ATTENUATION DUE TO PROPAGATION PATH OF VIADUCT EXPRESSWAY TRAFFIC NOISE OF HIGH-RISE BUILDING

BY

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INTRODUCTION

Viaduct expressways or elevated expressways on super-structures which passing through the city center always cause the noise impact which generated by traffic on those expressways to the nearby high-rise buildings along the expressway routes. This study project, therefore, aimed at the investigation of traffic noise from the viaduct type expressway and its traffic noise attenuation due to propagation path to the high-rise building along the side of this expressway.

Study was also done in order to build the analytical technique for analyzing the noise level which was generated by continuous traffic flow noise source on the viaduct expessway and also the noise propagation path from expressway to the different heights of surrounding buildings nearby the expressway's super-structure. Field data was collected on the traffic characteristics and traffic composition on expressway together with the generated traffic noise levels which were measured at the same time of collecting traffic data. Noise levels on the different heights of buidings adjacent to the expressway were also collected in order to study the traffic noise attenuation due to propagation paths from elevated and at-grade sections of this expressway on the buildings.

Finally, the statistical test was performed to study the accuracy of

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analytical model which was built in this study for analyzing traffic noise of viaduct expressway on the high-rise building.

LOCATION OF FIELD SURVEY AND DATA COLLECTION

Field survey for this study project was done along the viaduct section of Ayer Rajah Expressway which passing through the central business district of Singapore. The buildings along the side of this viaduct expressway where measurements of noise level were carried out consisted of 6 high-rise buildings, namely, IBM Tower, Commercial Complex, Jit Poh Building, Tanjong Pagar Complex, and 2 buildings of Keppel Warehouse.

Traffic conditions on the expressway and noise level measurements were done simultaneously on each section of the expressway adjacent to the selected building. Conditions of traffic included traffic volume, average spot speed, and combination of traffic flow on the expressway. At the same time, traffic noise levels were measured on the surface of the expressway and roadways under the expressway's super-structure by placing the noise level meters 1.2 m. above the road surface and 1 m. from pavement edge. The measurement of traffic noise was carried out by using integrating sound level meters with the measuring unit of dB(A). The period for each traffic noise measurement was 1 hour and the scale of noise level that was used in this study was Leq which is the equivalent sound pressure level in 1 hour period. Noise level measurements were also carried out by placing noise level meters at different elevations on building adjacent to the expressway. The time for traffic characteristics and traffic noise measurements of this study were during the peak hour periods of the morning peak from 7:30 AM to 9:30 AM and the afternoon peak from 4:30 PM to 7:30 PM. The concept of same time and same weekday were employed if the measurement was to be carried out repeatedly on different elevation in a particular section. This was to avoid bias results due to changes in traffic condition in each section of expressway during the measurement. All the measurements were done only on dry road surface and clear weather condition.

The locations of buildings and sites of traffic noise measurement on both of the elevated and at-grade level of expressway are shown in Figure 1. The cross-sectional dimension of this viaduct expressway together with each adjacent building were also measured. The example of this to-scale cross-section of Ayer Rajah Expressway and the nearby IBM Tower building is shown in Figure 2.

TRAFFIC NOISE LEVEL AND TRAFFIC NOISE PATH ANALYSIS

The traffic noise propagation path of the section of expressway adjacent to each selected building were analyzed. Noise paths from different line sources for both of the elevated expressway and the at-grade roadways were measured from the center of each line source to the point of receiver on the nearby high-rise building. The distances from noise sources of the near side and the far side of the elevated expressway carriageways to receiver on the building are identified as Dn and Df respectively. The D'n and D'f stand for the distances from receiver to the center lines of nearside carriageway and farside carriageway of the at-grade roadway under the viaduct expressway respectively. Identifications of Dn, Df, D'n, and D'f are shown in Figure 3.

