Structural equation model of road traffic noise annoyance in Vietnam

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ABSTRACT

The exposure-response relationships for road traffic noise annoyance in Vietnam were proposed according to over 4700 responses obtained in Hanoi, Ho Chi Minh, Da Nang, Hue and Thai Nguyen. However, the variation of the exposure-response curves found among the five cities implied that discrepancies could occur between different geographic regions like the north and the south of Vietnam. To assess the effects of acoustic and non-acoustic factors on road traffic noise annoyance in Vietnam, structural equation models were developed by linking the questionnaire items of the socio-acoustic surveys on road traffic noise annoyance conducted in the five cities. The sample sizes were 1174, 1403, 432, 592, and 633 to estimate the models for Hanoi, Ho Chi Minh, Da Nang, Hue and Thai Nguyen, respectively. The final model included three latent factors: activity interference; sensitivity; and satisfaction with living environment. 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 model provided good model fit and indicated that sensitivity and satisfaction with living environment were the main modifiers of road traffic noise annoyance in Vietnam

Keywords: Structural equation analysis, Road traffic noise annoyance, Non-acoustical factors
I-INCE Classification of Subjects Number(s): 66

1. INTRODUCTION

Several essential study themes were recommended for further researches on community noise: (a) Data analysis and policy issues of noise exposure above 75 dB; (b) Influence of non-acoustic factors on annoyance; (c) The influence of background noise level; (d) The use of separate versus combined noise annoyance curves; (e) Cultural and geographical differences in community responses; (f) Data from non-English publications (1). Regarding specific characteristics of road traffic noise in Vietnam, all above addressed problems could be looked inside.

Community response to road traffic noise in Vietnam was investigated initially in Hanoi and Ho Chi Minh City in 2005 and 2007. They are the two busiest major metropolitan areas in Vietnam with approximately 7 million inhabitants in each. These two cities are experiencing a serious noise pollution, where urban residents are exposed to high levels of noise from various noise sources. The dominant source is road traffic which is contributed to by a huge amount of motorbikes but not cars or light trucks as in other countries. High road traffic noise exposure in Hanoi and Ho Chi Minh City could provide data above 75 dB. Particularly, the noise exposure levels (L_{den}) were 70-83 dB in Hanoi and 75-83 dB in Ho Chi Minh City. Hanoi respondent seems to be more annoyed by noise than those in Ho Chi Minh City at the same noise exposure (7). This discrepancy was hypothesized to be due to difference in lifestyles, culture and climate between the North and the South of Vietnam. To achieve more valid exposure-response relationship for policy and regulatory purposes, Da Nang and Hue City, smaller size cities in the Middle of Vietnam were selected for the next target of the study on road traffic

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noise in Vietnam in 2011 and 2012. Da Nang and Ho Chi Minh City are quite similar in climate, history and social customs, while such similarity could be found between Hanoi and Hue. However, the annoyance to road traffic noise in both Da Nang and Hue was found to be lower than those in Hanoi and Ho Chi Minh City. Additional data obtained in the other survey conducted in Thai Nguyen, a small city near Hanoi, in 2013 could not provide any evidence for the difference in response to noise between the North and the South of Vietnam because the residents in Thai Nguyen have more similar response to noise with those in Ho Chi Minh, Da Nang and Hue than the respondents in Hanoi (2).

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 (3-5). 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. Numbers of studies have been made to access the effects of non-acoustical variables on perceived noise annoyance in Vietnam. Window orientation in home was found to significantly modify activity interference induced by road traffic noise in Hanoi and Ho Chi Minh City (6). Satisfaction with residential area, the comfort level in rainy season and the quietness in the residential area were significant modifiers of road traffic noise annoyance in Vietnam (7). In addition, different background noise level could affect the perceived annoyance at the same noise exposure level (8).

