Journal of Sound and Vibration (2002) **250**(1), 169–174
doi:10.1006/jsvi.2001.3890, available online at http://www.idealibrary.com on IDEAL®

COMPARISON OF COMMUNITY RESPONSE TO ROAD TRAFFIC NOISE IN JAPAN AND SWEDEN—PART II: PATH ANALYSIS

T. Yano

Department of Architecture and Civil Engineering, Faculty of Engineering, Kumamoto University, Kurokami 2-39-1, 860-8555, *Kumamoto, Japan. E-mail*: *yano@gpo.kumamoto-u.ac.jp*

T. Sato

Department of Architecture, Hokkai Gakuen University, Sapporo, Japan

AND

M. Björkman and R. Rylander

Department of Environmental Medicine, University of Gothenburg, Gothenburg, Sweden

(*Received* 5 *September* 2001)

Path analysis was applied to data obtained in social surveys in Kumamoto and Sapporo, Japan, and Gothenburg, Sweden, to cross-culturally compare the causal models that describe the multiple stratum relationships between road traffic noise annoyance and endogenous and exogenous variables. Path models can estimate not only the direct effect of a variable on annoyance but also the indirect effect of the variable via other variables. The exogenous variables were selected from housing, personal and environmental factors, and the endogenous variables were selected from various activity disturbances and related effects, based on the results of correlation coefficients between variables and discrimination by factor analysis. An *a priori* path model was constructed at the start of the analysis and the structure equations for the endogenous variables were formulated. The standardized partial regression coefficients are called path coefficients and show the strength of the linkage between variables. A revised path model was constructed by deleting insignificant paths. The characteristics of annoyance responses were as follows: (1) annoyance caused by exhaust has the strongest relation to noise annoyance and (2) structures of noise annoyance were different between Japan and Sweden and between housing types, probably owing to differences in lifestyle.

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1. INTRODUCTION

Path analysis [1] is used to investigate the structural linkage between many related factors and has been widely applied in the field of social sciences. Taylor [2] applied the method to a noise annoyance study around Toronto Airport and proposed an exploratory model for aircraft noise annoyance in relation to several acoustical and non-acoustical factors. Izumi *et al.* [3] made a path analysis with data from social surveys on community responses to road traffic noise in Hokkaido, Japan, and showed the relation between noise exposure, hearing, and sleep disturbances on road traffic noise annoyance. Osada *et al.* applied this method to social surveys on community responses to aircraft noise around Narita Airport [4] and to road traffic noise in Tokyo [5]. Osada *et al.* [4] confirmed that the main findings

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were consistent with those obtained by Taylor [2] and Izumi *et al.* [3]. The present authors have used this analysis in their own studies on the annoyance interaction of noise and vibration [6], the effects of noise barriers on road traffic noise annoyance [7], and comparisons of community responses to road traffic and railway noises [8]. It was found from these studies that path analysis is a useful tool for comparing the annoyance structures that show how various factors relate to noise annoyance.

This paper presents the results of path analysis of data obtained in social surveys on community responses to road traffic noise in Gothenburg, Sweden, and Sapporo and Kumamoto, Japan [9]. Differences between cities and countries in road traffic noise annoyance are discussed on the basis of the relationships between noise annoyance and acoustical and non-acoustical factors in the three cities.

2. PATH ANALYSIS

2.1. *A PRIORI* PATH MODEL

Path analysis was done to compare the models that describe the multiple-stratum relationships between road traffic noise annoyance and endogenous and exogenous variables. The path model not only estimates the direct relation of a variable on annoyance but also the indirect relation of the variable via other variables. The exogenous variables, which are not dependent on other variables in the model, were selected from housing, personal and environmental factors, and the endogenous variables were selected from various activity disturbances and related effects on the basis of the results of correlation between variables and discrimination by factor analysis. The endogenous variables are partially dependent on some of the exogenous and the endogenous variables and have a direct relationship with road traffic noise annoyance.

Noting the relations and the previous research findings, an *a priori* path model was constructed using nine exogenous variables and seven endogenous variables, as shown in Figure 1. The arrows show the relations between the variables. It is shown that $L_{Aeq(24)}$ relates to "road traffic noise annoyance" both directly and indirectly via "TV/radio listening disturbance." The linkage between the non-acoustical factors, "house vibration" and "exhaust", and noise annoyance can be interpreted such that vibration or exhaust strengthens the degree of noise annoyance when they exist simultaneously with noise.