The overall equivalent distance (Doel) from all of the noise path distances from both of the elevated section and at-grade section of this expressway cross-section could be determined from the following equations.

$$\mathrm{Doel} = \sqrt{\mathrm{Dee} * \mathrm{Deg}}$$

and

$$\mathrm{Dee} = \sqrt{\mathrm{Dn} * \mathrm{Df}}$$

$$\mathrm{Deg} = \sqrt{\mathrm{D'n} * \mathrm{D'f}}$$

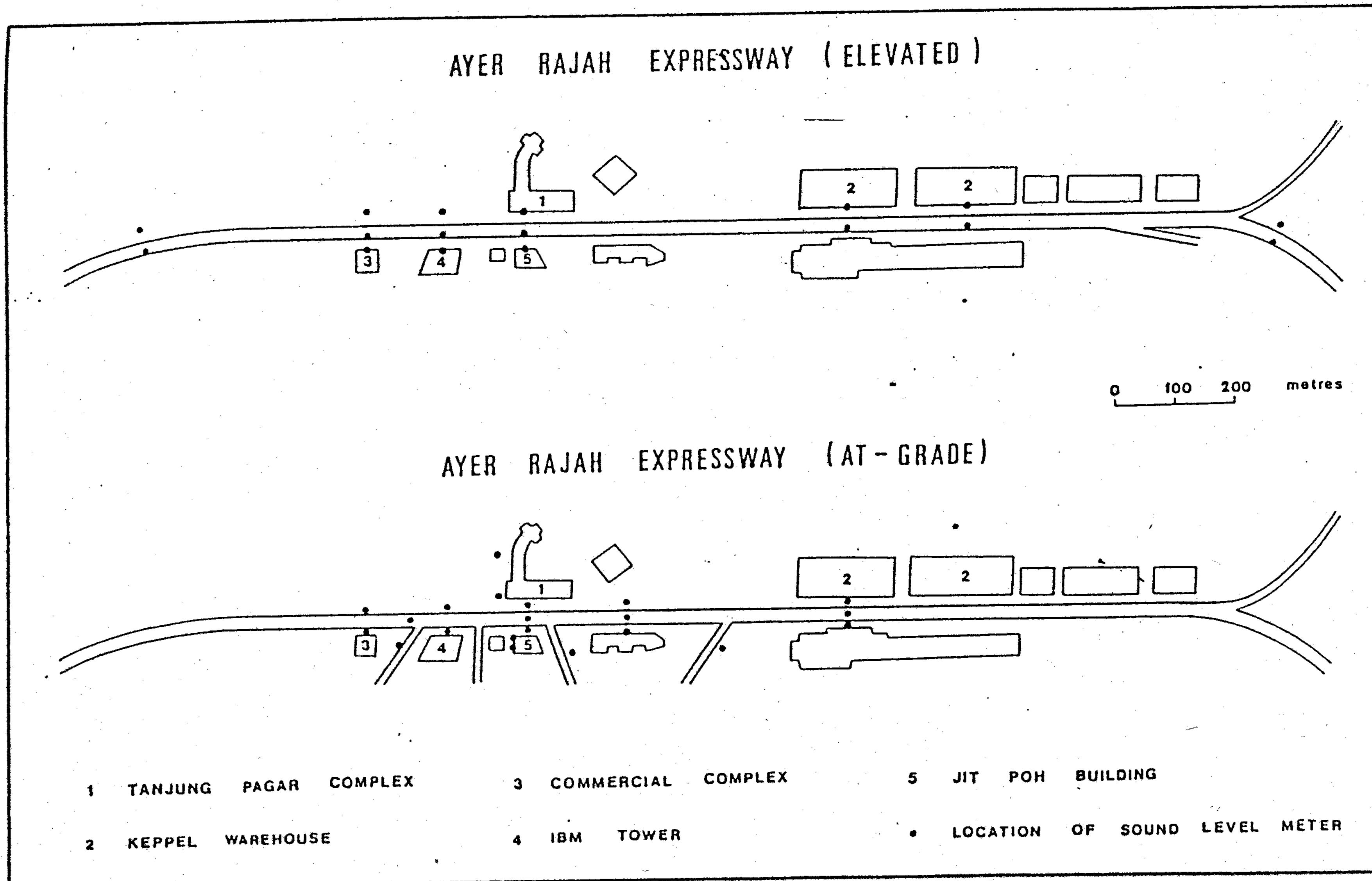

Figure 1 Location of Buildings and Sites of Traffic Noise Measurment on Both of Elevated and At-grade Levels of Ayer Rajah Expressway

