such as age, socio-economic status, and subjective noise sensitivity. This study also revealed that there were great differences in individual WTAs, and that only 7% of these individual differences were explained by factors such as area, gender, age, socio-economic status, and subjective noise sensitivity. These results suggest that these factors do not sufficiently explain individual differences in WTA for sleep disturbance due to traffic noise, and that WTA for sleep disturbance is strongly influenced by other individual attributes, including cultural factors, social factors, and so on. Thus, it should be concluded that a CVM study conducted in a certain area is not enough to clarify the universal economic value of sleep disturbance due to traffic noise.

CONCLUSION

This study examined the economic value of sleep disturbance due to traffic noise by means of the CVM. A questionnaire study was conducted in Urayasu, Chiba, Japan. Residents were asked about their WTA per month for once-a-month and once-a-week sleep disturbance due to traffic noise. Two versions of the questionnaire were prepared; one asking about aircraft noise and the other asking about road traffic noise.

The results suggested that respondents' WTA did not seem to differ depending on whether the disturbance was due to aircraft noise or road traffic noise. This suggests that there may be no difference between the economic value of sleep disturbance due to aircraft noise and that due to road traffic noise.

The median value of respondents' WTA for once-a-month sleep disturbance was 26,000 JPY/month (25–75th percentile: 3,000–"More than money"). The median value of respondents' WTA for once-a-week sleep disturbance was "More than money" (25–75th percentile: 15,000–"More than money"). These results strongly suggest that there are great differences between individual WTAs for sleep disturbance. It seems reasonable to conclude that the median and mean values of WTA for sleep disturbance do not give us useful information to help conduct a cost-benefit analysis.

On investigating the factors that caused individual differences in WTA, it was revealed that respondents' WTA for sleep disturbance varied significantly according to their basic attributes, such as age, socio-economic status, and subjective noise sensitivity. Moreover, it was also noted that these factors explained only 7% of the variance of WTA. These results suggest that WTA for sleep disturbance is strongly influenced by other individual attributes, including cultural factors, social factors, and so on. It should be concluded that a CVM study conducted in a certain area is not enough to clarify the universal economic value of sleep disturbance due to traffic noise.

The results mentioned above should be taken into consideration when applying the economic value obtained by the CVM to noise policy. Nonetheless, the CVM is still a useful method for obtaining economic value.

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REFERENCES

1 S. Navrud, "The State-of-the-Art on Economic Valuation of Noise" Final Report to European Commission DG Environment (2002)
2 World Health Organization Regional Office for Europe, "Night Noise Guidelines for Europe" (2009)
3 S. Riethmuller, R. Muller-Wenk, A. Knoblauch, O. D. Schoch, "Monetray value of undisturbed sleep" *Noise & Health* **10**(39), 46–54 (2008)
4 N.D. Weinstein, "Individual differences in reactions to noise: A Longtitudinal study in a college dormitory" *Journal of Applied Psychology* **63**(4), 458–466 (1978)
5 N.D. Weinstein, "Individual differences in critical tendencies and noise annoyance" *J. Sound. Vib.* **68**, 241–248 (1980)
6 H. Kishikawa, T. Matsui, I. Uchiyama, M. Miyakawa, K. Hiramatsu, S.A. Stansfeld, "The development of Weinstein's noise sensitivity scale" *Noise & Health* **8** (33), 154–160 (2006)
7 H. Kishikawa, T. Matsui, I. Uchiyama, M. Miyakawa, K. Hiramatsu, and S.A. Stansfeld, "Noise sensitivity and subjective health: Questionnaire study conducted along trunk roads in Kusatsu, Japan" *Noise & Health* **11**(43), 111–117 (2009)