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A COMPACT MODEL FOR PREDICTING ROAD TRAFFIC NOISE

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ABSTRACT
Noise is one of the most important sources of pollution in the metropolitan areas. The recognition of road traffic noise as one of the main sources of environmental pollution has led to develop models that enable us to predict noise level from fundamental variables. Traffic noise prediction models are required as aids in the design of roads and sometimes in the assessment of existing, or envisaged changes in, traffic noise conditions. The purpose of this study was to design a prediction road traffic noise model from traffic variables and conditions of transportation in Iran.

This paper is the result of a research conducted in the city of Hamadan with the ultimate objective of setting up a traffic noise model based on the traffic conditions of Iranian cities. Noise levels and other variables have been measured in 282 samples to develop a statistical regression model based on A-weighted equivalent noise level for Iranian road condition. The results revealed that the average L_{Aeq} in all stations was 69.04± 4.25 dB(A), the average speed of vehicles was 44.57±11.46 km/h and average traffic load was 1231.9 ± 910.2 V/h.

The developed model has seven explanatory entrance variables in order to achieve a high regression coefficient (R^2=0.901). Comparing means of predicted and measuring equivalent sound pressure level (L_{Aeq}) showed small difference less than -0.42 dB(A) and -0.77 dB(A) for Tehran and Hamadan cities, respectively. The suggested road traffic noise model can be effectively used as a decision support tool for predicting equivalent sound pressure level index in the cities of Iran.

Key words: Noise, Noise pollution, Traffic noise, Environment, Prediction model, Modeling

INTRODUCTION
Road traffic noise is the most significant source of environmental noise pollution in cities. Noise is almost one of the harmful agents for citizenships; therefore many countries have introduced noise emission limits for vehicles and issued other legislations to reduce road traffic noise (Abbaspour *et al.,* 2006; Ross, 2001; Stefano, 2001; Mansouri *et a.,l* 2006). In recent years, in certain countries, new restricting laws to control civic road traffic noise, have been performed.

The recognition of road traffic noise as one of the main sources of environmental pollution has led to design models that enable us to predict traffic noise level. Several models have been developed via a regression analysis of experimental data, from fundamental variables such as traffic flow, speed of vehicles and sound emission level (Stefano, 2001; Alimohammadi, 2005).

Traffic noise prediction models are required as aids in design of roads and sometimes in assessment of existing, or envisaged changes in traffic noise conditions. Several models have been developed from fundamental variables such as traffic flow and speed of vehicles using regression analysis of experimental data (Stefano, 2001). In recent years some developed models for prediction of road traffic noise were suggested (Lam, 1998’ Steel, 2001; Stefano, 2001; Li, 2002; Parida,

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2003; Gundugdu, 2005; Tansatcha, 2005). Traffic noise prediction models are commonly needed to predict sound pressure levels, specified in terms of L_{Aeq}, L_{10}, etc., set by government authorities (Steele, 2001).
Authors have suggested the four explanatory factors to predict equivalent sound pressure level L_{Aeq} (Golmohammadi *et al.*, 2007). The four explanatory factors, consisting twelve variables, are as follows: 4 road dimensions, traffic flow factor for 4 types of vehicles (cars, mini trucks, trucks and motorcycles) and 4 traffic speed factors for them. The developed model has twelve explanatory variables in order to achieve a proper fit for measured values of L_{Aeq} (R^2=0.913). Measuring of the 12 variables for predicting road traffic noise is difficult and long term. Therefore in this paper a compact model by 4 road dimensions and 3 variables for traffic flow were used to obtain a prediction of L_{Aeq}. The purpose of this study was to introduce a compact road traffic noise model from traffic variables and conditions for the transportation of cities of Iran.

