PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

# Effects of changes in operational and residential factors on public health and reactions at the vicinity of Noi Bai International Airport

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## ABSTRACT

The rapid development of air transport resulted in increased levels and wider influential scale of noise due to the airport operation. The number of flights operated and the housing conditions at residential areas around Noi Bai International Airport has increased significantly in the past nine years. The exposure noise levels ($L_{\mathrm{den}}$) at surveyed sites ranged between 48 and 61 dB in 2009, but increased to range between 54 and 76 dB in 2017. General health indicators such as Body Mass Index (BMI), blood pressure, etc. were investigated in two surveys conducted in November 2017 and August 2018. Exposure-response relationships established in the five surveys conducted from 2014 to 2018 were found to be higher than that established in 2009 survey. Comparisons of respondents with high blood pressure and insomnia ratios at different noise exposure level ranges showed that there is no significant association between ratios of hypertension and noise exposure levels ($L_{\mathrm{den}}$) but a significant exposure-response relationship was found between night-time noise exposure levels and insomnia. This study results suggested that improvement of residence quality and a restriction on nighttime flight operation should be considered to protect health of resident living around airports in Vietnam.
Keywords: Aircraft noise, Annoyance, Health Effects.

## 1. INTRODUCTION

An increase of flight operation to meet the growing air travel demand have various negative environmental impacts, particularly noise and air pollution, that affects quality of life and health of communities living near the airport (1). However, the number of studies on this issue is very limited in developing countries where the aviation transport has the fastest growth rate (2). A socio-acoustic survey on community response to aircraft noise around Hanoi Noi Bai International Airport (HNBIA), Vietnam, was conducted in 2009 (3). The operation status of HNBIA was considered to be stable around the survey period. Since then, the number of operations of the aircraft has gradually increased, especially after the opening of the new terminal building in December 2014. To assess effects of a step change of noise exposure levels around HNBIA, step-change surveys were conducted once before and twice after the operation change happened. As a result, an excess response due to the step-change were found (4). To clarify whether this excessive reaction decreases over time or continues afterwards, two follow-up surveys were conducted in 2017 and 2018, which are about 3 years and 4 years after the step-change. Study results of individual surveys up to 2017 have been reported at previous

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Internoise conferences (5).

In parallel with the change in air transport, the period from 2009 up to now has witnessed a dramatic change in Vietnam's economy and urbanization. As a result, the housing conditions of the Vietnamese people in general as well as the people living around HNBIA also changed. Since noise annoyance was found to vary through factors other than noise exposure such as housing, neighborhood environment, socio-demographic variables, and personal and environmental contexts (6, 7). Effect of noise change should be investigated using effects of both acoustic and such of non-acoustic variables. In this paper, the results of socio-acoustic surveys in nine years around HNBIA will be summarized with aims to assess effects of changes in operational and residential factors on public health and reactions at the vicinity of HNBIA. The outcomes from this study are expected to contribute to appropriate noise policy for improving the living environment around the airports in developing countries.

## 2. METHODS

### 2.1 Survey sites

HNBIA has two parallel runways in the east-west direction (11L-29R and 11R-29L). Since the operation direction of the runway is influenced by the wind direction, the use of the flight path toward the east occupied near 80% of the total movements at HNBIA. As shown in Figure 1, nine surveyed sites (Sites 1-9) were selected around HNBIA in the 2009 survey. Four sites (Sites 1-4) located under the main landing path, 3 sites (Sites 7-9) located under the main takeoff route, 2 sites (Sites 5-6) located to the south of the runway. In the surveys from 2014 to 2018, a total of 13 sites (Sites A1 - A13), including 7 sites investigated in the 2009 survey, were selected. Particularly, three new sites A5, A6, A8 located close to the end of the runway of the airport, and two control sites A12 and A13 located in the northeast direction of the airport. The control sites A12 and A13 have almost the same living environment as the other sites, but were assumed to be unaffected by aircraft noise.