In this study, the effect of non-acoustical factors on perceived annoyance induced by road traffic noise in Vietnam will be accessed using structural equation model (SEM). SEM is a tool allowing 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. (9-12). Within the context of SEM methodology, such unobserved variables can be linked to ones that are observable and thereby make their measurement possible. Regarding the issues of Vietnamese data analysis, SEM is an effective tool to synthesize various modifiers of road traffic noise annoyance which have been accumulated from 2005 to 2013 through five cities with about over 4700 responses. This study aims to propose a SEM for road traffic noise annoyance in Vietnam, to compare it with SEM of aircraft annoyance, and to determine the cause of different response to road traffic noise noise among cities in Vietnam.

2. METHODS

In our previous studies, we propose a structural equation model (SEM) for aircraft noise based on approximately 2,000 responses of the residents in the vicinities of the three largest airports in Vietnam (13). The SEM was developed 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) and Da Nang (2011). 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 transportation mode included safety, their value to society and frequency of use.

The model for road traffic noise annoyance in Vietnam was developed by referring the aircraft noise annoyance model with several modifications to fit the content of questionnaire survey on community response to road traffic noise in Vietnam. For example, the noise annoyance was changed to be an endogenous variable determined by noise annoyance, exhausted gas induced annoyance and vibration annoyance, etc. The target is to achieve a common model among the cities and between the noise sources. The surveys on community response to road traffic noise in the five cities in Vietnam were conducted by face-to-face interviews during the daytime on weekends. Road traffic noise exposure was measured every 1 s for twenty four hours by using sound level meters. Table 1 shows the questionnaire items of the surveys including not only on noise but also various components of the living environment.

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 - Q34	Socio-demographic variables	Occupation; Period to stay at home; Number of family members, Age, Gender, etc.
Q35 – Q41	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.

3. RESULTS

3.1 The model tests

The model test and parameter estimates are based on the covariance matrix and maximum likelihood estimation. The full model was estimated with the dataset of Hanoi, Ho Chi Minh City, Da Nang, Hue and Thai Nguyen. The constructed common model was fitted to the combined dataset of each city. To simplify the model, the three observed variables which have the highest regression weights were selected. The additional modifications to the existing aircraft noise annoyance model did not result in a better fit model. Therefore the final model for road traffic annoyance compose the same variables as those in aircraft noise annoyance model except the change in direction of the path between sensitivity and satisfaction with the living environment. This change was made by considering the sensitivity as an independent personal characteristic though the models seemed to fit better if the regression path leads toward sensitivity.

As presented in Figure 1, the final structural model included three latent variables indicated by the three circles labeled activity interference, sensitivity, and satisfaction with living environment. Each latent variable 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. After removing all responses which included blank data from the model dataset, the sample sizes in Hanoi, Ho Chi Minh City, Da Nang, Hue and Thai Nguyen are 1174, 1403, 432, 592 and 633, respectively. This large amount of data was sufficient to estimate the models and to certify the validity of the analysis results.

Table 2 – Overview of variables and their evaluation scale used in the model

Latent variable	Observed variable	Question	Range
	Noise annoyance	Within 12 months, how much does noise from road traffic/aircraft annoy/disturb you when you are at home?	0: Not at all -10: Extremely
Activity interference	Awakening	When you are awakened in your sleep	1: Not at all - 5: Extremely
	Rest	When you are indoor resting	1: Not at all - 5: Extremely
	Listening	When you are indoor listening to TV/radio	1: Not at all - 5: Extremely
Sensitivity		In daily life, climatic factors as well as environmental conditions affect us much, then how much are you sensitive to the following factors?	
	Noise	Noise	1: Not at all - 5: Extremely
	Vibration	Vibration	1: Not at all - 5: Extremely
	Heat	Heat	1: Not at all - 5: Extremely
Satisfaction with living environment	Quietness	Please evaluate your living area according to the quietness	1: Extremely good- 5: Extremely bad
	Preference to living area	How much do you like your living area?	1: Like very much - 5: Dislike very much
	Comfort in dry season (Winter)	Please evaluate the climate where you live in dry season	1: Extremely comfortable - 5: Extremely uncomfortable
	Safety	How safe is bike/airplane?	1: Extremely safe - 5: Extremely dangerous

