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How the residents respond to different changing scenarios of aircraft noise: comparison of two airports in Vietnam

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ABSTRACT

The expansion of air transport infrastructure in developing nations is contributing to adverse environmental change impacts, particularly noise issues. This research examines the applicability of recommendations for stable conditions to changing noise exposure scenarios by analyzing data obtained from a long-term investigation of two airports in Vietnam. The number of flights at Noi Bai Airport (NB) has steadily risen since the opening of a new terminal building in December 2014. Surveys were conducted once before and twice after the opening. Then, to elucidate whether this change effect decreases over time or persists afterward, two follow-up surveys were conducted in 2017 and 2018. In a contrasting scenario, the early 2020 epidemic outbreak resulted in a marked decrease in noise levels near Tan Son Nhat Airport (TSN). We carried out a survey in August 2019 and additional surveys three and six months after the change to compare the community response both before and after the change. The results of the surveys at NB showed that annoyance levels increased following the opening of the new terminal building compared to the pre-completion stage. In the follow-up surveys, even though noise exposure rose, annoyance levels decreased and approached the pre-completion exposure-response relationship. The results in TSN showed an increase in annoyance in 2020 compared to 2019. The patterns found in this study suggest that the impact of noise change includes an overreaction in NB and an underreaction in TSN, which deviates from what was observed in a stable state.

Keywords: Change effect, Aircraft noise, Exposure-response relationship, Annoyance, Community response

INTRODUCTION

In order to protect the health of residents, stricter restrictions on aircraft noise levels have been recommended by WHO [1]. However, there has been much discussion that the new limits did not adequately consider the overall state of affairs, as they included some abnormal conditions such as newly operational airports and areas around airports that have experienced specific incidents [2]. Developing countries such as Vietnam are expanding or constructing new airports, and there is a need to understand how aircraft noise affects residents' annoyance and well-being in these contexts. While some studies have examined the impact of noise exposure in steady-state conditions in developed countries, more research is needed to investigate how people's responses to noise change over time in developing countries. This paper presents findings from surveys conducted from 2008 to 2020 at two major airports in Vietnam: Tan Son Nhat Airport (TSN) in Ho Chi Minh City (HCM) and Noi Bai Airport (NB) in Hanoi (HN).

In 2009, a socio-acoustic survey was conducted to investigate community responses to aircraft noise around Hanoi Noi Bai International Airport (NBIA) in Vietnam [12]. The operation status of NBIA was considered stable around the survey period, but since then, the number of aircraft operations has gradually increased, particularly after the opening of a new terminal building in December 2014. In contrast, located about 1200 km to the south, the Tân Sơn Nhất (TSN) international airport is the largest airport in Vietnam, situated in a densely populated residential area. Aircraft noise exposure around TSN is extremely high in almost all areas. However, due to the COVID-19 pandemic and resulting travel restrictions, there has been a significant decrease in aircraft noise around TSN, resulting in a contrasting scenario to what occurred around NB.

These events enabled a study that compared community responses before and after a significant change in the acoustic environment. Based on data accumulated from long-term investigations at the two airports, this study aims to answer the following questions: (1) whether a change effect occurred with an increase or decrease in aircraft noise exposure, (2) whether noise limits recommended based on exposure-response relationships derived from studies conducted in steady-state conditions are applicable in the changing scenario of Vietnamese airports, and (3) to what extent non-acoustic factors influence the exposure-response relationships developed for these scenarios.

MATERIALS AND METHODS

Survey plan

A new terminal building was completed at NB in December 2014, resulting in an increase in the number of aircraft operations. We compared the survey results before and after the completion of construction to investigate how residents' reactions changed over time. Surveys were conducted once before and twice after the change in operation. Then, to elucidate whether this change effect decreases over time or persists afterward, two follow-up surveys were conducted in 2017 and 2018, approximately three and four years after the step change, respectively.