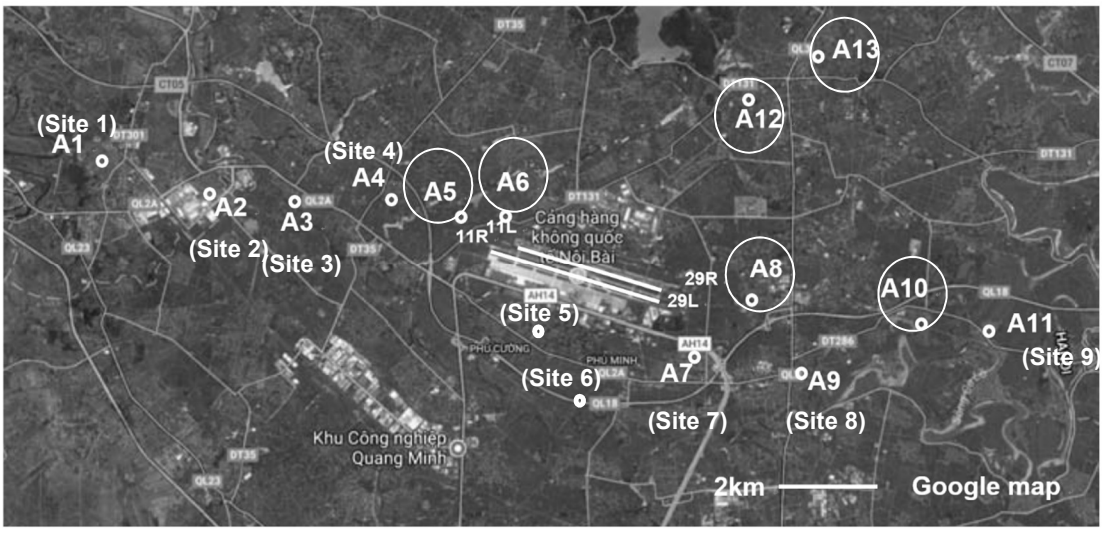



Figure 1. Map of all surveyed sites

( Site－) : Selected sites of 2009 Survey ○ Survey sites added since the 2014 survey

### 2.2 Socio-acoustic and health surveys

In the series of surveys, Vietnamese questionnaires including two standardized annoyance questions recommended by ICBEN (8, 9) were prepared. Community responses in the vicinity of HNBIA were collected by the interview method. The percentage of respondents who were highly annoyed (%HA) was defined as the percentage of respondents who chose 8, 9 or 10 of the 11-point numerical scale (0-10). At the survey since 2014, the percentage of insomnia (% ISM) was defined by the frequency of sleep effects as proposed by the International Institute of Sleep (10) was used as an indicator of sleep effect caused by the flight operation during the night time.

In addition to general annoyance and sleep impacts, exposure to high levels of aircraft noise may adversely affect cardiovascular disease and other health categories (1). Since studies of health effect of aircraft noise has not so far been conducted for residents living near airports in developing countries, in the survey of 2017, data on the health status of residents such as body mass index (BMI) and blood pressure based on self-report were collected to evaluate the health effects of aircraft noise around HNBIA. Furthermore, in the survey in 2018, the blood pressure was measured with a blood pressure meter (OMRON HEM-6324T). Instead of questions about living conditions and the surrounding environment, questions about current health status such as BMI, blood pressure and heart rate were added.

### 2.3 Noise measurement

In the surveys until 2017, day-evening-night noise level ($L_{\mathrm{den}}$) and nighttime equivalent noise level ($L_{\mathrm{night\ (22:00\text{-}6:00)}}$) were estimated from the field measurement of noise levels. Sound level meters (RION NL-42, NL-21, NL-22) were set up on the roof of houses selected at each surveyed site. A-weighted and S-weighted sound pressure levels ($L_{\mathrm{A,S}}$) sampled at 1 s were recorded continuously through 7 days. The noise data of each day for each site was compared with flight logs to identify the aircraft events and then calculate the $L_{\mathrm{den}}$. Since the day, evening and night periods are different between countries, depending on the activity pattern of daily life, in this study, they are defined as the periods from 06:00 to 18:00, from 18:00 to 22:00, and from 22:00 to 06:00, respectively.

### 2.4 Flight operation data and noise estimation

Airport operation data including flight logs and weather conditions were provided by the airport managers. Although HNBIA is in northern Vietnam which has four seasons, the flight operation at HNBIA is categorized into winter (late October to late March) and summer (in the remaining period) schedules. Depending on the weather condition, runway used for landing and taking off might varies. During the surveys conducted in 2014, 2015 and 2017, ADS-B (Automatic Dependent Surveillance-Broadcast) receiver was installed to collect the flight route information. According to the flight logs, the average arrivals and departures a day in HNBIA were counted.