2.2. REVISED PATH MODEL OF ROAD TRAFFIC NOISE ANNOYANCE

According to the normal solution of the path analysis, a series of structural equations was formulated to correspond with this *a priori* model. Most of the variables were of the ordinal scale, but they are commonly treated as those of interval scale. The equations are the same as the multiple linear regression equations and are solved by the least-square technique. The standardized partial regression coefficients are called path coefficients and show the strength of the linkage between variables. Among the paths in this model, some were not statistically significant. Deleting the insignificant paths above the 1% level, six revised path models were constructed for each housing type in the three cities.

3. RESULTS

Figure 2 summarizes the effects of significant variables on road traffic noise annoyance in the revised models. The profiles of the effects of various factors on traffic noise annoyance given in Figure 2 showed the following.

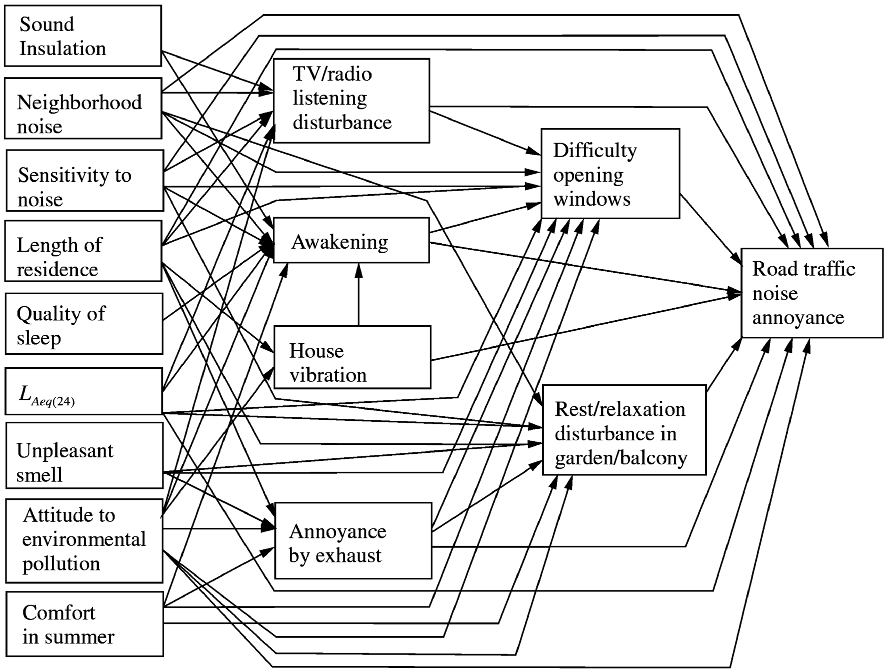

Figure 1. *A priori* path model of road traffic noise annoyance.

In almost all cases, it was found that annoyance caused by exhaust had the strongest relation with noise annoyance. This can be interpreted as an indication that exhaust tends to strengthen the degree of noise annoyance. The profiles of the relation of various factors on annoyance for the same house types were similar in Sapporo and Kumamoto while the profiles in Gothenburg were quite different from those in the two Japanese cities. This suggests the presence of cross-cultural differences in community responses to road traffic noise.

Rest disturbance in gardens or on balconies had a strong relation to noise annoyance for people living in detached houses and a weaker but still significant relation for those living in apartment houses in Gothenburg. There was no significant effect in Sapporo or Kumamoto. This is probably related to the Swedish customs of enjoying activities in gardens or on balconies.

TV/radio disturbance had quite a strong relation to noise annoyance in Sapporo and Kumamoto. In particular, disturbance among people living in apartment houses was stronger than for people living in detached houses. The disturbance in Kumamoto was greater than in Sapporo, possibly because apartment houses are apt to be more exposed to noise than detached houses and the sound insulation of windows in Sapporo is better than that in Kumamoto. Noise exposure is dependent on the positional relation between the road and houses. The higher the story in the houses, the more directly it is exposed to noise and the less exposed to exhaust. Also, double-paned windows are usually used in Sapporo while single panes are most common in Kumamoto. People living in apartment houses in Kumamoto appear to have the greatest exposure to indoor noise of the six cases, two housing types and three cities.

The relation with awakening was stronger in Kumamoto than in Sapporo and Gothenburg. This was more apparent for apartment houses. This trend may be due to the difference in sound insulation and noise exposure, as mentioned above.

