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A study of highway noise pollution in Tehran

M. Vaziri
Department of Civil Engineering
Sharif University of Technology, Iran

Abstract

Urban noise pollution has been a steadily growing problem for developing countries. Urban growth is accompanied by increased highway traffic which is a major contributor to noise pollution. Control laws and management rarely accompany the noise pollution growth. The Greater Tehran Metropolitan Area, GTMA, inhabitants along major highways are being continuously exposed to severe traffic noise health hazards. The objective of this research was to evaluate and model noise pollution due to highway traffic in the GTMA. The study database consisted of relevant information about the noise level, traffic, roadway and meteorological characteristics. The collected noise level information at the roadway sound level meter receptor site included equivalent noise level. The traffic information included traffic flows, traffic speed and composition. The roadway information included number of lanes, median type, roadway functional and location types. The meteorological information included air temperature. The univariate statistical analysis of the database shed some lights on the GTMA noise pollution. The noise level measured at reception points along the GTMA highways was found often in breach of noise standards. The noise level was found significantly correlated with distance from the roadway, traffic conditions, roadway conditions and local weather characteristics. The stepwise multiple regression analysis was used to develop highway noise level descriptive models. These models proved to be simple tools for noise level prediction and management. Although the study findings are for the GTMA and problem specific, the same methodology can be applied in any urban transportation noise pollution study.

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1 Introduction

Traffic noise is generated by the engine and exhaust systems of vehicles, by aerodynamic friction, and by the interaction between the vehicle and roadway. The key sources of vehicle noise are the engine, inlet, exhaust, fan, transmission, road surface, tires, brakes, body and load. Traffic noise at a specific point adjacent to roadway at any instant is the total of all the noises generated by roadway vehicles at various distances from that point. Standard procedures for measuring the noise from individual vehicles under specified conditions by sound level meter have been established in developed countries. The sound level meter is used for evaluation of sound pressure on linear or weighted scales. Its microphone picks up the air pressure waves and its meter reads the sound pressure level, directly calibrated into decibels, or using filtering curves, into weighted scale decibels. Roadway traffic noise can be directly measured by sound level meter or can be predicted by noise information of individual vehicles [1].

The equivalent sound level, L_{eq} is the most common roadway traffic noise exposure index, also recommended by the International Organization for Standardization, ISO [2]. The L_{eq} is computed according to the following equation:

$$L_{eq} = 10 \log (\Sigma f_i \sqrt{10^{(Li/10)}})^2. \tag{1}$$

Where L_i is the sound level in A-weighted decibel, dB(A), and f_i is the fraction of time that L_i is in progress. Empirical traffic noise models have long been developed, such as the following model which is more than half a century old [3], [4], [5]:

$$L_{50} = 68 + 8.5 \log V - 20 \log D. \tag{2}$$

Where L_{50} is mean noise level 50 percentile, exceeded 50 percent of time, measured in dB(A), V is traffic volume in vehicle per hour and D is distance from a traffic line to the observer in feet.

Individuals residing and/or working along traffic arteries are most severely affected by the negative health and welfare impacts of noise pollution. Indeed, traffic noise gives rise to psychological and physiological problems of adjacent roadway inhabitants. It also reduces adjacent roadway property and land values. Most countries have standards and regulations for both interior as well as exterior vehicle noise levels. Most countries have also established community noise standards and regulations. Noise barriers reduce road traffic noise levels and their effects to adjacent properties. Their effectiveness depends on the characteristics of barriers, the topography of the site, changes in the level of the roadway and the distance of the receptors from the noise sources [6].

As the GTMA auto travel continues to grow, noise pollution assails its inhabitants and the due cost to public health and environment escalates dramatically. The GTMA population has grown from about 0.7 million in year

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1941 to more than 9 millions in year 1999. Its current population, surface area and energy consumption are 15%, 0.16% and 20% of the nation, respectively. The average population density is about 10000 persons per square kilometer with higher values in the GTMA central parts. The average trip rate is 1.5 trips per day per capita with more than 30% by personal automobile. The highway fleet consisted of more than 1.5 million vehicles with an average age of 17 years. More than 80% of total roadway vehicle fleet is consisted of automobiles when more than 80% are built in Iran [7].