In the survey of 2018, $L_{\mathrm{den}}$ and $L_{\mathrm{night}}$ were estimated from a noise contours map created by using Integrated Noise Model (INM) instead of field measurements. The necessary data for creating the noise map such as flight logs was provided by the Civil Aviation Authority of Vietnam (CAAV). The flight route data were referred to the data of 2017 Survey.

## 3. RESULTS

### 3.1 Increase in number of flights and noise levels

The number of flights operated and passenger number at HNBIA have increased significantly in the past nine years. Table 1 shows the average number of daily flights operated by HNBIA during each survey period. It can be seen that the number of flights observed in 2018 is about three times higher that of 2009 and 1.7 times higher than that of 2014. It could be seen that the number of flights increased sharply after the new terminal building was put into operation and has gradually increased since then. It is worth noting that the most recent number of nighttime flight events increased by 2.5 times and 1.9 times, compared to the September 2014 “before new terminal building opened” survey and the latest “after the opening” survey for September 2015, respectively. Especially, the recent number of flight events at night increased sharply and occupied about one-fifth of the total number of flights.

Table 2 shows the noise levels obtained during each survey period. $L_{\mathrm{den}}$ measured at the sites which were surveyed since 2009 increased from 48 to 61 dB in 2009 and 54 to 66 dB in 2018. Especially, $L_{\mathrm{night\ (22:00\text{-}6:00)}}$ was found to increase about 10 dB higher at Sites A3 and A4. This result is consistent to the sharp increase of the flight movements during the night time at HNBIA

Table 1 – Average numbers of aircraft noise events

| Time period | Operation modes | Surveys | | | | | |
|---|---|---|---|---|---|---|---|
| | | 8/2009 | 9/2014 | 2-3/2015 | 9/2015 | 11/2017 | 8/2018 |
| Day (6:00-18:00) | Arrival | 50 | 84 | 104 | 100 | 125 | 141 |
| | Departure | 51 | 90 | 109 | 107 | 139 | 123 |
| | Total | 101 | 174 | 213 | 207 | 264 | 264 |
| Evening (18:00-22:00) | Arrival | 23 | 32 | 43 | 39 | 48 | 12 |
| | Departure | 14 | 16 | 27 | 22 | 35 | 13 |
| | Total | 38 | 48 | 70 | 61 | 83 | 25 |
| Night (22:00-6:00) | Arrival | 9 | 9 | 16 | 14 | 39 | 77 |
| | Departure | 10 | 21 | 26 | 25 | 37 | 94 |
| | Total | 19 | 30 | 42 | 39 | 76 | 171 |
| All day | Arrival | 82 | 125 | 163 | 153 | 211 | 230 |
| | Departure | 75 | 127 | 162 | 154 | 211 | 230 |
| | Total | 157 | 252 | 325 | 307 | 422 | 460 |

Table 2 – Changes of noise exposure levels: $L_{\text{night (22:00-6:00)}}$ and ($L_{\text{den}}$)

| Site | $L_{\text{den}}$ | | | | | | $L_{\text{night(22:00-6:00)}}$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8/2009 | 9/2014 | 3/2015 | 9/2015 | 11/2017 | 8/2018 | 8/2009 | 9/2014 | 3/2015 | 9/2015 | 11/2017 | 8/2018 |
| A1 | 55 | 55 | 55 | 53 | 55 | 53 | 47 | 45 | 46 | 45 | 47 | 44 |
| A2 | 56 | 55 | 56 | 54 | 54 | 56 | 49 | 45 | 48 | 46 | 47 | 47 |
| A3 | 61 | 62 | 64 | 62 | 62 | 61 | 51 | 53 | 56 | 55 | 54 | 52 |
| A4 | 56 | 54 | 56 | 57 | 63 | 61 | 44 | 46 | 48 | 48 | 55 | 53 |
| A5 | - | 61 | 61 | 68 | 76 | 71 | - | 51 | 53 | 59 | 69 | 63 |
| A6 | - | 65 | 64 | 64 | 53 | 64 | - | 50 | 57 | 56 | 44 | 56 |
| A7 | 57 | 66 | 62 | 62 | 65 | 64 | 48 | 55 | 56 | 55 | 57 | 56 |
| A8 | - | 66 | 66 | 65 | 66 | 66 | - | 58 | 58 | 58 | 59 | 57 |
| A9 | 61 | 63 | 60 | 63 | 65 | 66 | 54 | 55 | 53 | 56 | 58 | 57 |
| A10 | - | 60 | 58 | 59 | 60 | 60 | - | 52 | 52 | 53 | 53 | 50 |
| A11 | 52 | 60 | 57 | 59 | 59 | 58 | 45 | 52 | 50 | 52 | 52 | 49 |
| A12 | - | 45 | 45 | 49 | 38 | 41 | - | 36 | 38 | 39 | 30 | - |
| A13 | - | 47 | 44 | 51 | 38 | 40 | - | 36 | 38 | 44 | 29 | - |