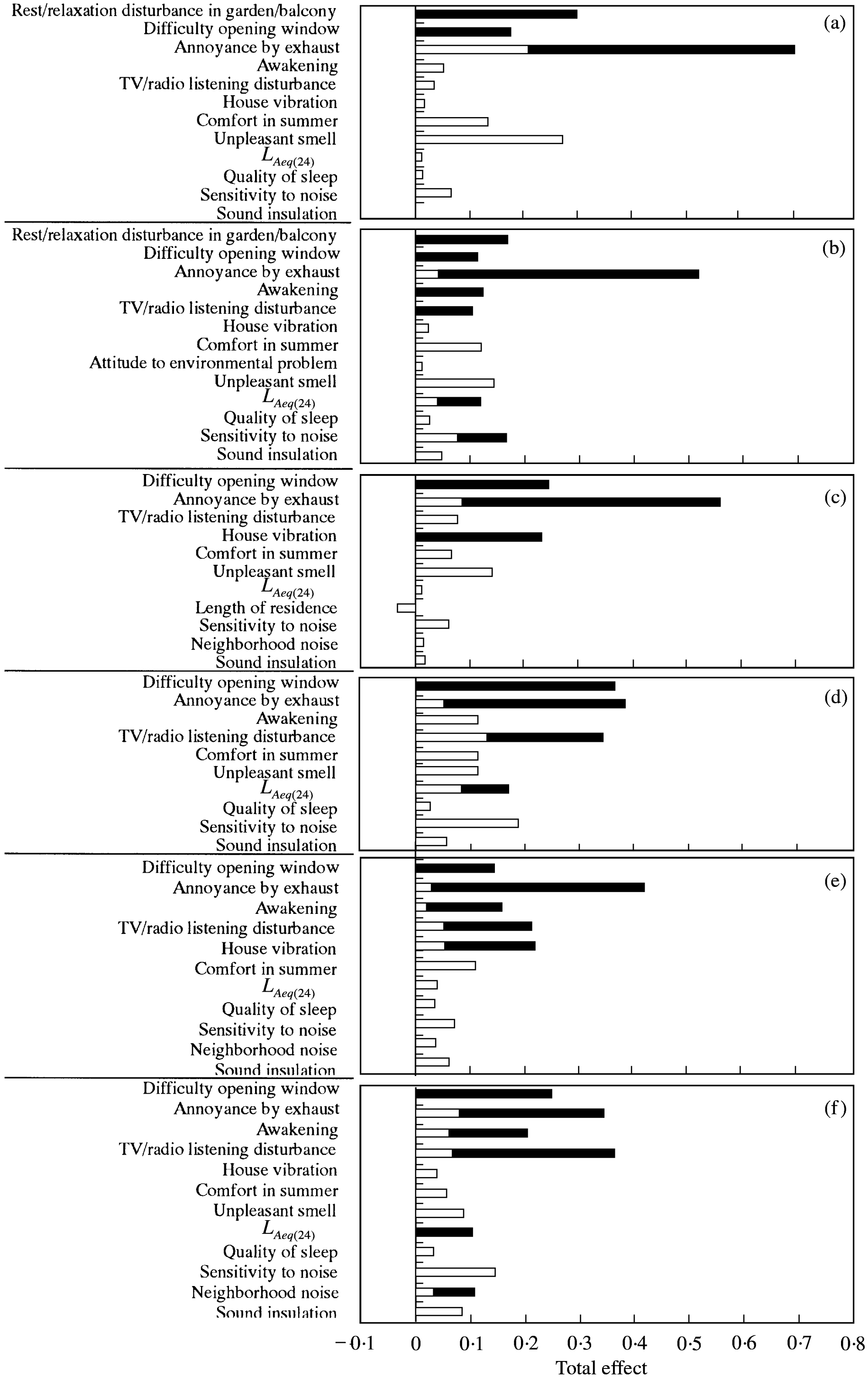

Figure 2. Effect of significant variables on road traffic noise annoyance for revised model. (a) Gothenburgh/Detached; (b) Gothenburgh/Apartment; (c) Sapporo/Detached; (d) Sapporo/Apartment; (e) Kumamoto/Detached; (f) Kumamoto/Apartment. ■, Direct effect; □, Indirect effect.

The relation with vibrations was more significant for people living in detached houses than for those living in apartments and greater in Kumamoto and Sapporo than in Gothenburg. The mass of apartment houses was larger than that of detached houses, and the mass of detached houses in Gothenburg was greater than that in Kumamoto and Sapporo. The ground consists of rock in Gothenburg and soil or clay in Kumamoto and Sapporo. Thus, vibration is less easily transmitted in Gothenburg than in Kumamoto and Sapporo.