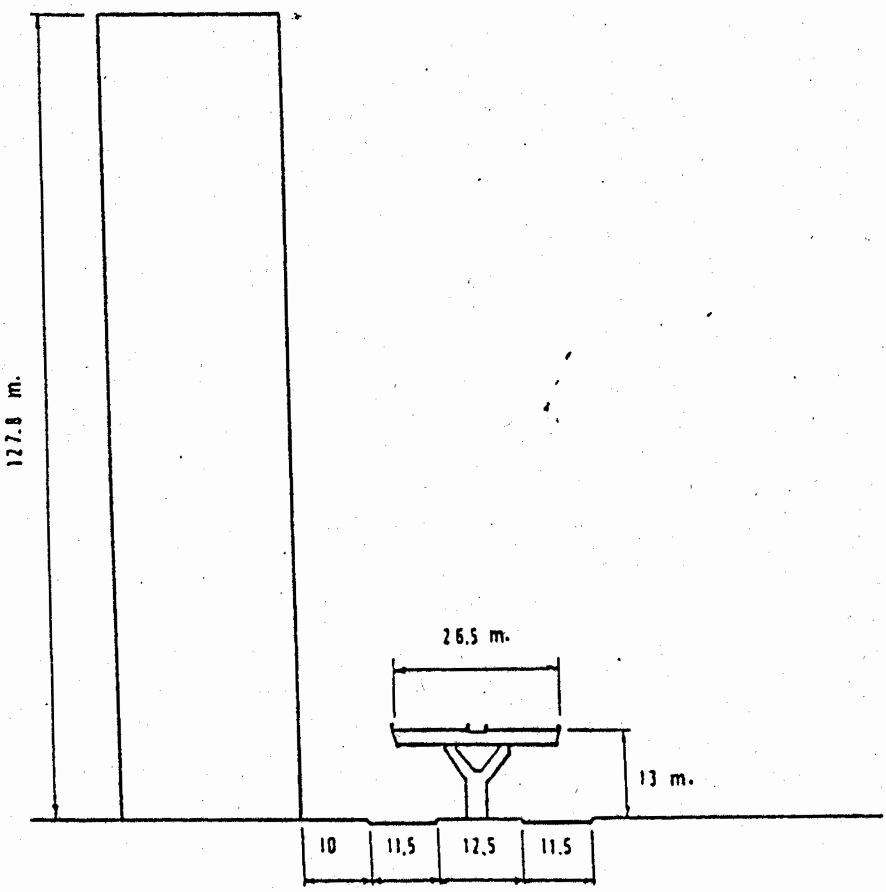

Figure 2 Cross-section of Ayer Rajah Expressway and IBM Tower Building

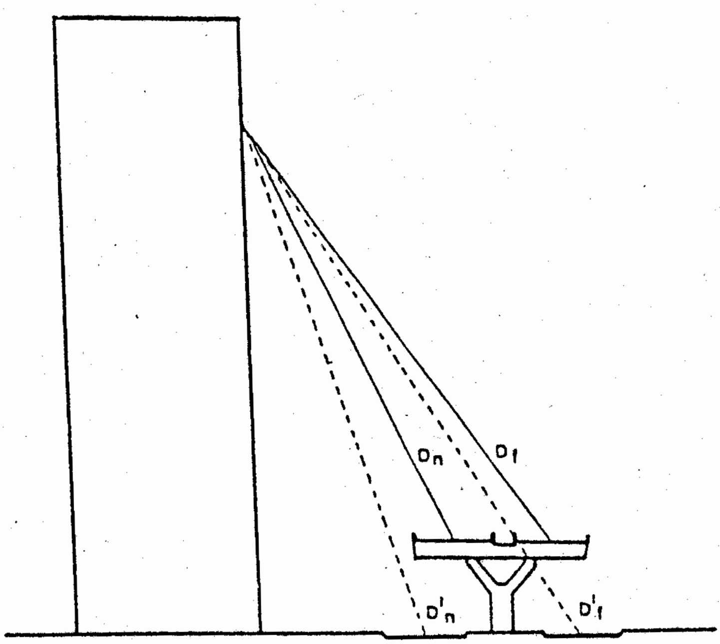

Figure 3 Identifications of Dn, Df, D'n, and D'f of Expressway Cross-section

where: Doel = Overall equivalent distance from cross-section

Dee = Equivalent distance from elevated section

Deg = Equivalent distance from at-grade section

Dn = Distance from point of receiver on building to center line of nearside carriageway (elevated)