### 3.2 Changes in Residential Factors

In this study, residential factors such as length of residence, total floor area of the house, evaluation on sound insulation, location of the bedroom, air-conditioner installation are considered to be factors related to respondents' reaction to noise. The average data of these factors obtained from the survey sites, including 9 sites of the survey in 2009, and 13 sites of the other surveys are summarized in Table 3. The short length of residence was assumed to increase the respondents' negative reaction to aircraft noise due to insufficient time to adapt to the living environment near the airport. The respondents living in larger houses with good insulation ability, bedroom not facing the road, and air-conditioner

installed were assumed to be less affected by noise than those living in smaller houses, with bad insulation ability, bedroom facing the road, and air-conditioner uninstalled. The survey result shows that more houses were installed air-conditioner after 2015. Within more than 2 years, corresponding to the positive change in the economy, the living amenities of the residents around HNBIA has been improved, including increased use of air conditioners. The percentage of the length of residence that is less than 5 years has decreased in the recent surveys.

Table 3 – Changes of residential factor through the surveys from 2009 to 2018

| Residential factors (%) | 8/2009 | 9/2014 | 3/2015 | 9/2015 | 11/2017 | 8/2018 |
|---|---|---|---|---|---|---|
| Length of residence <=5 years | 12.5 | 14.8 | 10.3 | 11.0 | 8.8 | 6.2 |
| Floor area <=100m$^2$ | 79.2 | 40.6 | 71.4 | 67.7 | 51.1 | - |
| Bad sound insulation | 32.1 | 33.0 | 31.0 | 38.9 | 32.4 | - |
| Bedroom facing road | 30.6 | - | 35.3 | 31.0 | 44.2 | - |
| Air-conditioner uninstalled | - | - | 71.5 | 71.2 | 50.1 | - |

### 3.3 Changes in Sleep Effects and General Annoyance

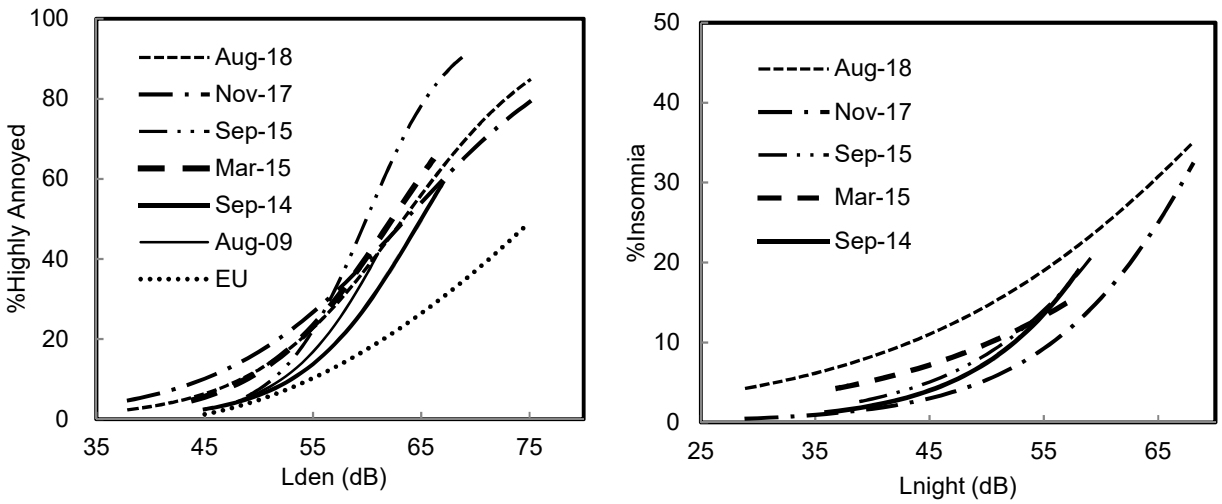
As shown in Table 4, there is a dramatic increase of %ISM at Site A5, which increased from 17% in September 2015 to 43.8% in November 2017. This result is consistent with a 10 dB increase in the nighttime noise level measured at Site A5. However, the same trends were not found with the general annoyance defined by %HA. Despite a slight increase in $L_{\mathrm{den}}$ between 2015 and 2017, %HA decreased at Sites A7 and A9, which located under the take-off path of aircrafts. A decrease in %HA was seen in all sites under the landing path, except for site A3.