The Iranian Environmental Protection Agency, IEPA, undertook the first GTMA noise level survey in 1977, and found its levels in the range of 55 to 88 dB(A). The Iranian Ministry of Housing, IMH, undertook the second GTMA noise level survey in 1983, confirming the first study results and identifying higher noise levels along urban highways. The GTMA Municipality is currently conducting the third noise level survey with results to become available in near future. The IEPA has established vehicle and community noise standards; nevertheless, they have not been effectively enforced. The objective of the research reported herein was to shed some light on the status of traffic noise pollution in the GTMA using the IMH 1983 database and limited field survey.

2 Data collection and analysis

The study relevant GTMA traffic noise level information consisted of two parts namely files A and B. The first part, file A, consisted of information extracted from the IMH 1983 databases. The file A consisted of relevant information for 288 roadway sites in the western part of GTMA. The noise level measurement had been carried out by a B&K 2203 sound level meter located at the pavement edge. The traffic noise level L_{eq} had been recorded for durations of 5, 15 and 30 minutes, respectively. The second part, file B, consisted of the field survey information gathered by a B&K 2203 sound level meter in June 1999. The limited resources confined the field survey data collection to 4 roadway sites. The selected sites were typical roadways with minimum environmental interference and were located in the western part of GTMA. The noise level measurements were taken at distances of 0, 10, 20 and 30 meters from pavement edge, respectively. The traffic noise level L_{eq} was recorded for 5 minutes duration. The study database files A and B consisted of 288 and 120 records, respectively.

The database univariate analysis shed some lights on the status of GTMA traffic noise pollution. The minimum, mean, maximum, range and standard deviation of the variables for 408 records are summarized in Table 1. The table has 16 and 8 variables from files A and B, respectively. For the nominal variables CBA, TAA, TBA, TCA, TDA and MDA, the minimum and maximum are listed as 0 and 1, respectively. The table shows similarity of files A and B regarding the means and standard deviations. The mean value of variables LAA, LBA, LCA and LQB were 74.86 dB(A) , 75.15 dB(A), 75.05 dB(A) and 76.74 dB(A) respectively. According to the Organization for Economic Cooperation and Development, OECD, noise levels above 55 dB(A) are undesirable. Urban

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Table 1. Results of univariate statistical analysis.

variable	description	file	min.	mean	max.	st. de.	dimen-sion
VHA	vehicle flow rate	A	17	2161	11988	2130	veh/hr
CRA	car flow rate	A	17	1753	10608	1059	veh/hr
CBA	central business district	A	0	0.052	1	0.226	n/a
TAA	expressway	A	0	0.115	1	0.321	n/a
TBA	arterial	A	0	0.283	1	0.452	n/a
TCA	collector	A	0	0.243	1	0.438	n/a
TDA	local street	A	0	0.358	1	0.475	n/a
LNA	number of traffic lanes	A	2	4.351	10	1.405	lane
LAA	5 minute L_{eq}	A	54.6	74.86	84.4	6.45	dB(A)
LBA	15 minute L_{eq}	A	55.7	75.15	85.5	6.29	dB(A)
LCA	30 minute L_{eq}	A	54.9	75.05	85.1	6.41	dB(A)
MOA	motorcycle flow rate	A	0	318	3481	459	veh/hr
SPA	speed	A	10	47.6	110	18.95	km/hr
TPA	temperature	A	2	19.9	34	6.77	celsius
MDA	median	A	0	0.27	1	0.44	n/a
TKA	truck flow rate	A	0	88	672	119	veh/hr
MOB	motorcycle flow rate	B	0	51	241	59	veh/hr
TKB	truck flow rate	B	0	367	1798	185	veh/hr
DSB	distance to pavement	B	0	15	30	11.25	meter
CRB	car flow rate	B	660	1545	3180	369	veh/hr
VHB	vehicle flow rate	B	960	1962	3542	456	veh/hr
LQB	5 minute L_{eq}	B	70.4	76.74	85.6	4.24	dB(A)
SPB	speed	B	65	78.96	85	5.75	km/hr
TPB	temperature	B	15	21	28	3.22	celsius