The first survey at TSN were conducted in 2019, to obtained data to understand the community responses to noise 11 years after the initial survey conducted in 2008 in nearly the same areas. After the epidemic outbreak in early 2020, most international flights to and from TSN were blocked in January and completely shut down in March 2020. Health surveys were conducted three months and six months after the change occurred, and the results were compared with those acquired from the study conducted in August 2019 to clarify the effect of decreased aircraft noise on the health of residents in the vicinity of TSN.

Although these studies examined various noise effects, this paper focuses on the noise annoyance effect.

Survey areas

NB has two parallel runways (11L–29R and 11R–29L) running in an east-west direction. Thirteen survey sites, labeled A1–A13 and shown in Figure 1, were selected around NB. These include six areas situated along the landing path, five under the take-off path, and two control sites located far away to the north. TSN also has two parallel runways (07L–25R and 07R–25L) running in an east-west direction. Figure 2 shows that the survey sites around TSN consist of twelve residential areas, ten sites under the landing and takeoff paths of the aircraft (Sites B1–B10), and the two others at the north of the airport (Sites B11 and B12). All survey areas were selected at varying distances along the runway extension to provide a broad range of aircraft noise exposures around both airports.

Figure 1 Map of the 2014-2018 surveys area around NB airport (A1-A13)

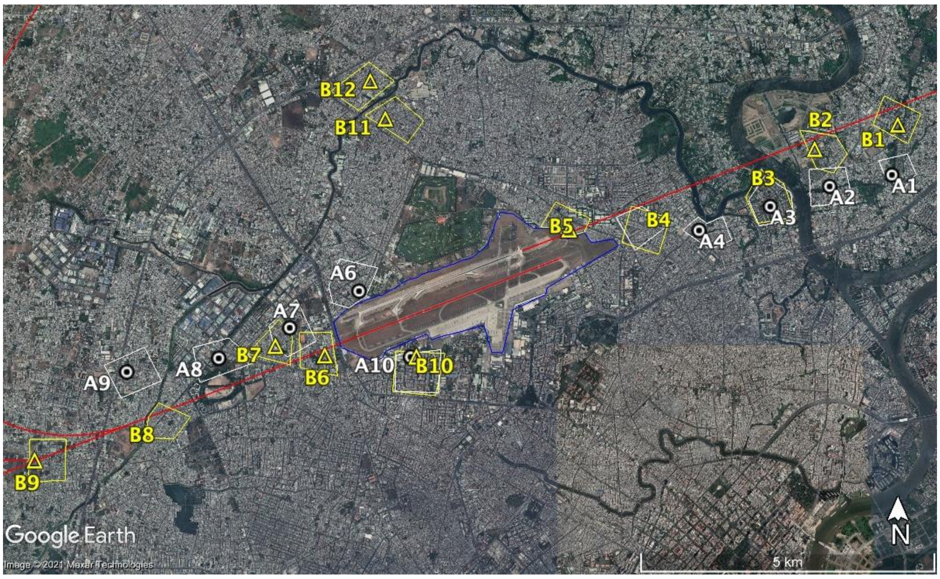

Figure 2 Map of surveyed sites around the TSN airport in 2019 and 2020 surveys (B1–B12)
(Map of surveyed sites in 2008 (A1–A10))

The questionnaire survey was conducted through in-person interviews, where one adult per household was selected as the survey subject. Interviewers visited all residences in the selected study areas over the weekend to collect responses. Previous research has suggested that noise exposure alone does not fully explain the level of annoyance experienced by individuals, as other non-acoustic factors may play a role, such as housing and neighborhood environment, demographic factors of respondents, and personal and environmental conditions [3]. In this study, we investigated the extent to which non-acoustic factors influence the relationship between aircraft noise exposure and social reactions in a residential area near an airport in Vietnam. The questionnaire was prepared in accordance with ISO/TS 15666 [4], with annoyance as the primary measure of noise effect. Table 1 displays the questions and scales used to assess annoyance, with the percentage of respondents who reported high levels of annoyance (%HA) used as the metric for aircraft noise annoyance. %HA was defined as the percentage of respondents who selected 8, 9, or 10 on an 11-point numeric scale (0-10).