Table 4 – Percentage of highly annoyed (%HA) and percentage of insomnia (%ISM)

| | %HA | | | | | | %ISM | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8/2009 | 9/2014 | 3/2015 | 9/2015 | 11/2017 | 8/2018 | 9/2014 | 3/2015 | 9/2015 | 11/2017 | 8/2018 |
| A1 | 6.5 | 8.2 | 5.7 | 2.0 | 0.0 | 20.0 | 1.4 | 1.1 | 0.0 | 0.0 | 20.0 |
| A2 | 11.5 | 9.1 | 35.8 | 28.9 | 14.3 | 20.0 | 0.0 | 6.9 | 3.1 | 4.2 | 20.0 |
| A3 | 57.0 | 59.1 | 71.1 | 65.3 | 95.7 | 60.0 | 17.0 | 20.2 | 21.9 | 2.2 | 22.2 |
| A4 | 68.4 | 48.2 | 83.3 | 92.0 | 77.8 | 60.0 | 17.5 | 26.5 | 22.4 | 19.1 | 20.0 |
| A5 | - | 47.7 | 73.9 | 96.0 | 91.7 | 90.0 | 8.9 | 33.7 | 17.0 | 43.8 | 40.0 |
| A6 | - | 70.8 | 63.8 | 84.0 | 83.0 | 60.0 | 4.6 | 7.5 | 20.0 | 17.0 | 10.0 |
| A7 | 8.3 | 44.1 | 12.4 | 60.6 | 10.4 | 20.0 | 5.4 | 17.5 | 9.0 | 0.0 | 10.0 |
| A8 | - | 58.2 | 55.1 | 68.5 | 33.3 | 80.0 | 33.3 | 1.0 | 7.4 | 8.3 | 10.0 |
| A9 | 20.0 | 28.4 | 37.8 | 56.0 | 53.2 | 10.0 | 6.7 | 5.6 | 24.0 | 10.6 | 10.0 |
| A10 | - | 10.1 | 10.3 | 28.0 | 34.0 | 0.0 | 6.1 | 5.1 | 12.1 | 10.4 | 10.0 |
| A11 | 4.7 | 9.0 | 5.5 | 11.2 | 12.0 | 40.0 | 0.0 | 4.2 | 5.1 | 0.0 | 30.0 |
| A12 | - | 0.0 | 0.0 | 2.0 | 0.0 | 9.1 | 0.0 | 0.0 | 1.0 | 0.0 | - |
| A13 | - | 0.0 | 0.0 | 3.2 | 0.0 | 0.0 | 6.3 | 1.4 | 1.0 | 0.0 | - |

Figure 2 shows a comparison of (a) $L_{\mathrm{den}}$ - %HA and (b) $L_{\mathrm{night(22:00\text{-}6:00)}}$ - %ISM relationships established by using data obtained from all the surveys. The $L_{\mathrm{den}}$ - %HA relationships of the follow-

up survey in 2017 and 2018, which were conducted about 3 and 4 years after the step-change, are lower than that of the 2015 surveys which were carried out immediately after the change within the range of $L_{den}$ over 60 dB, but higher than the exposure-response relationship established for the 2009 and 2014 surveys and the curved presented in EU position paper (11). In other words, the excess response due to the step change seems to decrease with time, but still remains higher than the reaction before the terminal is completed at the same noise exposure level. However, considering the $L_{night(22:00-6:00)}$ - %ISM relationships, the relationship obtained by the 2017 survey data is lower, while that of the 2018 survey is higher than the relationships obtained in the previous survey. This result indicates that causal structure of insomnia might be different from that of annoyance. This discrepancy should be explained not only by the amount of noise exposure but also by other various non-acoustical factors.




