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Designing a Traffic Noise Prediction Model for Highways in Iranian Megacities (Case study: Ahvaz City)

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ABSTRACT: One of the important factors in urban construction designs is noise prevention. According to results of this study (2011-2012), a suggested model is presented for traffic noise compatible to conditions in Ahvaz. Data was colleted to design a model from totally 112 measuring stations, 4 weekdays and 2 intervals as rush hours, yielding to a total number of 1344 traffic noise measurements (L_{eq}) and the effective factors from traffic load, speed of vehicles, environmental and dimensional factors of roads. In the next step, based on desired overall structure, using analytical and experimental modeling strategies, several Regression multi-variables were tested on data in order to design a model. The model designed for Ahvaz consists of 9 inputs with high clarification coefficient (R^2=0.92) and correlation coefficient (R= 0.95). Due to precision and minuteness of designing as well as the number of inputs, the model can be a suitable one to define half – hour equal level for traffic noise and estimation of noise pollution in Ahvaz.

Key words: Noise pollution,FHWA- STAMINA,Validity, Model development, Urban area, Southwest of Iran

INTRODUCTION

Environmental pollution has been a growing global concern in the last three decades. Noise pollution among all other types is a worldwide concerning issue (Abbaspoor & Nassiri, 1996; Sazegar niya *et al.,* 2005). Traffic and transportation of vehicles are two of the main causes (Omidvari *et al.,* 2003; Corbitt, 1998; Kiely, 1997). Since transportation of vehicles at streets, roads, and highways directly affects the lives of people living near there, an evaluation of traffic noise and predictions for decreasing environmental pollutions is getting a more and more important issue in urban areas (Golmohammadi, 2010; Alimohammadi, 2005). An appropriate model for environmental noise caused by traffic can portray a clear picture of distribution and quality of noise pollution in an urban area, so that the application of such a model and city management can provide a healthful and peaceful living condition to the inhabitants. If the model is able to estimate and predict traffic noise too, it can be one of the main components of urban designing and civil development (Golmohammadi, 2007). In many developed countries, there are comprehensive, elaborated national models designed for this. Rahmani *et al.,* (2011), reported two statistical models for road traffic noise in Mashhad, by applying analytic algorithm and considering parameters of traffic load, vehicles combination and speed, in order to calculate L_{eq}.

Banerjee *et al.,* (2008), studied effective factors on L_{eq} and developed models for industrial city, Asansol, India. Gundogduo et al. (2005), Presented a model for Erzurum, western Turkey by applying a genetic algorithm model. They classified vehicles in 3 groups, and passage slope, vehicles combination, maximum distribution level of cars were there variables. Pamanikaboud and Viuitajinda (2002), presented a separate model for seven groups of vehicles In Thailand. Seung cho & Mun (2008), depicted a model in order to evaluate highway traffic noise in Northern korea. Abu-Qudais & Alhiary (2007), developed 3 models for L_{max}, L_{eq}, L_{min} based on analyses 14235 records in Jordan. Ahwaz, the center of Khouzestan Province, of 220 m^2 area and a population of over

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1405939, is amongest important cities due to its geographical and industrial status. Drastiz expansion in urban areas, universities and industries, in the last few years in Ahwaz, has increased transportations through city roads and routs so that total number of vehicles including bicycles, motorcycles, cars, taxies, van and long vehicles are over 336710, a fact which has caused various types of pollution, especially noise pollution. Therefore, the present study was an attempt to measure traffic noise and its causes based on appropriate strategies and data transferred by modeling techniques and databases to calculating software in order to designs a model. Advanced statistical techniques and multi- variable Regression Aralyser in SPSS were both applied to relate a comprehensive model for research on highways in Ahwaz.