Noise exposure data

Prior to 2017, it was not possible to obtain the necessary data to predict noise exposure, including flight paths, runway use, flight operation data, and aircraft performance, which are required to estimate noise exposure levels.

For noise measurements, a sound level meter was placed on the roof of the tallest house in each survey area and set to measure A-weighted $L_{eq, 1sec}$ and $L_{p, 100ms}$ continuously for seven days. The 2008 surveys at TSN and the 2014 and 2015 surveys at NB assigned one exposure level per study area from field measurements. In the 2019 survey at TSN and the 2017 and 2018 surveys at NB, predictions were made using the Integrated Noise Model 7.0 (INM) instead of field measurements, and noise exposures were assigned to each household.

Table 1. The question and scale used to assess annoyance in the surveys.

Question: Thinking about the last 12 months or so, what number from 0 to 10 best shows how much you are bothered, disturbed, or annoyed by aircraft noise? Answer: 11-point numerical scale: from 0 (not annoyed at all) to 10 (extremely annoyed) Evaluation: The percentage of highly annoyed (%HA): defined by the response numbers counted from top thee categories 8, 9, 10

RESULTS

Demographic data of the survey respondents

Table 2 summarizes the demographic data of respondents from all surveys conducted around NB and TSN Airports. There were no significant differences in demographic data between the 'before' and 'after' surveys, except for the proportion of respondents living in the area for less than five years and the proportion of employed respondents in the 2018 NB survey. In all surveys, the proportion of women was slightly higher than that of men, and respondents aged over 60 years accounted for less than 30% of the total number of respondents. These proportions reflect the characteristics of Vietnam's young population [5]. All surveys had high response rates, except for the TSN survey conducted in March 2020, when the city municipality was urging residents to implement social distancing measures to limit the spread of infection. During this survey, many residents who had previously agreed to be interviewed during the "before" survey refused face-to-face interviews. For clarity, the data from the 2019 survey from those who did not continue to participate and the data on the respondents who continued to participate were compared.

Change in the average number of daily flights

The change in the average number of daily flights is presented in Table 3, which displays the average number of daily flights operated by the surveyed airports during each survey period. The total number of flights observed per day during the investigation period was consistent with the changes in operations at the two airports. The number of flights increased sharply after the new terminal building was put into operation in NB and has gradually increased since then. The number of flights observed in 2018 was about 1.8 times more than that in 2014 and 1.5 times more than that in 2015. Notably, the number of flight events at night has increased sharply, occupying about two-fifths of the total number of flights. This increase in nighttime flights is due to the rapid growth of low-cost carriers, which prefer to operate during the nighttime (22:00–6:00) to save costs. In contrast, the number of flights observed in TSN during the 1st survey in August 2019 dropped from 728 to 413, as observed in the 2nd survey following the decision to stop international flights in March 2020. The number of flights decreased to 299 in the 3rd survey as the travel ban was extended to domestic passengers due to the re-emergence of the pandemic in July 2020.

Table 2. Demographic characteristics of the survey respondents, including age, gender, length of residence, and occupation

NB surveys							
		Sep 2014	Mar 2015	Sep 2015	Nov 2017	Aug 2018	Vietnam Census (2018)*
Number of respondents		890	1109	1286	623	132	
Response rate (%)		68.5	85.3	98.8	95.8	83.3	
Gender	Male	54.1	52.4	49.4	47.7	40.9	49.5
	Female	45.9	47.6	50.6	52.3	59.1	50.5
Age	20–50 years	82.2	84.3	84.7	75.5	71.2	88.6
	≥60 years	17.8	15.7	15.3	24.5	28.8	11.4
Length of residence	Under 5 years	15.5	10.1	10.7	9.0	6.4	
	5 years or more	84.5	89.9	89.3	91.0	93.6	
Occupation	Employment	53.5	60.3	60.4	51.4	75.0	56.5
	Student, housewife, retired, unemployed	46.5	39.7	39.6	48.6	25.0	43.5
TSN surveys							
		2019	2020 June	2020 Sep			Vietnam Census (2019)*
Number of respondents		502	145	519			
Response rate (%)		60.3	28.9	68.6			
Sex	Male	46.2	46.5	49.2			49.9
	Female	53.8	53.5	50.8			50.1
Age	<60 years old	81.9	70.6	89.9			88.1
	≥60 years old	18.1	29.4	10.1			11.9
Length of residence	0-5 years	51.1	27.7	40.0			
	Above 5 years	48.9	72.3	60.0			
Occupation	Employed	53.6	37.4	40.0			55.5
	Student, housewife, retired, unemployed	46.4	62.6	60.0			44.5