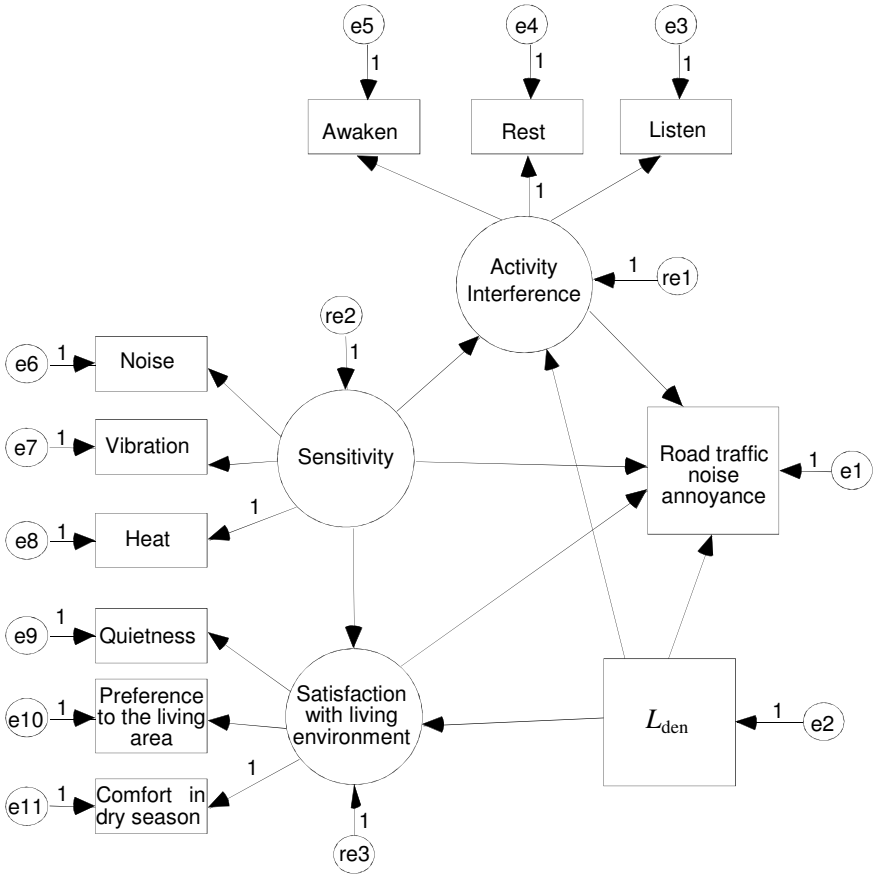


Figure 1 – The revised model

The structural component of this model represents the following relationships:

- Road traffic noise annoyance is directly influenced by noise exposure (L_{den}) and the three latent variables.
- Sensitivity influences noise annoyance directly as well as indirectly via activity interference. Sensitivity also affects satisfaction with living environment directly.
- Satisfaction directly influences aircraft noise annoyance.
- The effect of noise exposure on annoyance is mediated by the satisfaction with living environment. In addition, noise exposure indirectly influences noise annoyance through activity interference.

3.2 The final structural models for the five cities

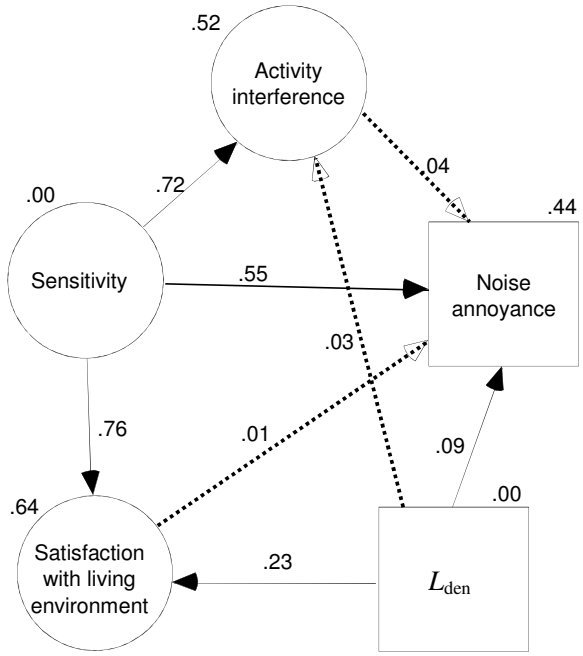
The models for road traffic noise annoyance in the five cities are depicted in Figure 2. The chi-square value is statistically significant (Chi^2 = 1430.4, p=0.000). This means that the implied covariance matrix is significantly associated with the observed covariance matrix. The values for the goodness-of-fit 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 variable on the variable at the arrow-shaped end.