MATERIALS AND METHODS

In this study, the main roads of Hamadan city, in the west of Iran, were classified to 64 sections. The basic data were gathered using digital maps and field observation. In each road restriction, ten probable stations at two sides of the road section were specified and then for each section, two random stations were selected. After eliminating repeated stations, neighbor and opposite stations, finally 94 stations were chosen. In the pilot stage of the study, for optimizing duration of noise measurement time, 30 random stations were selected. The results of pilot stage of this study showed that a 10-minute interval measurement of equivalent sound pressure level could effectively forecast the hourly values of L_{Aeq} 30 to 60 minutes (Abbaspour *et al.*, 2006) in each stations (p = 0.998).
Estimation the necessary number ofsamples was based on the mean and standard deviation of equivalent noise pressure level at pilot stations and considering maximum sampling error equal to 0.5 dB(A) with a confidence Interval equal of 99%. Therefore, in the main stage of study in 94 cited stations, totally 282 measurements including two 10min noise measurements at day's hours (7am to 10pm) and one at night hours (10pm to 7am) were conducted. For each sample, the following parameters were simultaneously measured: LAeq [dB(A)], total quantity of vehicles per hour, mean vehicles speed (km/h). Road dimensions were also recorded on measurement sheet including: length of road section, road pathway width, gradient of road and buildings height around the road.
Noise measurements were done at a distance of 3 m from the road side of the nearest road band on the height of 130cm above the road surface (BS 4142, 1997). A B&K sound pressure level meter type 2260 has been used for measurements.
Entire data set was utilized to develop a compact model for Iranian city conditions by using multiple regression analysis. All of collected data were recorded in statistical sheet of Excel and SPSS software. The plot of data between L_{Aeq} and mean vehicles speed or vehicle flow showed a logarithmic variations for obtaining convenient linear regression fit.
After testing different states of effective variables, finally seven explanatory variables were selected for multiple variable regression method to obtain the model. Traffic flow was considered, linear, two lines and free flow. This designed model can predict L_{Aeq} in distance of 3m from the roadside edge. Fig. 1 shows the position of microphone in all of noise variable measurements in this study for designing of the model. For other distances far from the base distance, existing equations of other studies were applied (Steele, 2001; Zannetti, 2004).

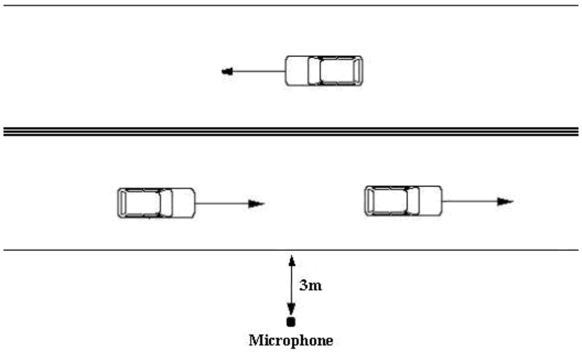

Fig. 1: Position of microphone in all measurements

RESULTS

The results of the pilot stage of the study showed that the mean equivalent sound pressure level at measuring stations was 70.76±2.11 db(A), 70.88±2.19 dB(A) and 70.93±2.13 dB(A). The results showed that there is no significance difference between the L_{Aeq} in time intervals of 10, 30 and 60 minutes (p= 0.998), respectively. In the pilot stations the mean of background sound pressure level was 60.77±5.04 dB(A). The results showed that the background level had not considerable effect on traffic noise level.