(*): Adapted with permission from ref. [5]. 2019 Copyright by General Statistics Office of Vietnam

Table 3: Average number of flights observed per day during the investigation periods of all surveys

	NB					TSN		
	2014	2015-Mar	2015-Sep	2017	2018	2019	2020-Jun	2020-Sep
Day (6–18)	174	213	207	255	264	458	306	207
Evening (18–22)	48	70	61	82	25	137	68	55
Night (22–6)	30	42	39	74	171	133	39	37
All day	252	325	307	411	460	728	413	299

Relationship between exposure and annoyance

Brown and van Kamp defined the effects of noise exposure in steady-state conditions as the "exposure effect" and the additional effects caused by a change in noise exposure as the

"change effect" [6]. An "excess response" is the state in which the response to an increase or decrease in noise exposure results in a corresponding increase or decrease in the response compared to the response in the steady-state condition. The opposite is known as "under response." In this paper, we use these terms to describe the findings of our research.
The average day–evening–night weighted sound pressure levels (L_{den}) and the percentage of respondents who reported high levels of annoyance (%HA) estimated for all surveys, as listed in Tables 4 and 5, show that noise changed proportionally with the fluctuation in the number of flights. While the noise level in NB increased over time, annoyance did not increase monotonically (Table 4). Despite a slight increase in L_{den} between 2015 and 2017, %HA decreased at Sites A7 and A8, which are located under the take-off path of aircraft. Among the sites under the landing path, %HA increased remarkably at Site A3 from 65% in 2017 to 96% in the 2018 survey, then decreased to 60% in the 2018 survey. The highest %HA in the 2018 survey was found at the two sites with the highest L_{den}, Sites A5 (90%) and A8 (80%). In TSN surveys, as listed in Table 5, compared to the sound levels measured in the 2019 survey, the surveys conducted during the pandemic in 2020 showed a significant decrease in noise exposure.

Table 4: Percentage of highly annoyed (%HA) and average noise level (L_{den}) at each surveyed site of NB airport

	2014-Sep		2015-Mar		2015-Sep		2017-Nov		2018-Aug	
	%HA	L_{den}	%HA	L_{den}	%HA	L_{den}	%HA	L_{den}	%HA	L_{den}
A1	8	55	6	55	2	53	0	53	20	55
A2	9	55	36	56	29	54	14	56	20	58
A3	59	62	71	64	65	62	96	60	60	62
A4	48	54	83	56	92	57	78	61	60	63
A5	48	61	74	61	96	68	92	71	90	73
A6	71	65	64	64	84	64	83	64	60	65
A7	44	66	12	62	61	62	10	64	20	67
A8	58	66	55	66	69	65	33	65	80	67
A9	28	63	38	60	56	63	53	65	10	66
A10	10	60	10	58	28	59	34	58	0	60
A11	9	60	6	57	11	59	12	57	40	59
A12	0	45	0	45	2	49	0	42	9	44
A13	0	47	0	44	3	51	0	42	0	44

Table 5: Percentage of highly annoyed (%HA) and average noise level (L_{den}) at each surveyed site of TSN airport

