Comparing causal structures of aircraft noise annoyance in Ho Chi Minh City, Hanoi and Da Nang using structural equation analysis

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ABSTRACT

The exposure-response relationship, with which the community response at certain noise levels can be predicted, is a basis for noise policies. However, variations in exposure-response curves have been found among different regions. The various degrees of annoyance at the same noise exposure implied the effects of non-acoustic factors on each community response to noise. To assess the effects of modifying factors and a causal structure of aircraft noise annoyance in Vietnam, structural equation models were developed based on socio-acoustic survey data collected in Hanoi, Ho Chi Minh City, and Da Nang. The sample sizes of 723, 805 and 445 were sufficiently large to estimate the models for Hanoi, Ho Chi Minh City, and Da Nang, respectively. The endogenous variables were selected from the questionnaire items of the social surveys. The model provided good model fit and indicated that sensitivity and satisfaction with living environment, including the quietness of the surrounding environment, preference to the living areas and comfort in the dry season, were the main modifiers of aircraft noise annoyance in the cities. Furthermore, the models showed that dissatisfaction with living environment increased sensitivity of the respondents. The effect of noise exposure on noise annoyance was much stronger in Ho Chi Minh City than the others. Findings of this study suggest some measures to decrease aircraft noise annoyance for urban residents in Vietnam.

INTRODUCTION

Noise policies have been established based on the exposure-response curves. Thus, the prevalence of annoyance can be predicted from noise exposure levels. However, noise annoyance varies through queries on housing, neighborhood environment, interference with daily activities, sensitivity, attitude towards noise source, socio-demographic variables, personal backgrounds and other objective contexts such as living environment and quality. These factors have been proven to modify human noise perception considerably. Therefore, noise annoyance should be investigated not only as the direct effect of noise but also as the indirect effect via various influences by many variables.

Previous studies proposed many theoretical models to explain the human perception of aircraft noise. Taylor (1984) used path analysis to estimate the direct and indirect effects of independent variables on individual annoyance. Taylor pointed out that the strongest indirect effects are for noise exposure ($L_{\mathrm{Aeq,24h}}$) and sensitivity. He showed the importance of personal sensitivity to noise annoyance. Yano et al. (2002) applied path analysis to cross-culturally compare the annoyance structures of road traffic noise among cities in Japan and Sweden. The results suggested that cultural differences and housing types are significant modifiers of road traffic annoyance.

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While path analysis is based on only observed measurement, structural equation modeling (SEM) allows incorporating both unobserved (latent) and observed variables. Therefore SEM is very effective to address studies involving investigation of modifiers of noise annoyance which are often not observed directly such as personal sensitivity, attitude to noise source, etc. Within the context of SEM methodology, such unobserved variables can be linked to ones that are observable and thereby make their measurement possible. Given these advantages, SEM has become a popular methodology for numerous noise studies. For example, in a study investigating structures of noise annoyance caused by railway and road traffic noises, Morihara et al. (2004) applied SEM and pointed out an influence of the distance from noise sources to houses to the reaction structure of railway noise. Personal sensitivity was found to have the strongest effect in both noises. Yokoshima et al. (2006) applied SEM to clarify the structures of noise and vibration annoyance [4]. Kroesen et al. (2008) proposed a theoretical model of aircraft noise annoyance based on the psychological stress theory. This study found insignificant relationships of noise sensitivity and fear of noise source with other variables in the model and relatively small size of total effect of noise exposure on noise annoyance. Pedersen and Larsman (2008) investigated the influence of visual attitude on noise annoyance by using structural equation modeling. This study found that negative visual attitude towards the noise source increased the risk for noise annoyance.

In previous studies, we proposed representative exposure-response relationships for aircraft noise annoyance in Ho Chi Minh City, Hanoi, and Da Nang, and then we produced a single curve based on the combined dataset of the three Vietnamese cities and compared it with the curve in the European Union position paper (Nguyen et al. 2013). We found that aircraft noise annoyance is slightly higher in Vietnam than in the E.U. However, we also found significant differences within Vietnam. Ho Chi Minh City and Da Nang's curves are much lower than Hanoi's. The scatter of data points around the exposure-response curves implied the influence of non-acoustic factors on annoyance among cities. In addition, the variation of the exposure-response curves implied the difference in causal structures of noise annoyance among the three cities. In order to establish policies and to perform appropriate noise countermeasures for the communities, it is essential to understand the variations in the responses among communities. Results from some previous studies implied that discrepancies could occur between different geographic regions like the north and the south of the same country. This study aims to find the causal structures of aircraft noise annoyance to explain the differences in noise annoyance among the cities in Vietnam by applying SEM.