(a) %Highly Annoyed (%HA) (b) %Insomnia (%ISM)

Figure 2 – Comparison of the relationships synthesized from the data of each survey from 2009 to 2018

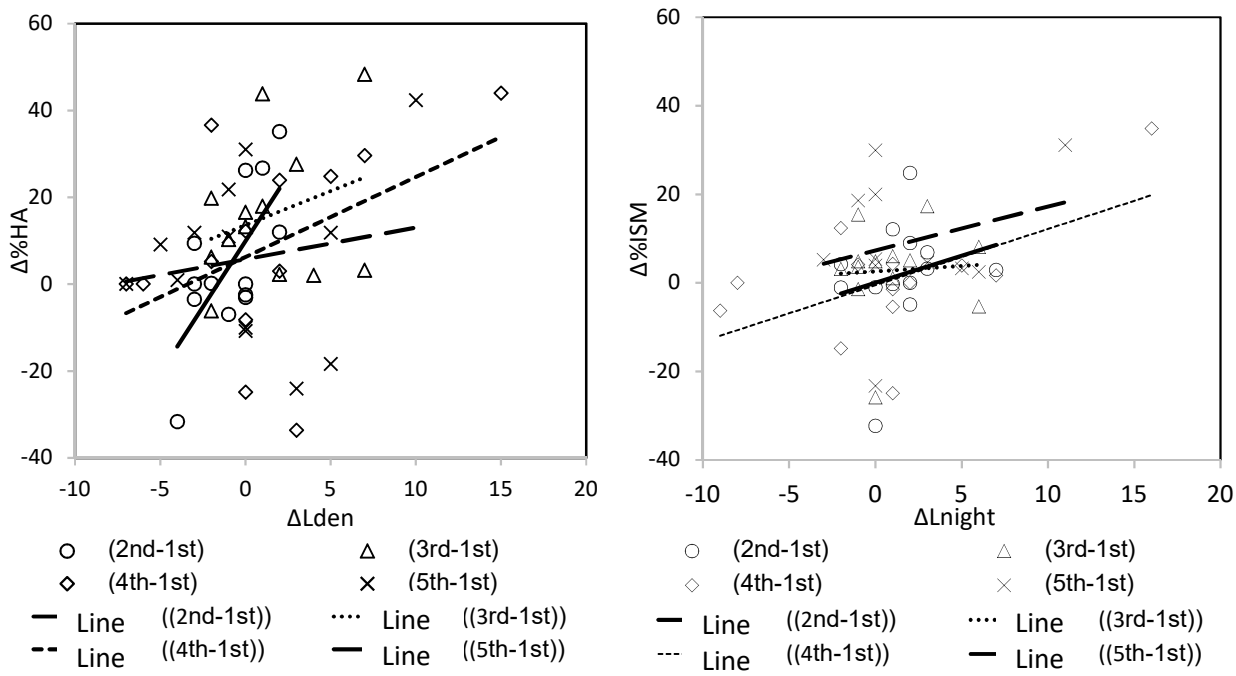



Figure 3 – Comparing relationships between the changes in noise levels and the change in highly annoyance and insomnia ($\triangle L_{den}$ - $\triangle$%HA and $\triangle L_{night(22:00-6:00)}$ - $\triangle$%ISM)

The association between changes in noise levels ($\triangle L_{den}$ and $\triangle L_{night(22:00\text{-}6:00)}$ ) and the change in highly annoyance (△%HA) and insomnia (△%ISM) were compared in Figure 3. The data of the survey conducted in 2014 (1st) was considered as a base of the comparisons. The difference in data of the surveys conducted in Mar 2015, Sep 2015, 2017, and 2018 compared with the data of the 2014 survey were (2nd-1st ), (3rd-1st ), (4th-1st ), (5th-1st ), respectively. Regarding the relationships of $\triangle L_{den}$ and △%HA, the slope of the regression line for the (2nd–1st) Survey is steepest. It could be observed that the slope is decreasing with the recent surveys. Accordingly, the lowest slope is found with the data of the most recent survey compared to the first survey. In other words, the change of annoyance corresponding to the noise level has become less excessive in the follow-up surveys than the survey conducted shortly after the change. This trend could not be seen clearly with the changes in $\triangle L_{night(22:00\text{-}6:00)}$ and △%ISM. A significant association was found between ISM and $L_{night(22:00\text{-}6:00)}$ (Table 6). An increase in noise level due to the increase in the number of flight movements at night has been shown to have an adverse effect on the quality of sleep and the health of residents living near the airport. According to the results of logistic regression analysis shown in Table 5, the residential factors such as sound insulation, location of the bedroom, the use of air-conditioner had significant effect on the rates of annoyance and insomnia.