Df = Distance from point of receiver on building to center line of farside carriageway (elevated)

D'n = Distance from point of receiver on building to center line of nearside carriageway (at-grade)

D'f = Distance from point of receiver on building to center line of farside carriageway (at-grade)

TRAFFIC NOISE ATTENUATION ON BUILDING WITH RESPECT TO OVERALL EQUIVALENT PROPAGATION PATH

The relationship between traffic noise which generated by elevated expressway and the at-grade roads under that expressway and its propagation path to the high-rise building was determined by performing the linear regression analysis based on the data of measured traffic noise levels (Leq) on the different heights of high-rise building and the overall equivalent distance (Doel) from the expressway to those points of measurement on the building. This relationship is shown in Figure 4, and the model could be mathematically express as the following.

$$Leq(mob)\ (1\text{-hour}) = 76.46 - 0.094\ Doel$$

where: Leq(mob) = Overall traffic noise measured on building

Statistical test of this model gave a highly significant value of R^2 equal to 0.882, and the standard error of estimate equal to 1.42. The gradient of this model was -0.094 which indicated that a reduction of 0.094

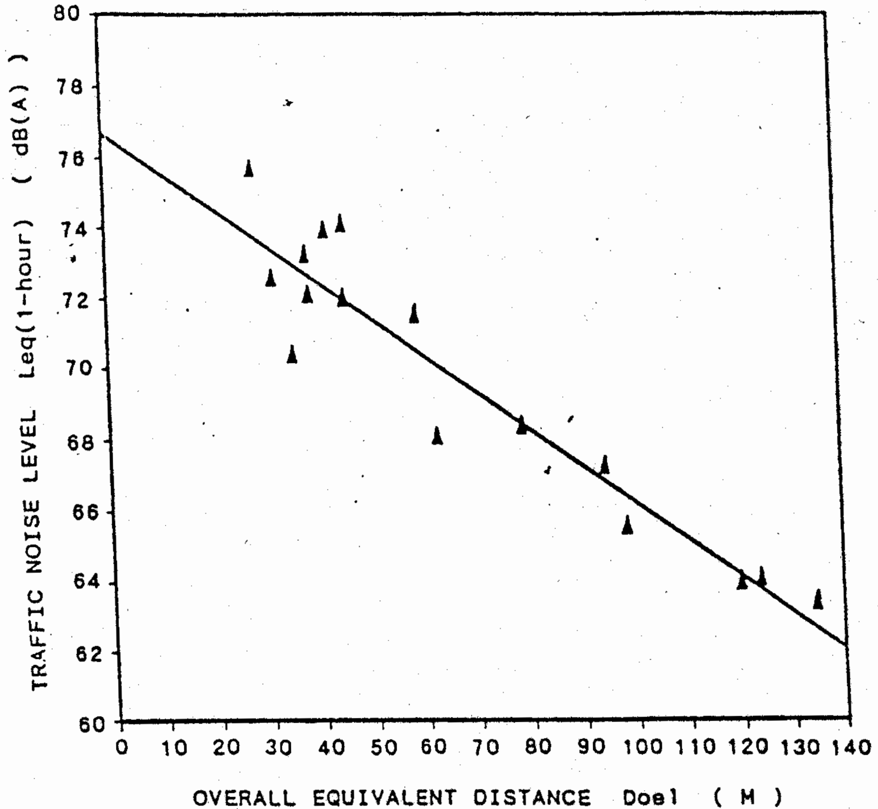

Figure 4 Relationship of Overall Traffic Noise from Expressway Cross-section on Building and the Overall Equivalent Distance (Doel)