The results of the main stage of the study showed that the average of L_{Aeq} at all stations was 69.04±4.25 dB(A), average of vehicles speed was 44.57±11.46 km/h and average of vehicle flow was 1231.9±910 per hour. The mean values of the main variables are shown in Table 1. Statistical analysis showed that the mean of L_{Aeq} in day-night hours is significant (p = 0.003). The noise map of Hamadan`s main roads is shown in Fig. 2 The distribution of equivalent day-night noise levels in main stage of the study are shown in Fig. 3 Distribution of L_{Aeq} with logarithmic variations of total traffic flow are presented in Fig. 4 In this study, the compact traffic noise prediction model from multiple regression analysis between variables, were calculated as follows:

Table 1: Details of noise measurement, environmental and dimensional factors of roads

parameter	n	Mean	SD
Total number of vehicles (v/hr)	282	1231.9	910.24
Mean speed of total vehicles (km/hr)	282	44.57	11.46
SPL_{min} dB(A)	282	52.32	8.62
SPL_{max} dB(A)	282	82.94	4.21
LAeq dB(A)	282	69.04	4.25
Road section length (m)	282	1045.0	889.6
Road section gradient (%)	282	2.01	1.5

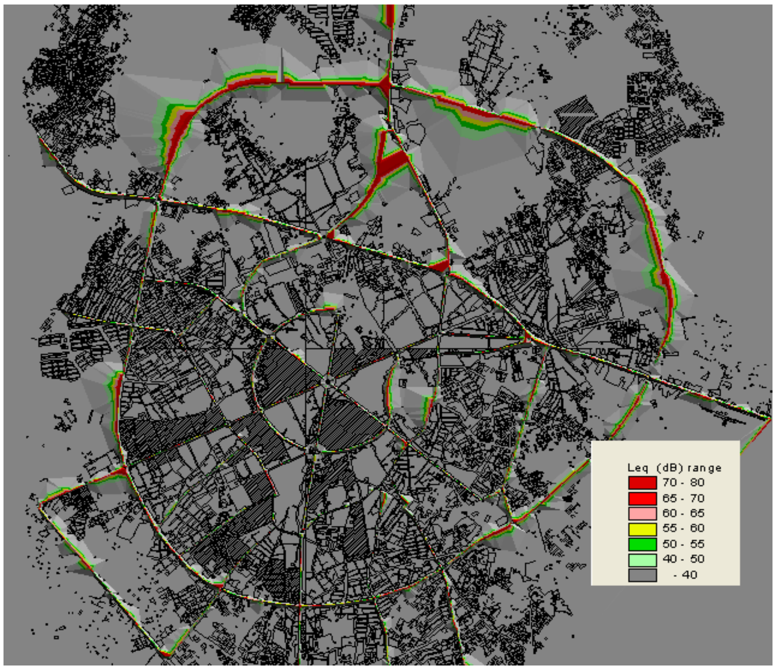

Fig. 2: Noise map of Hamadan main roads showing identified field study

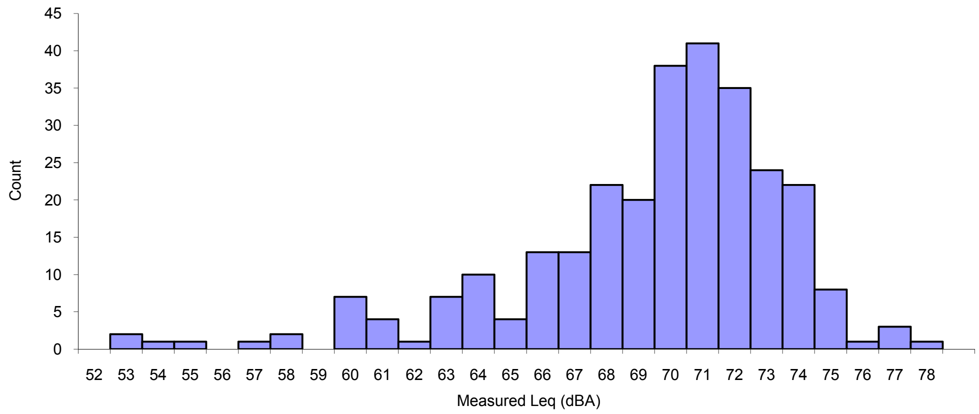

Fig. 3: Distribution of equivalent day night noise levels in main stage of the study