areas with noise levels above 70 dB(A) are not permitted for housing development in France. Table 1 shows that the GTMA roadway traffic is a major noise pollution generator contributing significantly to the overall levels of its environmental pollution. Although the observed traffic noise levels were in breach of noise standards, mitigation measures and noise barriers have not been utilized effectively. Table 1 confirms the severity of traffic noise pollution in the GTMA when relevant noise management schemes such as noise barrier, traffic and land use control have considerable potentials for preventing inhabitants' exposure to excessive traffic noise.

To develop an understanding of the interrelationships among the files A and B variables, pairwise correlation analyses were performed. The size of 16 by 16 and 8 by 8 correlation matrices prevented their display herein. The matrices revealed a number of interesting patterns and were found useful in modeling

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phase of the study. Many pairs of variables were found significantly correlated. On the average, each of the variables was correlated, at a level of significance 0.05, with 38 percent of the others in its file. The results of correlation analyses conformed to expectations. Traffic flows and speed variables of VHA, CRA, MOA,, TKA and SPA demonstrated positive associations with equivalent noise level variables of LAA, LBA and LCA. Traffic flows and speed variables of VHB, CRB, MOB, TKB and SPB demonstrated positive associations with equivalent noise level variable LQB. Distance variable DSB demonstrated negative association with equivalent noise level variable LQB.

3 Regression modeling

Stepwise regression analysis was carried out to develop noise equivalent level prediction models. For file A, variables LAA, LBA and LCA, and for file B, variable LQB were used as dependent variables. For file A, variables VHA, CRA, CBA, TAA, TBA, TCA, TDA, LNA, MOA, TKA, SPA, MDA and TPA were candidate independent variables. For file B, MOB, TKB, DSB, CRB, VHB, SPB and TPB were candidate independent variables. Many models were developed and evaluated.

Based on coefficient of determination and independent variables' description, the following five models were selected from file A:

$$\mathrm{LAA} = 67.34 + 0.0016\ \mathrm{VHA} + 0.08\ \mathrm{SPA}. \tag{3}$$

$$\mathrm{LAA} = 70.19 - 4.56\ \mathrm{TDA} + 1.16\ \mathrm{LNA} + 3.07\ \mathrm{CBA} + 0.0008\ \mathrm{VHA}. \tag{4}$$

$$\mathrm{LAA} = 69.59 - 4.12\ \mathrm{TDA} + 1.21\ \mathrm{LNA} + 0.0025\ \mathrm{MOA} + 0.0074\ \mathrm{TKA}. \tag{5}$$

$$\mathrm{LBA} = 69.29 - 4.16\ \mathrm{TDA} + 0.75\ \mathrm{LNA} + 0.04\ \mathrm{SPA} + 0.0007\mathrm{VHA}. \tag{6}$$

$$\mathrm{LCA} = 68.64 - 3.77\ \mathrm{TDA} + 0.73\ \mathrm{LNA} + 0.05\ \mathrm{SPA} + 0.0007\mathrm{VHA}. \tag{7}$$

Where variables are defined in Table 1. Eqn (3) shows the effect of traffic flow rate and traffic speed on 5 minute L_{eq} with a coefficient of determination of 0.40. Eqn (4) shows the effect of existence of local street, number of traffic lanes, existence of central business district and traffic flow rate on 5 minute L_{eq} with a coefficient of determination of 0.43. Eqn (5) shows the effect of existence of local street, number of traffic lanes, motorcycle flow rate and truck flow rate on 5 minute L_{eq} with a coefficient of determination of 0.46. Eqn (6) shows the effect of existence of local street, number of traffic lanes, traffic speed and traffic flow rate on 10 minute L_{eq} with a coefficient of determination of 0.51. Eqn (7) shows the effect of existence of local street, number of traffic lanes, traffic speed and traffic flow rate on 15 minute L_{eq} with a coefficient of determination of 0.52.