Site	2019-Aug		2020-Jun		2020-Sep	
	%HA	L_{den}	%HA	L_{den}	%HA	L_{den}
B1	0	64	5	59	0	64
B2	7	65	0	53	7	65
B3	0	66	7	55	0	66
B4	2	63	9	57	2	63
B5	3	81	52	71	3	81
B6	18	74	49	64	18	74
B7	13	70	34	66	13	70
B8	6	66	11	62	6	66
B9	0	64	3	62	0	64
B10	2	67	1	60	2	67
B11	0	47	0	62	73	62
B12	0	45	0	59	0	60

Logistic regression analysis was used to determine the exposure-response relationship for each survey. Figure 3(a) compares the relationship between L_{den} –%HA using data obtained from all the surveys conducted in HN. The number of aircraft operations gradually increased after the opening of a new terminal building in December 2014. Step-change surveys were conducted once before and twice after the change, and a significant change effect was observed with respect to annoyance. It has been suggested in other studies that the reaction to noise shortly and long after the step change in noise exposure may differ [7,8]. The change effect was observed immediately after the step change occurred, as seen in the results of surveys conducted in NBIA. The L_{den} –%HA relationships of the follow-up surveys in 2017 and 2018, conducted about 3 and 4 years after the step change, were lower than those of the 2015 surveys carried out 3 and 8 months after the change. The exposure-response relationship established in the 2018 follow-up study was closer to that established in the survey before the change but significantly higher than that in the European Union Position paper [9]. In other words, the effect of the step change appears to decline over time, and the 2018 follow-up exposure-response relationship is close to that of the pre-change situation.

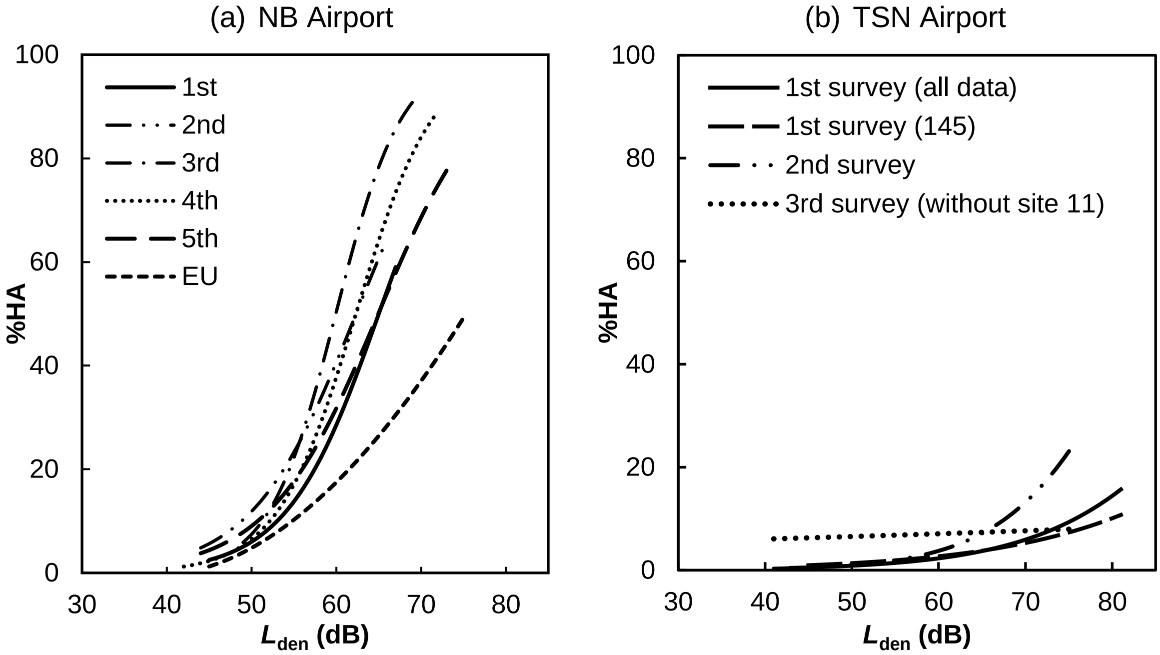

Figure 3. Comparison of the L_{den} –% HA relationships synthesized from the data of each survey: (a) NB Airport; (b) TSN Airport