The models established for each city pointed out that the community response to noise in the surveyed cites had relatively different structures. Road traffic noise annoyance in Hanoi was directly modified by sensitivity and noise exposure level (Fig.2-a). Although no significant direct modifiers was found for road traffic noise annoyance in Ho Chi Minh City, the path linking sensitivity to annoyance had high regression weight (Fig.2-b). Noise annoyance in Da Nang is directly modified by activity interference, sensitivity and satisfaction with living environment. Noise exposure level indirectly influences noise annoyance through activity interference and satisfaction with the living environment. The sensitivity influences noise annoyance in Da Nang via activity interference and satisfaction with the living environment (Fig.2-c). The only significant direct modifier of annoyance in Hue is satisfaction with living environment. However, the noise exposure level and sensitivity indirectly modify the noise annoyance via satisfaction with living environment (Fig.2-d). Significant direct modifiers of annoyance in Thai Nguyen model are activity interference and noise exposure level. Sensitivity and noise exposure levels have indirect influence on noise annoyance in Thai Nguyen through activity interference (Fig.2-e). It needs to be noted that the sensitivity had strong regression to activity interference and satisfaction with living environment variables in all the models. The significant direct and indirect effects of sensitivity to noise annoyance were found in all the models except Ho Chi Minh City model.

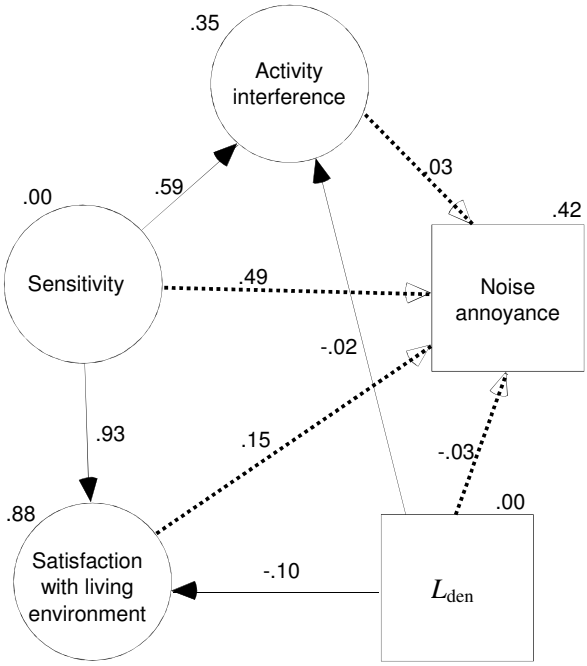
In order to compare the importance of each variable on the key variable, noise annoyance, standardized total effect, which is the sum of direct and indirect effects, are presented in Table 3. The total effect of sensitivity is the highest in Hanoi, Ho Chi Minh, Da Nang and Hue, while L_{den} has strongest effect in Thai Nguyen model. In other words, L_{den} is the most important determinant of noise annoyance in Thai Nguyen, while that in the other cities is sensitivity. The effect size of noise exposure level (L_{den}) on noise annoyance is considerably smaller than that of sensitivity in all the models except Thai Nguyen.

The explained variances for dependent variables in the models of the five cities were shown in Table 4. The explained variance of road traffic noise annoyance are 44%, 42%, 41%, 55% and 33% for respondents in Hanoi, Ho Chi Minh City, Da Nang, Hue and Thai Nguyen, respectively. The explained variances of satisfaction with living environment are considerably higher than noise annoyance and activity interference. This result can be easily observed because both sensitivity and L_{den} are significant determinant of satisfaction with living environment with high regression weights in the models of all the cities.