METHODS

The conceptual SEM model was proposed by linking the questionnaire items of the socio-acoustic surveys on aircraft noise annoyance conducted in residential areas around three airports in Ho Chi Minh City (2008), Hanoi (2009), Da Nang (2011) (Table 1). The surveys were conducted by face-to-face interviews during the daytime on weekends. The questionnaire was not only on noise but also various components of the living environment. Aircraft noise exposure was measured every 1 s for seven successive days by using sound level meters. The sample sizes of 723, 805 and 445 were sufficiently large to estimate the models for Hanoi, Ho Chi Minh City, and Da Nang, respectively. The variety in culture, geography, climate, history and economy serves to delineate the three cities from each other. These differences were assumed to be reflected in the noise perception of the respondents in the three cities. Therefore, all the variables were included into the structural equation model. The following

endogenous variables were selected from the questionnaire items of the social surveys: coping ability, attitude to the transportation modes, seasonal comfort, satisfaction with the surrounding environment, and personal sensitivity. Each latent variable was measured by a group of data which indicates the same concern on a correspondent issue represented by that variable. Coping capacity included the ability to open windows in each season and window directions of the living room and bedroom of the house. Attitude to the aircraft included safety of airplanes, their value to society and frequency of use.

The relations among variables were developed by referring to the following hypotheses:

(1) Latent variables directly and indirectly modify noise annoyance.
(2) Aircraft noise exposure directly and indirectly modifies noise annoyance through activity interference.

Table 1: Questionnaire items of the surveys

Q1-Q6	Housing factors	House type; Length of residence; Area of first floor; Comments on quality of housing
Q7, Q8	Residential environment	Climate in the area; Quality of residential environment, etc.
Q9-Q17	Annoyance	From traffic noise, From air pollution; From neighbor; Frequency of annoyance; Annoyance at specific time and seasons; Annoyance due to vibration caused by traffic, etc.
Q18	Interference with daily activities	Disturbance while listening, sleeping, resting, talking, gardening, etc.
Q19-Q27	Sensitivities, attitudes, etc.	Sleeping with open window in certain seasons; Time to go to bed and get up on weekends and weekdays; Sleep quality; Sensitivity to weather and environmental factors; Attitudes to the use of transportation vehicles; Frequency of use; Comments on safety, etc.
Q28-Q33	Socio-demographic variables	Occupation; Period to stay at home; Number of family members, Age, etc.
F1	Gender of respondents	
F2-F8	Structural details of the house	Main structure; Number of window panes; Types of window and door frames in living rooms and bedrooms; Whether doors and windows face the road or not, etc.

RESULTS

The model tests

The model test and parameter estimates are based on the covariance matrix and maximum likelihood estimation.

(1) The full model was estimated with the dataset of Ho Chi Minh City, Hanoi and Da Nang.
The first priority was made to achieve a common model that fits well to the data sets of the three cities.

(2) The constructed common model was fitted to the combined dataset of each city.

The process to revise the model by adding and removing the variables was done with the following modifications:

- Climate and environmental comfort were combined considering the correlation between indicators of the two variables. The name was changed to satisfaction with living environment.
- The coping variable was removed because it has no significant relation to a key variable, noise annoyance.
- To simplify the model, the three measuring variables which have the highest regression weights were selected.

- The procedure to remove insignificant paths from the models was done by deleting the path having the highest p value in a regression weights table. After one path was removed, the model was re-calculated to check if there is any insignificant path and the next one to be removed was selected. This procedure was repeated until all the paths in the model were significant.
- The attitude variable was removed from the model of Hanoi because there is no significant path link to it.
- When considering the standardized total effects of each variable on noise annoyance in the models of Ho Chi Minh City and Da Nang, the effect of Attitude is negative while those of the others are positive in the Ho Chi Minh City model and vice versa in the Da Nang model. This suggests that Attitude variable was not matched with other variables in the models and therefore was removed from the models.