Figure 3(b) shows a comparison of the L_{den} –%HA relationships for the three surveys conducted in TSN. It can be observed that the relationship established by the data of 502 people (all participants) and that of 145 people who continued to participate in the next survey of the 2019 survey are not significantly different. At the same noise level, the percentage of people having a negative reaction is higher in the 2nd survey, but this percentage is reduced dramatically in the 2020-Sep survey. The exposure-response relationship in the September 2020 survey is lower than in the June 2020 survey, but it remains higher than in the 2019 survey, regardless of the continuous decrease of noise exposure during the pandemic. In other words, an "under response" occurred with the reduction of aircraft noise exposure around TSN shortly after the change, but it eased six months later. This result demonstrates that noise limits recommended based on the exposure-response relationship derived from the studies conducted in steady-state conditions may not be applicable in the scenario of increased or decreased exposure around TSN.

It can be said that the noise reduction at TSN airport did not cause an excess response, but rather an under response at the time of the 2nd survey. The cause of this under response is assumed to be the decrease in road traffic noise levels during the lockdown period. Low background noise levels may result in aircraft noise events being noticeable and more

annoying even though the numbers of events decreased. The relationship of the 3rd survey was located closer to the relationship of the 1st survey, indicating that the under response was eased in the 3rd survey. This finding also supports the hypothesis that change effects are usually strong shortly after the step change but become less significant over time.
The results of this study are in agreement with recent investigations based on meta-analysis, which found that step changes in traffic noise cause an excess response. The findings from the changing scenarios of the two airports in Vietnam indicate that the WHO-recommended limit values need to be corrected for application in cases of ongoing change. The exposure-response relationship for surveys conducted in HCM is lower than that established by WHO guidelines. On the other hand, the relationships obtained from all surveys in HN are higher than those in the EU. This suggests that annoyance is affected not only by noise exposure but also by non-acoustic factors such as regional characteristics.

Effects of non-acoustic factors

It is widely acknowledged that noise exposure is not the only factor affecting annoyance and disturbance responses [10-11]. Other variables, such as housing, neighborhood environment, sociodemographic factors, and personal and environmental contexts, were found to moderate the community's response to noise, particularly with respect to annoyance and insomnia [9,10]. Recent research (2017-2021) has reported a significant variance in the level of annoyance at a given sound level, indicating that general exposure-response functions may not be applicable to local situations [12]. Thus, tailored exposure-response information specific to local communities would be more helpful for noise interventions aiming to minimize noise health effects, including annoyance. Therefore, it is necessary to analyze socio-acoustic survey data considering acoustic and non-acoustic factors that contribute to local and global noise annoyance. In this study, we analyzed the interactive effects of acoustic and non-acoustic variables on noise annoyance under the significant change in aircraft noise in Vietnam by multiple regression analysis, focusing on the perception of the sound environment by Vietnamese residents in two different regions.

The non-acoustic factors of respondents collected in surveys in HCM and HN include residential environment, personal, and attitude factors, all of which are assumed to influence the response to aircraft noise. Multiple logistic regression models were constructed using only non-acoustic factors that significantly affected annoyance. Considering the effects of non-acoustic factors, we examined how the relationship between noise exposure and resident response changes. This analysis was adjusted for other non-acoustic factors and aimed to establish a correlation between L_{den} and %HA. All statistical analyses were performed using JMP 13.0.