Based on coefficient of determination and independent variables' description, the following two models were selected from file B:

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$$LAB = 67.11 - 0.35\ DSB + 0.14\ SPB + 0.022\ TKB + 0.008\ CRB. \qquad (8)$$

$$LAB = 67.78 - 0.34\ DSB + 0.12\ SPB + 0.011\ VHB. \qquad (9)$$

Where variables are defined in Table 1. Eqn (8) shows the effect of distance from pavement edge, traffic speed, truck flow rate and car flow rate on 5 minute L_{eq} with a coefficient of determination of 0.88. Eqn (9) shows the effect of distance from pavement, traffic speed and traffic flow rate on 5 minute L_{eq} with a coefficient of determination of 0.89. Eqns (3) to (9) can be used in equivalent noise level prediction. Based on the study field survey reliability, variable description and coefficient of determination, eqn (9) is suggested as the best-developed model.

4 Conclusions

Roadway traffic noise pollution for the GTMA was studied. Relevant information was extracted from the IMH 1983 noise level survey databases and was also collected from a field survey. The study database consisted of 408 records with relevant information about the noise level, traffic, roadway and meteorological characteristics. The univariate statistical analysis of the database 24 variables shed some lights on the GTMA noise pollution. The equivalent noise level at reception points along the GTMA roadways was found often in breach of noise standards. The minimum, mean, maximum, range and standard deviation of the variables revealed a number of interesting patterns and were found useful in multivariate statistical analysis and modeling phases of the study. The equivalent noise level was found significantly correlated with traffic flow rates, traffic composition, traffic speed, roadway type, roadway location and distance from roadway pavement. This study is the first effort to develop prediction models for equivalent traffic noise level for the GTMA. Although the study findings are based on a rather limited database and are location specific, the same methodology can be applied in future traffic noise pollution studies.

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References

[1] Watkins, L.H. Environmental impact of roads and traffic (Chapter 2). *Vehicle and Traffic Noise*, Applied Science Publishers, London, pp. 10-49, 1981.

[2] Sincero, A.P. and Sincero, G.A. Environmental engineering, a design approach (Chapter 14). *Noise Pollution and Controls*, Prentice-Hall International Inc., London, pp. 686-752, 1996.

Paper from: *Urban Transport VIII*, LJ Sucharov and CA Brebbia (Editors).
ISBN 1-85312-905-4

[3] Papacostas, C.S. Fundamentals of transportation engineering (Chapter 10). *Air Quality, Noise, and Energy Impacts*, Prentice-Hall International Inc., London, pp. 343-374, 1990.

[4] Parida M. and Jain S.S. Urban noise modeling and abatement measures. *Proc. of the 2nd Asia Pacific Conference & Exhibition on Transportation and The Environment, Volume 2,* People's Communications Publishing House, Beijing, pp. 869-877, 2000.

[5] Yuan, W., Cao, W., and Zhang, Y. Test research on sound intensity of traffic noise of city roads. *Proc. of the 2nd Asia Pacific Conference & Exhibition on Transportation and the Environment, Volume 2,* People's Communications Publishing House, Beijing, pp. 883-888, 2000.

[6] Haling, D. and Cohen, H. Residential noise damage costs caused by motor vehicles. *Transportation Research Record,* No. 1559, pp. 84-93, 1996.

[7] Haj-Nasrlahi, K. and Tabatabai, A. Development of urban rail transport for Tehran, *Traffic Engineering Issues*, Vol. 7, pp. 36-42, 2000.