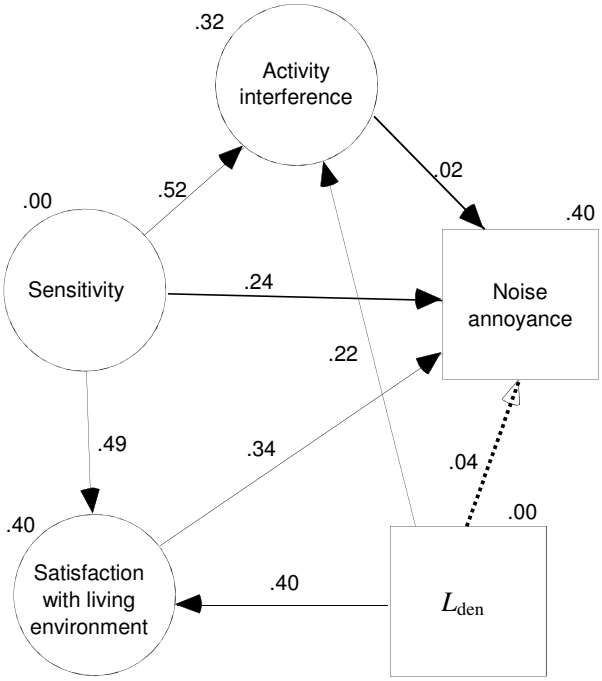
It can be summarized that, the respondents in Hanoi, Ho Chi Minh City evaluated their annoyance by road traffic noise mainly based on their sensitivity. The response to road traffic noise in Da Nang and Hue was influenced by satisfaction with living environment. Those in Thai Nguyen are modified by noise exposure and activity interference. The finding of structural equation model indicated different mechanism of road traffic noise annoyance in the five cities in Vietnam.