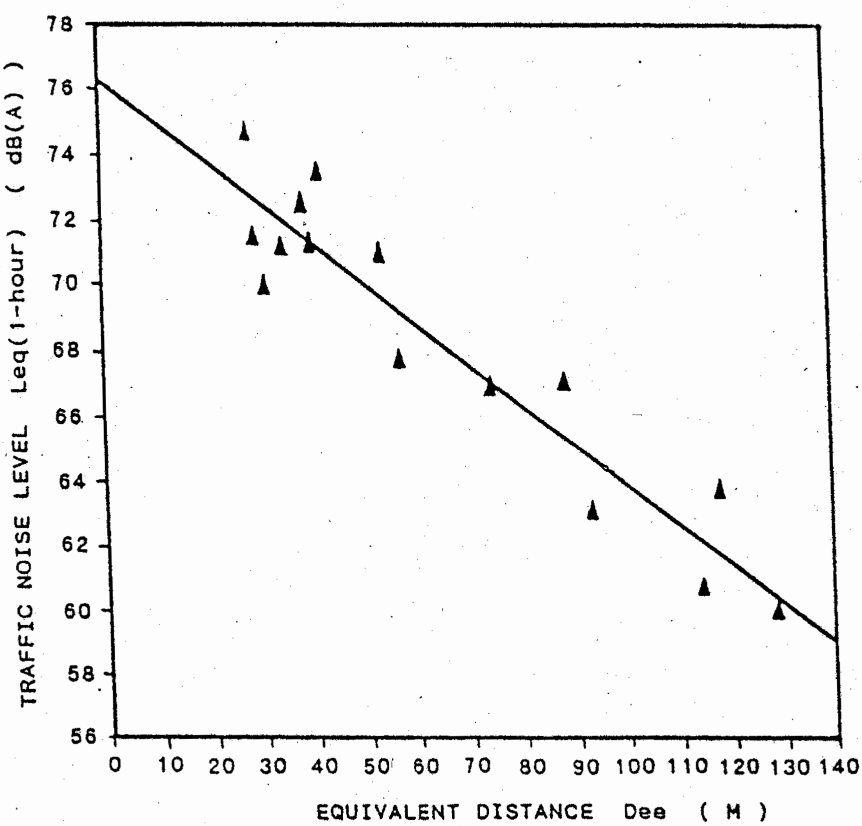

Figure 5 Relationship of Traffic Noise from Elevated Section of Expressway on Building and the Equivalent Distance of Elevated Section (Dee)

dB(A) in Leq of traffic noise would caused by every metre of increment in model. The model also showed that the overall traffic noise level in Leq of this expressway and at-grade road beneath this expressway was 76.46 dB(A) at the zero overall equivalent distance.

The establishment of this model provided a mean of predicting noise level on buildings adjacent to the expressway. Hence, this will facilitate the disign of building and/or the expressway to suit the standard noise level requirement for various category of development.

TRAFFIC NOISE ATTENUATION ON BUILDING WITH RESPECT TO PROPAGATION PATH FROM ELEVATED SECTION OF EXPRESSWAY

The estimation of traffic noise contribution from elevated level of expressway was achieved by filtering the traffic noise contribution from roadway on the at-grade level of this expressway. This was done by estimating traffic noise for at-grade level by using FHWA model with the modified motorcycle noise source into the model.(3,7) This noise was then excluded in logarithmic scale from the Leq(mob) to arrive at Leq(E). The mathematical formular of Leq(E) could be described as the followings.

$$\mathrm{Leq(mob)} = 10 \log \left(10^{\mathrm{Leq(E)}/10} + 10^{\mathrm{Leq(N)}/10} + 10^{\mathrm{Leq(F)}/10} \right)$$

$$\therefore \mathrm{Leq(E)} = 10 \log \left(10^{\mathrm{Leq(mob)}/10} - 10^{\mathrm{Leq(N)}/10} - 10^{\mathrm{Leq(F)}/10} \right)$$

where:

Leq(mob) = Overall traffic noise meassured on building

Leq(E) = Traffic noise contributed from elevated section of expressway

Leq(N) = Traffic noise contributed from near side carriageway of at-grade section.