The relation with sensitivity to noise and $L_{aeq(24)}$ was stronger for apartment houses than for detached houses in the three cities. This may also be because apartment houses are apt to be more affected by noise than detached houses.

4. DISCUSSION

The profiles of the relation between various variables and road traffic noise annoyance reflect the lifestyles and the characteristics of noise exposure relating to culture and housing types. There appear to be consistent rationales for the difference in annoyance profiles between cities and between housing types.

In Kumamoto and Sapporo, activity disturbance indoors, such as disturbance in listening to TV/radio, significantly affects noise annoyance, especially in apartment houses, while activity or rest disturbance in gardens or on balconies has a stronger effect in detached houses in Gothenburg. This may be due to the different customs in Japan and Sweden, such as spending a great deal of time in well air-conditioned rooms in the hot climate of Kumamoto, while people enjoy the outdoors in gardens or on balconies in Gothenburg. Auditory effects such as TV/radio disturbance and awakening are stronger for people living in apartment houses than detached houses, probably due to the difference in the balance of noise and exhaust exposure depending on the floor level.

The above differences in path models suggest that cultural differences and housing types must be considered when proposing effective noise counter-measures. For example, sound insulation measures such as airtight structures and windows with double or even more panes are more effective in apartment houses than in detached houses and more useful in Kumamoto than in Gothenburg. An effective noise counter-measure for detached houses in Gothenburg, where people enjoy activities in gardens or on balconies, may require not only noise abatement by sound insulation but also a reduction of noise from sources and measures against other pollutants such as exhaust. Outdoor activities are not affected by sound insulation of houses but by pollutants emitted from road traffic. Taking into consideration such factors may improve the prediction of community response to noise when the lifestyle changes over time with the social or economical conditions.

The two kinds of analyses made in Parts I and II lead us to conclude that non-acoustical factors, particularly exhaust from road traffic and the different customs of the people living in the two different countries and in the different types of housing, are important for the evaluation of annoyance caused by road traffic noise.

5. CONCLUSION

The characteristics of annoyance responses obtained by path analysis showed that: road traffic noise annoyance was most strongly related to exhaust fumes. In Sapporo, and particularly in Kumamoto, activity disturbance indoors, such as disturbance of TV/radio listening was significantly related to noise annoyance, while activity or rest disturbance in gardens or on balconies showed a strong relation in Gothenburg, owing to the difference in customs between Japan and western Sweden. The auditory effects of noise such as disturbance to TV/radio listening and awakening were more pronounced among people living in apartment houses than among those living in detached houses.

ACKNOWLEDGMENT

We gratefully acknowledge the late President Kiyoto Izumi of Muroran Institute of Technology for giving us the opportunity to conduct the international joint study.

REFERENCES

1. H. B. ASHER 1976 *Causal Modeling*. London: Sage.
2. S. M. TAYLOR 1984 *Journal of Sound and Vibration* **96**, 243–260. A path model of aircraft noise annoyance.
3. K. IZUMI and T. YANO 1991 *Journal of Sound Vibration* **151**, 505–512. Community responses to road traffic noise: social surveys in three cities in Hokkaido.
4. Y. OSADA and T. YOSHIDA 1997 *Journal of Acoustical Society of Japan* **53**, 599–604. Path analysis of aircraft noise annoyance in a community response survey (in Japanese).
5. Y. OSADA, T. YOSHIDA, K. YOSHIDA, K. KAWAGUCHI, Y. HOSHIYAMA and K. YAMAMOTO 1997 *Journal of Sound and Vibration* **205**, 493–498. Path analysis of the community response to road traffic noise.
6. T. SATO 1994 *The* 1994 *International Congress on Noise Control Engineering*, *Tokyo*, Vol. 2, 923–928. Path analyses of the effects of vibration on road traffic and railway noise annoyance.
7. T. YANO, K. KUROSAWA and K. KAWAI 1997 *The* 1997 *International Congress on Noise Control Engineering*, *Budapest*, *Hungary*, Vol. 3, 1253–1256. Effects of noise barriers on annoyance caused by road traffic noise from Kyushu highway.
8. T. YANO, Y. MURAKAMI, K. KAWAI and T. SATO 1998 *Seventh International Congress on Noise as a Public Health Problem*, *Sydney*, Vol. 2, 582–585. Comparison of responses to road traffic and railway noises.
9. T. SATO, T. YANO, M. BJORKMAN and R. RYLANDER 2001 *Journal of Sound and Vibration* Comparison of community responses to road traffic noise in Japan and Sweden—Part I: outline of surveys and dose–response relationships (submitted).