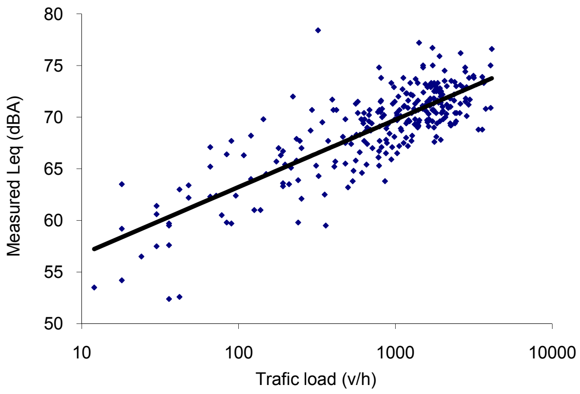

Fig. 4: Distribution of L_{Aeq} with total traffic flow

a) Calculation of traffic flow and traffic speed effect:

$$\Delta NV(\text{dBA}) = (7.228 \log N_t) - (0.238 \times \log V_t) + (0.208 \times P) \quad (1)$$

Where:
Nt= Number of vehicles (v/h)
Vti= Mean speed of vehicles (km/h)
P= Percent of heavy trucks (%)

b) Calculation of road dimensions effect:

$$\Delta D = (5.624\times10^{-4} L) - (8.13\times10^{-2} W) - (3.71\times10^{-2} H) - (7.65\times10^{-2} S) \quad (2)$$

Where:
L= Length of road section (m)
W= width of road section (m)
H= Height of building around the road (m)
S= Gradient (gradient) of road section (%)

c) Calculation of equivalent sound pressure level ($L_{Aeq\,(ref)}$) 3 meters near road side:

$$L_{Aeq(ref)}(\text{dBA}) = 48.48 + \Delta D + \Delta NV \quad (3)$$

d) Calculation of equivalent sound pressure level (L_{Aeq}) in other distances from road side:

$$L_{Aeq}(dBA) = L_{Aeq_{(ref)}} - \Delta_e \quad (4)$$

Where:
Δe= Effect of distance, surface, foliage, air temperature, humidity and barriers (dBA) (Zannetti P . 1997)

The fitted multiple regression models were based on standardized variables. The results showed a high determination coefficient (R^2=0.901). The results of verification of designed model in this study showed the mean of predicted L_{Aeq} was 68.27±3.81 dB(A). Comparing means of predicted L_{Aeq} and measuring L_{Aeq} [69.04±4.25 dB(A)] showed small difference of -0.77 dB(A). The scatter plot of predicted and measured values of L_{Aeq} is shown in Fig. 5. Also, Fig. 6 shows the trend of predicted and measured values of L_{Aeq} during day-night in the study. Table 2 shows a between measured L_{Aeq} and predicted values based on different empirical models containing the suggested model.

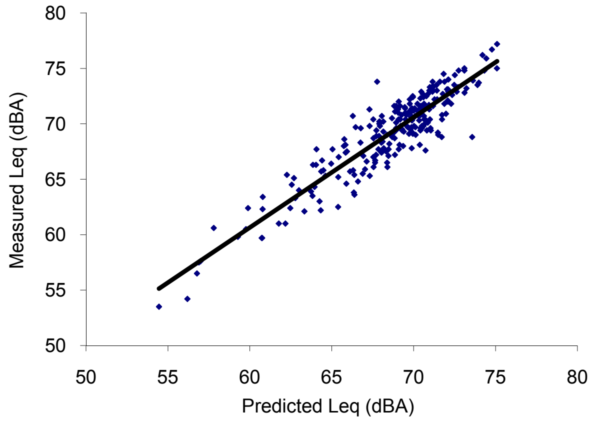

Fig. 5: Distribution of predicted L_{Aeq} by model and measured values in reference distance from roadside