Leq(F) = Traffic noise contributed from far side carriageway of at-grade section

Assumption made in this analysis is that traffic characteristics are the same during the same time period of the same day in the week at a particular section.(2,8) The modification was also given to the original FHWA model that the motorcycle volume in this analysis is classified under the heavy truck category in traffic noise estimation as previously studied by Pamanikabud.(7)

Linear regression analysis was then performed between the data on Leq(E) and the equivalent distance from elevated seotion of the expressway in order to find the relationship of these two fectors. The result of this relationship is shown in Figure 5, and it could be mathematically expressed as the following.

$$\text{Leq(E) (1-hour)} = 76.12 - 0.12 \text{ Dee}$$

This model gave a highly significant value of R^2 equal to 0.892 and the standard error of estimate equal to 1.55. The magnitude of this value showed the validity of this linear equation.

The model obtained from this analysis provided a mean of predicting potential noise hazard from elevated section of expressway if it passed through a certain land development. Hence, a proper planning on location and height of buildings or the expressway itself could be achieved by controlling the noise propagation path from the elevated expressway to the building in order to reduce critical noise problem.

CONCLUSION

From this project, the results from analyssis of noise propagation path showed that the overall equivalent distance (Doel) which calculated from the geometric mean of equivalent distance of noise source from at-grade section of roadway under the expressway to receiver (Deg) and the equivalent distance of noise source from elevated section of expressway to receiver (Dee) had a highly correlation with the noise level in Leq (1-hour) which received on the different height levels of high-rise building. This model relationship could be expressed as :

$$Leq(mob)\ (1\text{-hour}) = 76.46 - 0.094\ Doel$$

This model provided a high value of R^2 in the ANOVA test equal to 0.882 and the standard error of estimate equal to 1.42. The model can significantly be applied to forcast the overall traffic noise from the combination of both of elevated section of expressway and at-grade roadway below this viaduct expressway.

In the study of noise attenuation on building with respect to only the traffic from elevated section of expressway, the relationship of traffic noise on building in Leq (1-hour) from elevated section of expressway Leq(E) and the geometrical equivalent distance from elevated section of expressway to receiver on building (Dee) could be mathematically described as :

$$Leq(E)\ (1\text{-hour}) = 76.12 - 0.12\ Dee$$

This noise model on building gave a highly significant in the ANOVA test with R^2 equal to 0.892 and standard error of estimate equal to 1.55, and it can be used effectively in combination with the modified FHWA model for foracasting of traffic noise level on high-rise building due to the elevated section of viaduct expressway.

Crocker, M.J., and Kessler, F.M., *Noise and Noise Control*, Vol 11, CRC Press, Florida, 1982.

Box, P.C., and Oppenlander, J.C., *Manual of Traffic Engineering Studies*, 4th Ed., Institute of Transportations Engineers, Virginia, 1976.

Kugler, B.A., Commins, D.E., and Galloway, W.J., *Highway Noise-A Design Guide for Prediction and Control*, National Cooperative Highway Research Program, Report No. 174, Transportation Research Board, Washignton D.C., 1976.

Samuels, S.E., "Traffic Noise Measurement and Prediction Practices in Australia, *Traffic Planning and Safety*, Vol.13, August 1986.

National Association of Australian State Road Authorities, *Guide Policy for Traffic Noise Measurement Procedures*, National Association of Australian State Road Authorities, Sydney, Australia, 1980.

Valerie, B., et al, "Minimising Traffic Noise in Planning New Residential Areas", *Traffic, Transportation and Urban Planning*, Vol.2, Godwin, London, 1981.

Pamanikabud, P., "Highway Traffic Noise Prediction Model for Asian Contry", Proceeding, The Institute of Engineers Australia-Vibration and Noise Conference, Melbourne, Australia, September 1990.

Pamanikabud, P., "Evaluation of the Effect of Bangkok's One-Way Traffic System on the Environmental Quality", *Science of the Total Environment Journal*, The Natherlands, Volume 59, pp.19-30, January 1987.

Bolt Beranek and Newman, *Highway Noise - Generation and Control*, National Cooperative Highway Research Program, Report No. 173, Transportation Research Board, Washington D.C., 1976.