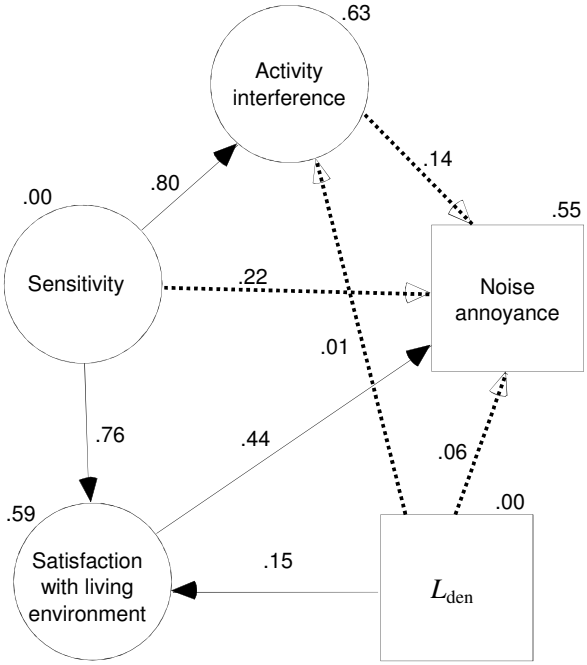
(a) Hanoi



(b) Ho Chi Minh



(c) Da Nang



(d) Hue

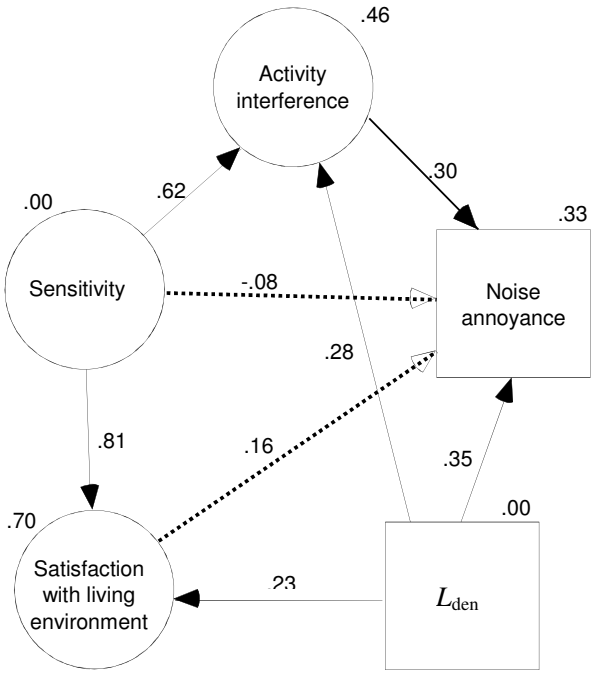


Figure 2 – The estimated road traffic noise annoyance model

n=, 1174 (Hanoi), 1403（Ho Chi Minh City）, 432 (Da Nang), 592 (Hue) and 633 (Thai Nguyen) Chi^2 = 1430.4, p=0.000, Df=190, GFI=0.944, CFI= 0.902, and RMSEA=0.039.

Statistically significant paths and standardized regression weights are annotated with (p<0.01). Non-significant paths are represented with dashed lines.

Explained variances are annotated above each variable.

(e) Thai Nguyen

Table 3 – Standardized total (direct/indirect) effects of each variable on noise annoyance among the cities

	L_{den}	Sensitivity	Satisfaction	Activity interference
Hanoi	0.112	0.652	0.096	0.044
	(0.088/ 0.024)	(0.547 / 0.105)	(0.096 / -)	(0.044/ -)
HCM	-0.041	0.647	0.149	0.030
	(-0.025/ -0.016)	(0.490 /0.157)	(0.149/-)	(0.030/ -)
Da Nang	0.221	0.510	0.337	0.201
	(0.041/0.180)	(0.242/0.269)	(0.337 /-)	(0.201/ -)
Hue	0.121	0.670	0.441	0.141
	(0.056/0.065)	(0.225/ 0.445)	(0.441 /-)	(0.141/ -)
Thai Nguyen	0.469	0.229	0.161	0.295
	(0.350/ 0.119)	(-0.083/ 0.312)	(0.161 /-)	(0.295/ -)

Table 4 – Output of explained variance of variables (squared multiple correlations) in the models

Variables	Hanoi	HCM	Da Nang	Hue	Thai Nguyen
Satisfaction	.636	.879	.400	.592	.702
Activity interference	.515	.353	.320	.634	.460
Annoyance	.442	.424	.405	.550	.327

4. DISCUSSION AND CONCLUSIONS

Comparing the results of structural equation models for the five cities in Vietnam, it is noted that Hanoi and Ho Chi Minh City, the two biggest urban areas of Vietnam, have relatively similar structure, while the similarity was found between Da Nang and Hue. Thai Nguyen is different from the others but has some features meditating in between the two groups mentioned above.

The respondents' dwellings in Hanoi and Ho Chi Minh City share the typical features of residence in the densely populated metropolis. That is, the population pursued chances to own and live in the house along the road for the benefit from combining living activity with commercial activities. In the smaller cities whose population sizes are about one-tenth of the two big cities, many people living along main road do not involve in commercial activity to take advantage of their house's position. This feature can be found in Da Nang, Hue and Thai Nguyen. The population sizes influenced much to the lifestyle of the residents as well as the soundscape of the cities. The result of noise measurement in these cities show that noise exposure ranged from 73-81, 77-83, 66-76, 61-80 and 61-77 dB (L_{den}) at the most exposed facade in Hanoi, Ho Chi Minh City, Da Nang, Hue and Thai Nguyen, respectively. It is noted that the quietest sites found in Hanoi and Ho Chi Minh City were exposed to levels of 73 and 77 dB (L_{den}). These are much higher than those in the other small sized cities. Several studies pointed out the benefit of a quiet side in the house for decreasing the sleep disturbance and noise annoyance (14). This finding might be also right in bigger scaled circumstances. The respondent will feel less annoyed if they have more chance to access the quiet area. It means that the people living in the cities occupied by more quiet areas will be less annoyed by noise than the residents of big metropolis where the urbanization makes the whole city noisy by continuous traffic flows. This inference is reasonable because access to quite sides is associated with satisfaction with residential environment.