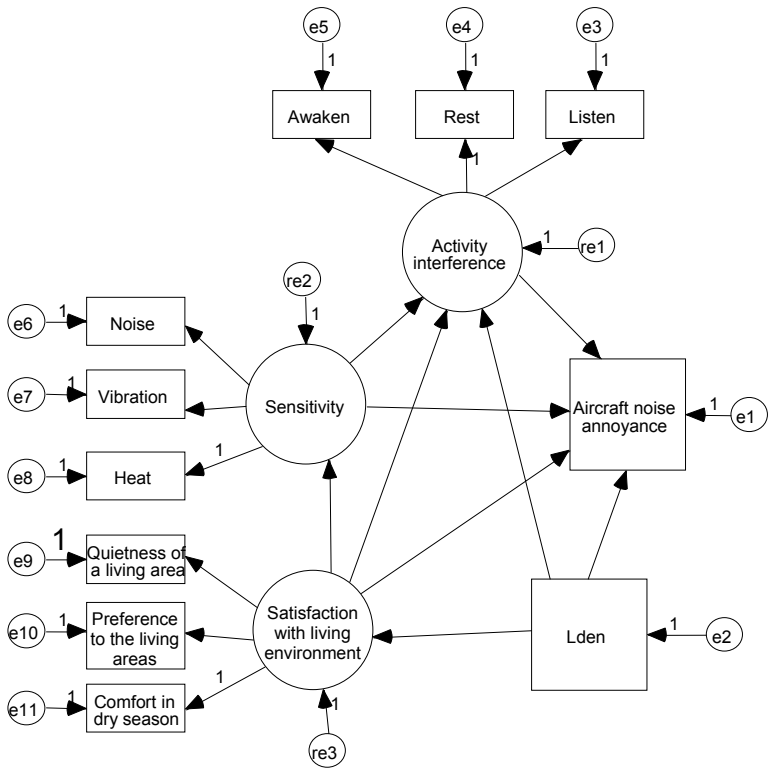


Figure 1: The revised model

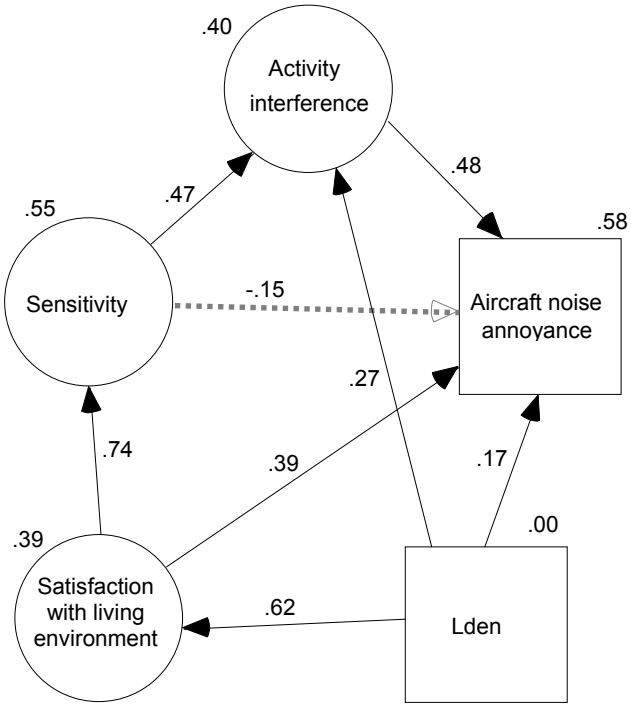
The final structural model

As presented in Figure 1, the final structural model included three latent factors indicated by the three circles labeled activity interference, sensitivity, and satisfaction with living environment. Each factor is measured by three observed variables. Sensitivity to noise, vibration and heat are determinants of personal sensitivity. Activity interference was measured by awakening in the sleep, rest and listening disturbance. Evaluations on quietness of living areas, preference to the living areas and comfort in the dry season are loaded in satisfaction with living environment.

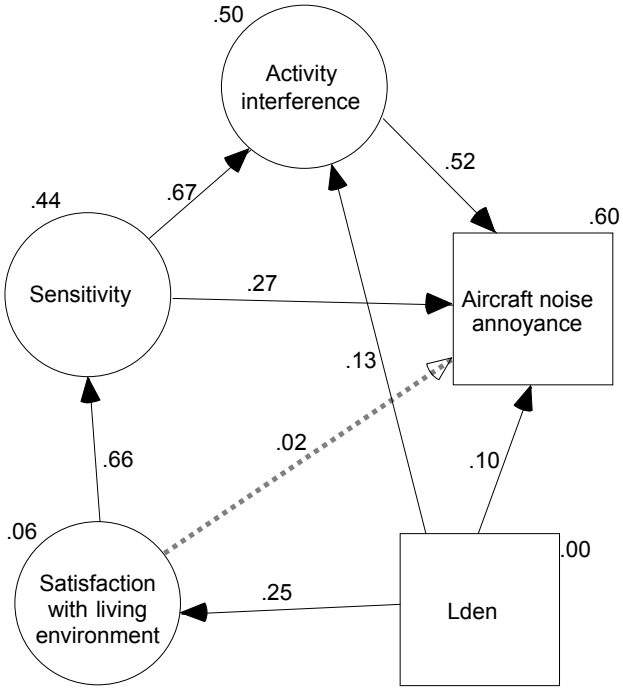
The structural component of this model represents the following hypotheses:

- Aircraft noise annoyance is directly influenced by noise exposure (L_{den}) and the three latent factors.
- Sensitivity directly influences aircraft noise annoyance as well as indirectly via activity interference.

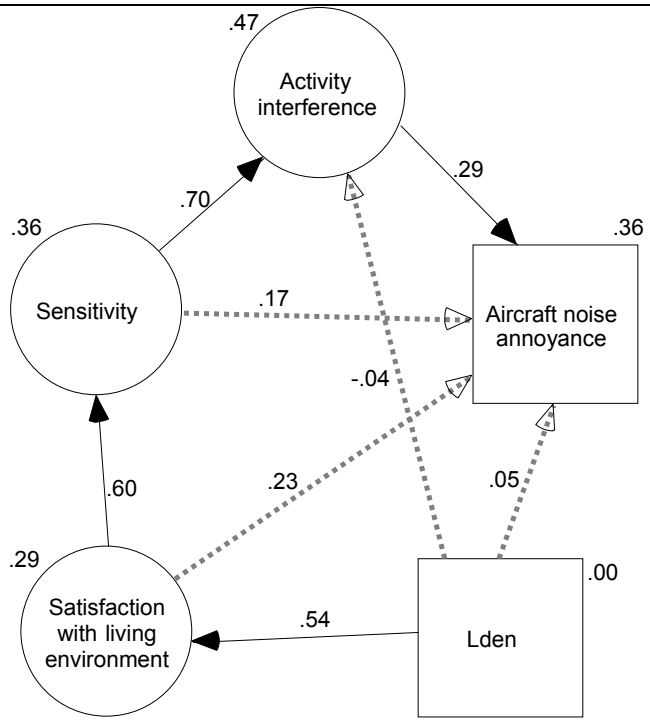
- Satisfaction directly influences aircraft noise annoyance as well as indirectly via sensitivity.
- The effect of noise exposure on annoyance is mediated by the satisfaction with living environment. In addition, aircraft noise exposure directly influences activity interference.



(a) Ho Chi Minh City



(b) Hanoi



(c) Da Nang

Figure 2: The estimated aircraft noise annoyance model
n=805（Ho Chi Minh City）, 723 (Hanoi), 445 (Da Nang), X^2 = 557.7, p=0.000, Df=114, GFI=0.95, CFI= 0.94, and RMSEA=0.044.
Statistically significant paths and standardized regression weights are annotated with (p<0.01). Non-significant paths are represented with dashed lines and are not annotated.
Explained variances are annotated above each variable.

Figure 2 presents the final models for aircraft annoyance in the three cities. The chi-square value is statistically significant (X^2 = 557.7, p=0.000). This means that the implied covariance matrix is significantly associated with the observed covariance matrix. The values for the goodness-of-fit index (GFI) and the comparative fit index (CFI) are well above the recommended lower limit of 0.90. The root mean square error of approximation (RMSEA) has a value below the recommended upper limit of 0.05. These results suggest a good model fit. The standardized regression weight annotated for each path in the models indicates the relative importance of each path and the effect size of determinant factor on the factor at the arrow-shaped end. In order to assess the direct and indirect effect of each variables on the key variable, noise annoyance, standardized direct and indirect effect are presented in Table 2.

The significant direct modifiers of aircraft noise annoyance in Ho Chi Minh City are activity interference, satisfaction and noise exposure level. Those in Hanoi are activity interference, sensitivity and noise exposure level. The only significant direct modifier of annoyance in Da Nang is activity interference. Noise exposure has both a direct and an indirect effect on noise annoyance in Hanoi and Ho Chi Minh City. The direct effect size is small in both Ho Chi Minh City (0.17) and Hanoi (0.1). The indirect effect is stronger in Ho Chi Minh City (0.4) than in Hanoi (0.17). Noise annoyance in Da Nang was not directly but indirectly influenced by noise exposure via satisfaction, sensitivity and activity interference.