1) <u>HN surveys</u>

The noise exposure change was represented by the difference in noise levels between the after–change surveys and those measured in the first survey (before the change), ΔL_{den}, in form of dummy variables. In particular, regarding analysis for annoyance and L_{den} association, four dummy variables were created by combining the survey year and the change in the noise levels. For example, $\Delta L_{den} \leq 0$, 2nd & 3rd: Among the respondents that participated in the 2nd and 3rd surveys, the value of 1 was given to those who lived in the area such that L_{den} was similar to or lower than that of the 1st survey, and otherwise 0.
Based on the analysis results shown in Table 6, personal and living environment factors such as noise sensitivity, duration of residence, and sound insulation ratings significantly affected annoyance. The interaction of noise sensitivity and noise exposure (noise sensitivity * L_{den}) also significantly affected annoyance. The coefficient of interaction between L_{den} and noise sensitivity is negative, indicating that increasing noise exposure reduces the effect of noise sensitivity. The L_{den}–%HA relationship was significantly affected by the categories of ΔL_{den}, except for those between the 4th and 5th surveys. This indicates an excess response when $\Delta L_{den}>0$ and an under response when $\Delta L_{den}\leq 0$. The NB results are in partial agreement with the results of the Amsterdam Schiphol Airport study by Breugelmans et al. [13], which showed

that noise annoyance overreaction gradually decreased within 2 years. This suggests that overreaction to changes in noise levels asymptotically approaches the state before changes in exposure after several years. Future WHO guidelines require clear classification criteria for the effects of changes in aircraft noise.

Table-6**:** Multiple logistic regression for annoyance of surveys in HN (Generalized R^2: 0.1516; AUC: 0.747).

Item	Category	Estimate	Std Error	*p*-Value	Odds Ratio
Annoyance					
Intercept		−18.008	1.227	<0001	
L_{den} [a]		0.260	0.020	<0001	1.297
ΔL_{den} [b]	1st Survey				1
	$\Delta L_{den} \leq 0$, 2nd & 3rd	0.563	0.140	0.0001	1.757
	$\Delta L_{den} > 0$, 2nd & 3rd	2.206	0.191	<0001	9.079
	$\Delta L_{den} \leq 0$, 4th & 5th	0.267	0.226	0.2362	1.307
	$\Delta L_{den} > 0$, 4th & 5th	1.331	0.306	<0001	3.785
Sex	Male				1
	Female	0.153	0.100	0.1283	1.165
Age	≤ 60 years				1
	> 60 years	−0.055	0.137	0.6887	0.947
Noise sensitivity	Not sensitive				1
	Sensitive	2.065	0.119	<0001	7.883
Noise sensitivity * L_{den}		−0.096	0.025	0.0001	
Length of residence	>5 years				1
	≤ 5years	−0.446	0.169	0.0083	0.640
Floor area	> 100 m^2				1
	≤ 100 m^2	−0.044	0.108	0.6831	0.957
Sound insulation	Good				1
	Not good	0.367	0.104	0.0004	1.443

2) HCM surveys

Multiple logistic regression analysis was performed using data from the 2019 and 2020 surveys in HCM to verify whether the response of Ho Chi Minh residents to noise was affected by the change before and after the step change and whether it was influenced by any non-acoustic factors. Only the data from the survey conducted in September 2020 was included in the analysis to ensure a comparable number of responses with the 2019 survey, as the number of responses in March 2020 was too small. Additional study factors were added to examine whether there was a change in population response over time with changing exposure. The survey factor, represented by the dummy variable with a value of 0 for the 2019 survey and 1 for the 2020 survey, was used to indicate the differences between the two surveys. First, all variables and study factors were analyzed using multiple logistic regression analysis. Then, the analysis was performed using only variables that significantly affected the prevalence of annoyance in the surveys. The analytical results are shown in Table 7.

Several non-acoustic factors were investigated, including short residence length, negative home views, large floor area, and stressful situations. These factors were found to be significantly associated with an increase in the prevalence of annoyance. Additionally, a survey factor was included in the analysis as a dummy variable representing the differences between the 2019 and 2020 surveys. The survey factor had a significant effect on the prevalence of annoyance at a level of <0.05. Interestingly, despite a considerable decrease in noise levels from the 2019 survey, the prevalence of highly annoyed individuals in the 2020 survey was significantly higher. The variable representing the interaction of noise exposure and survey factor, ΔL_{den} x survey factor, significantly affected annoyance at a level of <0.01. Notably, the coefficient of the interaction between L_{den} and the survey factor was negative, indicating that the effect of the survey factor decreased as noise exposure increased, and vice versa.