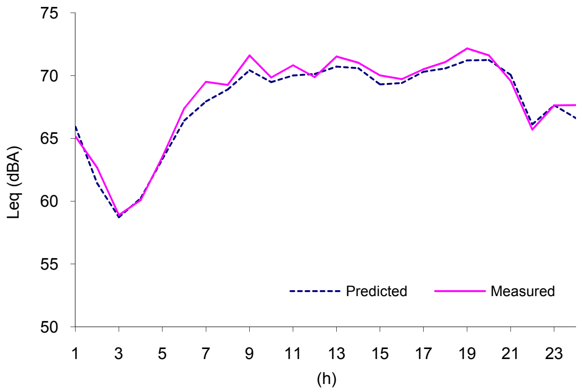

Fig. 6: Trend of prediction and measurement of L_{Aeq} during day-night for the studied field.

Table 2: Comparing prediction of L_{Aeq} by designed model and some empirical models for studied data

parameter	Mean	SD	Mean difference
Measured L_{Aeq}	69.04	4.25	-
Suggested model for study field	68.27	3.81	-.077
Suggested model for Tehran's data (Mohsseni, 1998)	74.75	1.02	-0.42
FHWA-TNM 2.5	65.38	4.69	-3.65
Parida, 2003	72.24	4.50	+3.20
Lam, 1998	64.07	5.71	-4.97
Li, 2002	65.43	5.21	-3.61
Calixto, 2003	71.85	4.02	+2.81
Gundogdu, 2005	59.98	1.36	-9.06

DISCUSSION

Traffic noise prediction models are required as aids in the design of roads and sometimes in the assessment of existing, or of envisaged changes in, traffic noise conditions. They are commonly needed to predict sound pressure levels, specified in terms of L_{Aeq_i} - L_{10}, etc. Several models have been developed via a regression analysis of experimental data, from fundamental variables such as the traffic flow, speed of vehicles and dimension of roads (Stefano, 2001). This paper is the result of one study performed in 2005-2006 in Iran. Study data from 282 samples were utilized to develop a compact model for Iranian conditions using regression analysis.

The developed regression model can be suitably applied for all urban areas in the country. The suggested model has a high coefficient of determination, which indicates adequacy of the model. This is applicable only for urban roads with speeds less than 90 km/h and traffic flow less than 5000 v/h.

The results of the pilot stage of this study suggested that one 10min measurement sufficed for prediction of $L_A$eq of 30min to 1h in the main stage of the study. Therefore, in the main stage of the study, a 10-minute duration measurement in each station for predicting the 30min to hourly equivalent levels was performed. The reliability of FHWA TNM 2.5 model based on 15-minute measurement has been verified (Steele, 2001). These experiences point out that the changes in sound pressure levels in a time interval of 10 to 15 minutes could forecast the hourly changes.

Logarithmic distribution plot between speed of vehicles and traffic flow was shown a nice condition for predicting L_{Aeq} in the designed linear regression model. Other researchers also showed to be confirmed this matter (Steele, 2001;

Parmanikabud, 2002; Li, 2002; Calixto, 2003; Parida, 2003; Tang, 2004; Gundugdu, 2005; Tansatcha, 2005).

The developed model has seven explanatory variables in order to achieve a high R square coefficient. In the suggested model, some additional variables such as road length, gradient and height of building around the roads were considered. The important point in this study was the number of explanatory variables and mean difference between measured and predicted value of L_{Aeq} compared to the other empirical models (Tang, 2004; Calixto, 2003; Pamanikabud, 2002; Li, 2002; Parida, 2003; Lam, 1998). Comparing the designed model and some empirical models showed a minimal difference between prediction and measured L_{Aeq} (Table 2). Results showed the minimal difference of prediction of $L_A$eq by FHWA-STAMINA [-2.22 dB(A)] to maximal difference of Gundugdu model [-9.06 dB(A)] below the measured values. Also, Calixto model [+2.81 dB(A)] and Parida model [+3.20 dB(A)] showed the minimal and maximal values above the measured values of equal sound pressure levels respectively, whereas the suggested model had a minimum difference between predicted and measured L_{Aeq} [-0.77 dB(A)].