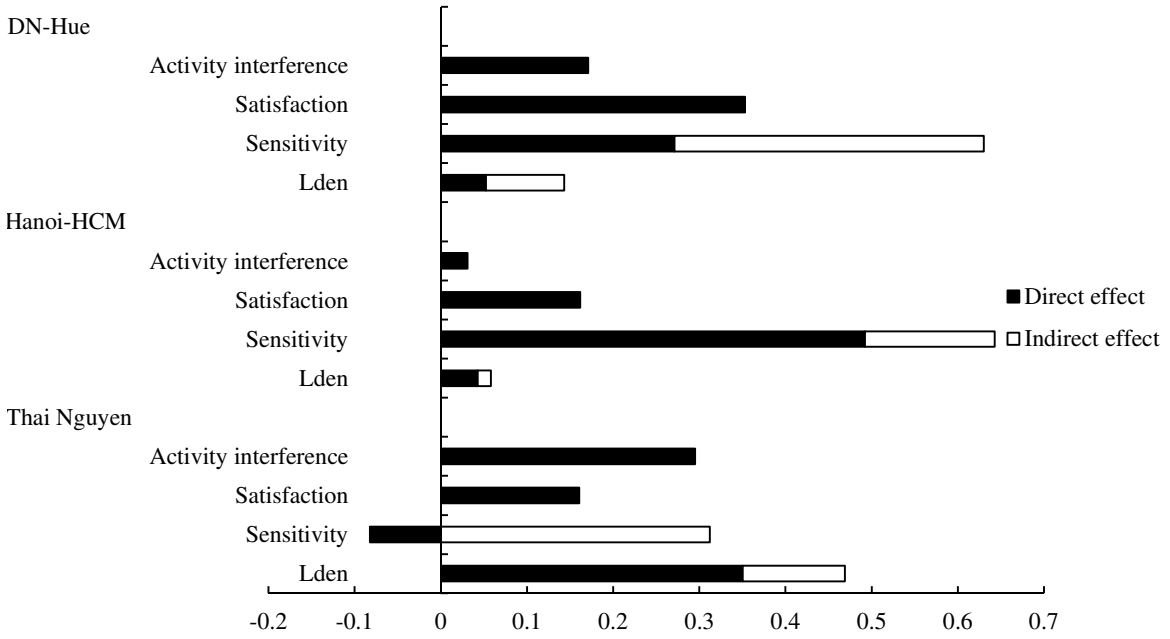


Figure 3 – Comparison the effect of each variables on noise annoyance of three groups of the cities

To investigate whether difference in living environments among the cities affect evaluation about road traffic noise induced annoyance, SEM was developed with the data of the five cities divided into 3 groups: (1) Group 1: Large cities with bad environment (Hanoi and Ho Chi Minh City), Group 2: Small cities with good environment (Hue and Da Nang), Group 3: a small cities with moderate townscape and good environment (Thai Nguyen). The better model fit were archived with this division (GFI=0.958). The results of total effects of variables on noise annoyance in these three groups are compared in Figure 3. It could be found that the effect of satisfaction on road traffic noise annoyance is greater in smaller cities. The category pattern of the respondents' selection when answering the questions relating their evaluation on their living environments revealed that the respondent in Hanoi, Ho Chi Minh City and Thai Nguyen were less satisfied with the environmental quality of their living area than those in Da Nang and Hue (2). When the residents' satisfaction is strong enough, it will influence the noise annoyance. The sensitivity will become greater modifier of road traffic noise annoyance if the residents do not satisfy with their living area, like the situation in Hanoi and Ho Chi Minh City.

In summary, this study found that the community response to noise was affected by the respondents' satisfaction with their surrounding environment and their sensitivity. The effect of noise exposure level seemed modest in comparison with the other non-acoustical modifiers. This study suggests that

annoyance caused by road traffic noise in Vietnam can be decreased by creating more quiet areas and improving the living environment to raise the residents' satisfaction level.

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