Table 5 – Multiple logistic regressions for annoyance and insomnia

| **Annoyance** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Term | Estimate | Std Error | ChiSquare | Prob>ChiSq | Odds Ratio | 95% CI Lower | 95% CI Upper |
| Intercept | -11.428 | 0.692 | 273.020 | <.0001 | | | |
| $L_{den}$ | 0.196 | 0.011 | 307.390 | <.0001 | 1.217 | 1.190 | 1.244 |
| Live<5years | 0.373 | 0.173 | 4.650 | 0.031 | 1.452 | 1.035 | 2.037 |
| S<100m$^2$ | -0.185 | 0.108 | 2.920 | 0.088 | 0.831 | 0.672 | 1.028 |
| Sound insulation | -0.828 | 0.101 | 67.120 | <.0001 | 0.437 | 0.358 | 0.533 |
| Bedroom direction | -0.303 | 0.106 | 8.140 | 0.004 | 0.739 | 0.600 | 0.910 |
| Air conditioner | -0.623 | 0.114 | 30.150 | <.0001 | 0.536 | 0.429 | 0.670 |
| **Insomnia** | | | | | | | |
| Intercept | -5.802 | 0.721 | 64.840 | <.0001 | | | |
| $L_{night(22:00\text{-}6:00)}$ | 0.083 | 0.013 | 43.250 | <.0001 | 1.087 | 1.060 | 1.114 |
| Live<5years | 0.162 | 0.246 | 0.440 | 0.509 | 1.176 | 0.726 | 1.906 |
| S<100m$^2$ | 0.020 | 0.147 | 0.020 | 0.892 | 1.020 | 0.765 | 1.361 |
| Sound insulation | -0.514 | 0.136 | 14.270 | <.0001 | 0.598 | 0.458 | 0.781 |
| Bedroom direction | -0.496 | 0.138 | 12.860 | <.0001 | 0.609 | 0.464 | 0.799 |
| Air conditioner | -0.760 | 0.172 | 19.550 | <.0001 | 0.467 | 0.334 | 0.655 |

### 3.4 Health Effects

In this study, hypertension was defined as if the systolic and diastolic blood pressure were higher than 120 and 80 mmHg, respectively. A comparison was made to examine the relationship between $L_{den}$ and % hypertension (Table 6). Comparisons of respondents with high blood pressure at different noise exposure level ranges showed that there is no significant association between ratios of hypertension and noise exposure levels ($L_{den}$).

Table 6 – Comparison of high blood pressure ratios at different noise level ranges of the 2017-2018 surveys

| | | Noise level ranges $L_{den}$ (dB) | | | | | | p value |
|---|---|---|---|---|---|---|---|---|
| | | <50 | 50-55 | 55-60 | 60-65 | 65-70 | >70 | |
| 11/2017 | % | 57 | 47 | 41 | 20 | 71 | 100 | 0.677 |
| | Response number | 21/37 | 27/58 | 9/22 | 5/25 | 5/7 | 12/12 | |
| 8/2018 | % | 55 | 50 | 66.7 | 72.5 | 45 | 70 | 0.681 |
| | Response number | 11/20 | 5/10 | 20/30 | 29/40 | 9/20 | 7/10 | |

## 4. CONCLUSIONS

In this study, it seems that the excess response due to the step-change decreases over time, but the response is still high compared with those obtained before the opening of the new terminal at the end of 2014 at the same noise level. An increase in the number of flights operated at night negatively affects the quality of sleep. It should be considered to protect the living environment in the vicinities around the airports in Vietnam by improving the residence quality and restricting night operation and formulating policy regarding aircraft noise.

## ACKNOWLEDGEMENTS

This study was financially supported by Grant-in-Aid for Research Activity Start-up by Japan Society for Promotion of Science (No. 17H06875). We acknowledge gratefully the staffs of Civil Aviation Authority of Vietnam (CAAV), Noi Bai International Airport (NIA), and all the lecturers and students of National University of Civil Engineering (NUCE) and Hanoi University of Mining and Geology (HUMG) for supporting social survey and noise measurement.

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