Verification of developed model for 48 samples of road traffic data in Tehran city (Mohsseni, 1998) showed that difference between mean predicted of L_{Aeq} and measurement values was -0.42 dB(A) (p=0.168), Therefore, this road traffic noise model can be effectively used as a decision support tool for prediction of traffic noise index [$L_{Aeq\ (30min)}$] in the same Iranian cities.

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REFERENCES

Abbaspour, M., Golmohammadi, R., Nassiri, P., Mahjub, H., (2006). An Investigation on Time-Interval Optimization of Traffic Noise Measurement. Journal of low frequency noise vibration & active control, **25(**4**):** 267-273.

Alimohammadi, I., Nassiri ,P., Behzad, M., Hosseini, M .R., (2005) .Reliability analysis of noise estimation in highways of Tehran by Monte Carlo simulation method, Iranian Journal of Environmental Health Science and Engineering, **2(**4**)** : 229-236.

BS, Method for rating industrial noise affecting mixed residential and industrial areas, British Standard, BS 4142, 1997.

Calixto, A., et al., (2003). The statistical modeling of road traffic noise in an urban setting. Cities. **20**: 23-29.

Golmohammadi, R., Abbaspour, M., Nassiri, P., Mahjub, H., (2007). Road traffic noise model, Journal of Research in Health Sciences, **7(**1**):** 13.17.

Gundogdu, O., Gokdag, M., Yuksel, F., (2005). A traffic noise predication method based on vehicle composition using genetic algorithms. Applied acoustics, **66:** 799-809.

Lam, W. H .K. & Tam, M . L., (1998). Reliability analysis of traffic noise estimates in Hong Kong. Transportation research Part-D. **3(**4**):** 239-248.

Li, B., et. al., (2002). A GIS based Road Traffic Noise Predication Model, applied acoustics, **63:** 679-691.

Li, B., Shu ,T., Dawson, R .W., (2002). Evaluation and analysis of traffic noise from the main urban road in Beijing. Applied acoustics. **63:** 1137-1142.

Mansouri, N.A., Pour Mahabadian, M., Ghasemkhani, M .,(2006). Road Traffic Noise in Downtown Area of Tehran, Iranian Journal Of Environmental Health Science And Engineering, **3(**4**):** 261-266.

Mohseni PH, Correction for the road traffic noise model in Tehran, MSc thesis, Islamic Azad University (IAU)-Research branch, 1998.

Parida, M., Jain, S.S., Mittal, N., (2003). Modelling of metropolitan traffic noise in Delhi, ITPI Journal. **21(**1**):** 5-12.

Pamanikabud, P., & Prakob, V., (2002). Noise prediction for highways in Thailand, Transportation research part D. **7:** 441-449.

Ross, M., Brain & Wolde, T., (2001). noise from traffic as a worldwide policy problem. Noise control engineering journal. **49(**4**)**: 159-161.

Stefano, R ., Danato, D., & Morri, B., (2001). A Statistical Model for Predicting Road Traffic Noise on Poisson Type Traffic Flow. Noise control engineering journal. **49(**3**)**: 137-143.

Steele, C., (2001). A Critical Review of Some Traffic Noise Prediction Models, applied acoustics. **62**: 271-287.

Tang, S .K., & Tong, K .K., (2004). Estimating traffic noise for inclined roads with freely flowing traffic, applied acoustics. **65:** 171-181.

Tansatcha, M ., Pamanikabud, P., Brown, A.L., Affum, J. K., (2005). Motorway noise modelling based on perpendicular propagation analysis of traffic noise, Applied acoustics. **66:** 1135-1150.

Zannetti, P., Environmental Modeling Vol(I), CMP & Elsevier, New York, 1997.