Table 7. Multiple logistic regression for annoyance of surveys in HCM (Generalized R^2: 0.1531; AUC: 0.771).

Item	Category	Estimate	Std Error	*p*-Value	Odds Ratio
Intercept		-10.658	2.675	<.0001	
L_{den}[a]		0.109	0.039	0.0048	1.115[b]
Survey factor	1st survey				1
	3rd survey	1.087	0.451	0.0159	2.966
L_{den}[a] x Survey factor		-0.161	0.055	0.0037	
Residence length	>5 years				1
	≤5 years	0.920	0.382	0.016	2.509
View from home	Good				1
	Bad	1.521	0.450	0.0007	4.579
Floor area	>50 m^2				1
	≤50 m^2	-1.063	0.403	0.0084	0.345
Stress	Not stressful				1
	Stressful	1.261	0.534	0.0182	3.528

[a] Day-evening-night-weighted sound pressure level. [b] Odds ratio in 1 dB change.

DISCUSSION AND CONCLUSION

In this paper, we compare the data from eight aircraft noise surveys that consider changes in noise annoyance through two scenarios of noise exposure change: when noise levels increased (NB) and decreased (TSN), respectively. We summarize the results of socio-acoustic surveys conducted over five years (2014-2018) around NBIA to assess the effects of changes in operational and residential factors on public health and reactions in the vicinity of the airport. We find that non-acoustic factors such as noise sensitivity and survey are important factors that moderate annoyance responses. Among the residential factors that influence responses to noise at NB airport, the assessment of sound insulation and duration of occupancy significantly affect annoyance. The 2017 and 2018 surveys found that more homes had improved sound insulation, and the proportion of residences of less than five years decreased. Changes in these residential factors reduce the adverse effects of increased exposure and reduce overreaction.

This result differs from Fields' findings [3], which stated that adaptation to resident noise does not occur with increasing years of residence. In tandem with the change in air transport, there has been a drastic change in Vietnam's economy and urbanization in recent years, leading to changes in the housing conditions of the Vietnamese people, including those living around NBIA. Noise annoyance varies among factors other than noise exposure, such as housing, neighborhood environment, socio-demographic variables, and personal as well as environmental contexts. This study suggests that the effect of noise change should be investigated using both acoustic and non-acoustic variables. The outcomes of this study are expected to contribute to the establishment of appropriate noise policies for improving the living environment around airports in developing countries.

For the scenario of noise decrease, we compare the data from three aircraft noise surveys considering changes in noise annoyance before and after aircraft noise emissions decreased due to travel restrictions at twelve residential areas around TSN. We find that annoyance was not reduced but significantly increased in the survey conducted three months after the change and returned closer to the state before the change. In other words, an "under-response" occurred with the decrease in aircraft noise exposure around TSN shortly after the change but eased six months later. This result demonstrates that noise limits recommended based on the exposure-response relationship derived from studies conducted in steady-state conditions may not be applicable in the scenario of decreased exposure around TSN. View from home, residence length, floor area, and stress are non-acoustic factors found to moderate annoyance response. The exposure-response relationship observed in the third survey was found to be lower than in the second survey. However, it still remained higher than that observed in the first survey, despite the continuous decrease in noise exposure during the pandemic. This suggests that there may have been an under-response to the changes in the living conditions of people around TSN. Further surveys will need to be conducted in the future to confirm if this response in HCM returns to the levels observed before the pandemic.

According to a survey conducted near Noi Bai Airport, annoyance levels increased after the completion of the new terminal building compared to before. However, in a follow-up survey, even though noise exposure increased, annoyance decreased and approached the pre-completion exposure-response relationship. Noise sensitivity is an important factor that influences annoyance among residents near Noi Bai Airport. Our findings suggest that the impact of noise sensitivity can become saturated for respondents living in high-noise exposure areas. This study suggests that simply trying to decrease noise levels might not be effective in mitigating the impact of noise. The social and beneficial relationships between the perceivers and sources of noise should be given more attention, and community awareness should be enhanced.

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