The high regression estimate which were found for the path from the activity interference to aircraft noise annoyance is logically plausible because the judgment of a

respondent on their annoyance can be a combination of their entire activity disturbance. It is suggested that activity interference can be representative index of noise annoyance. Standardized direct and indirect effects of each variable on activity interference presented in Table 3 indicate the direct effect size of L_{den} on activity interference is considerably smaller than that of sensitivity.

Table 2: Standardized total (direct/indirect) effects of each variable on aircraft noise annoyance among the cities

	L_{den}	Satisfaction	Sensitivity	Activity interference
HCM	0.567 (0.165/0.402)	0.485 (0.388/0.054)	0.032 (- /0.222)	0.439 (0.477/ -)
Hanoi	0.273 (0.101/0.173)	0.403 (- /0.41)	0.682 (0.271/0.348)	0.51 (0.516/ -)
Da Nang	0.28 (-/0.235)	0.491 (- /0.223)	0.341 (- /0.204)	0.274 (0.293/ -)

Table 3: Standardized direct and indirect effects of each variable on activity interference

	L_{den}	Satisfaction	sensitivity
HCM	0.483 (0.2/ 0.283)	0.454 (0.203/0.25)	0.343 (0.343 /0)
Hanoi	0.234 (0.138 /0.096)	0.382 (-0.163 /0.545)	0.794 (0.794 / 0)
Da Nang	0.178 (-0.116/0.294)	0.541 (0.205/ 0.336)	0.586 (0.586 / 0)

Table 4: Output of explained variance of variables (squared multiple correlations) in the models for the three cities

Variables	Hanoi	HCM	Da Nang
Lden	.000	.000	.000
Satisfaction	.062	.389	.290
sensitivity	.438	.549	.355
Activity_interference	.498	.402	.469
Annoyance	.596	.580	.365

The explained variances in noise annoyance are considerably high, 60%, 58%, and 36% for respondents in Hanoi, Ho Chi Minh City and Da Nang, respectively (Table 4). It can be summarized that, excluding the effect of activity interference, aircraft noise annoyance in Hanoi was mainly influenced by sensitivity, while the responses to noise in Ho Chi Minh City were associated with satisfaction with the environment. All these variables had comparable effect sizes on responses in Da Nang and played a role ato mediate between L_{den} and noise annoyance. The proposed model indicated different structures of aircraft noise annoyance in the three cities.

DISCUSSION AND CONCLUSIONS

This study yielded two unexpected results that coping capacity to the situation and attitudinal factors had no significant influence on community annoyance in the three cities in Vietnam. Respondents in Hanoi judged their annoyance associated with their sensitivity while the response to noise in Ho Chi Minh City most related to satisfaction

with the living environment. The respondents in Da Nang judged their aircraft noise annoyance based on the evaluation of their activity interference indirectly influenced by noise through satisfaction and sensitivity. The finding in Hanoi is consistent to Miedema and Vos (1999) which found sensitivity has a large impact on annoyance. Sensitivity is considered one of personal characteristics which are thought to be a result of the individual development of a person. Satisfaction with living environment can be considered as a social characteristic which can be shared by a larger group in the society (Guski 1987). Social characteristics can be used for noise abatement programs while personal characteristics are difficult to use. However the sensitivity in all the three cities is closely related to satisfaction with the environment. It is noted that the discrepancy found among Hanoi, Ho Chi Minh City and Da Nang is consistent with other studies on the cultural differences between the regions in Vietnam (Phuc 2009). The Northerners are more formal, conservative and resistant to change while the Southerners are more direct and dynamic. The Centrals are more patient and show more foresight than the others. These regional traits originate from their geographical location and history. Hanoi is an old urban area, that developed inside the curve of the Red River with a wide ranging changeable climate. Ho Chi Minh City is a young urban international harbor, blessed with fertile land, hot throughout the year, inhabited by a mixed population. The people in Central Vietnam suffer from poor resources and harsh nature. Cultural differences resulting from these environmental factors might be used to explain the structural differences of aircraft noise annoyance in the three cities.

Though sensitivity is a personal characteristic and difficult to use in noise abatement programs, the evaluation of their own sensitivity in the three cities is much modified by their satisfaction with the environment. This finding suggests that aircraft noise annoyance for urban residents in Vietnam can be decreased by improving the quality of the living environment to raise the level of community satisfaction.

Acknowledgement

The present study was supported by *Grant-in-Aid* for Scientific Research C of Japan Society for the Promotion of Science (No.23560695).

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