MATERIALS & METHODS

Data was collected form 1344 measurments of traffic noise (L_{eq}) along with effective parameters including traffic load, speed, environmental features, road sizes and climate conditions in 112 stations on 7 main roads of the city. (Pasdaran Highway, Ayatollah Behbahani H.W, Enqhelab Bolivar, Chamran B.L.V, Gohestan Blv, Dr. Shariati St and Azadegan st.) Measurments were performed on 4 days of a week (sat, Tue, Thur, Fr) which represented weekdays and weelcend (Omidvari *et al.,* 2003; Wetzel *et al.*, 1999; Naddafi *et al.*, 2008; Mary Aryad *et al.*, 2007). According to EPA samples were mainly collected at rush hours. Measurements were done at three rush hours (7-8 A.M. 12-13 P.M. 8-9 P.M.). Squares, intersections, areas between the selected spots were considered as stations (Wetzel *et al.,* 1999; Owaysi *et al.*, 2003; Emam Jomah *et al.,* 2010). Measurements were recorded by advanced Sound Level Meter CEL-450. The device is so accurate and in accordance with international standards. The above mentioned system has various models and applications, able to measure various noise pollution variables (Naddafi *et al.*,2008). The S.L.M was calibrated daily and before measuring when the device was stopped and in order to eliminate wind effect, a sponge protector was used on microphone (Golmahammadi., 2010; Sanford., 1978). The device was mounted at 1.6 m from the ground (Rahmani *et al.,* 2011; Pamanikabud & vivitjinda, 2002; Abo-Qudais & Alhiary, 2007; Tansatch *et al.,* 2005). Noise recording was done based on the standard distance from roadway (3 meters) (Golmahammadi, 2007; Givargis & Rahmani, 2010; Givargis & Mahmoodi, 2008), and in frequency distribution network A (Sazegar niya *et al.,* 2005; Abo-Qudais & Alhairy, 2007). Each sampling lasted for 30 minutes (Golmahammadi, 2007; ISO, 1996; Banerjee, 2008). All measurements were done on two sides of the road (Golmahammadi, 2007; ISO, 1996; ISO, 131- 1979; Pamanikaboud *et al.,* 2008; Benang *et al.,* 2002).

As mentioned above, the best multivariable Regression line model was required, according to the research objective, to be based on relations between independent variables effective on traffic noise and dependent variable (L_{eq}). Regarding designed models in various countries (Golmahammadi, 2007; Rahmani *et al.,* 2011; Gundogdu *et al.,* 2005; Wetzel *et al.,* 1999; Tansatch *et al.,* 2005; Givargis Karimi, 2010; Benang Li *et al.,* 2002). It was hypothesized that dependent variable (L_{eq}) was to be a function of 15 independent variables. Fifteen applied dependent variables with their indices are listed below:

L: The length of the path (m).
W: Overall width of the road m).
H: Height of the surrounding buildings (m).
S: Slope of the path. (%) percent
F: The orea planted on the path (m^2)
N1: Number of passing vehicles including cars, vans, per hour. (with maximum weight of 4500 kg).
N2: Number of passing long vehicles including trucks, minibuses per hour. (with overall weight between 4500-12000 kg).
N3: Number of passing vehicles including trucks, buses, per hour with overall weights over 12000 kg).
N4: Number of passing motorcycles and tricycles per hour.
V1: Average speed of passing cars and vans (km/h)
V2: Average speed of passing trucks and minibuses (km/h)
V3: Average speed of passing trucks and buses (km/h)
V4: Dry weather temperature (ċ)
RH: Relative humidity (%)

Denotational Count (cars, semi – long, long vehicles, motor-cycles) was done at the same time of noise measuring. In order to calculate average speeds, the time of passage of each type of vehicle passing through two spots was recorded by a chronometer, and then it was calculated by given distances and speed formula. The climate conditions effective on sound such as dry temperature and relative humidity as well as dimension features of roads (Planted areas sizes, surrounding buildings, and heights) were recorded while measuring. After recording all required samples, in order to design the model, collected data was transferred to Excel and SPSS. In the next step required calculations were performed on traffic data to prepare the model. To study relations between each of the 15 independent variables and dependent variable (L_{eq}) Stepwise Method was applied on SPSS. This is the best method for statistical modeling. Modeling was done in several steps by multivariable Regression Analysis. This technique is able to correlate independent variables to a dependent one.

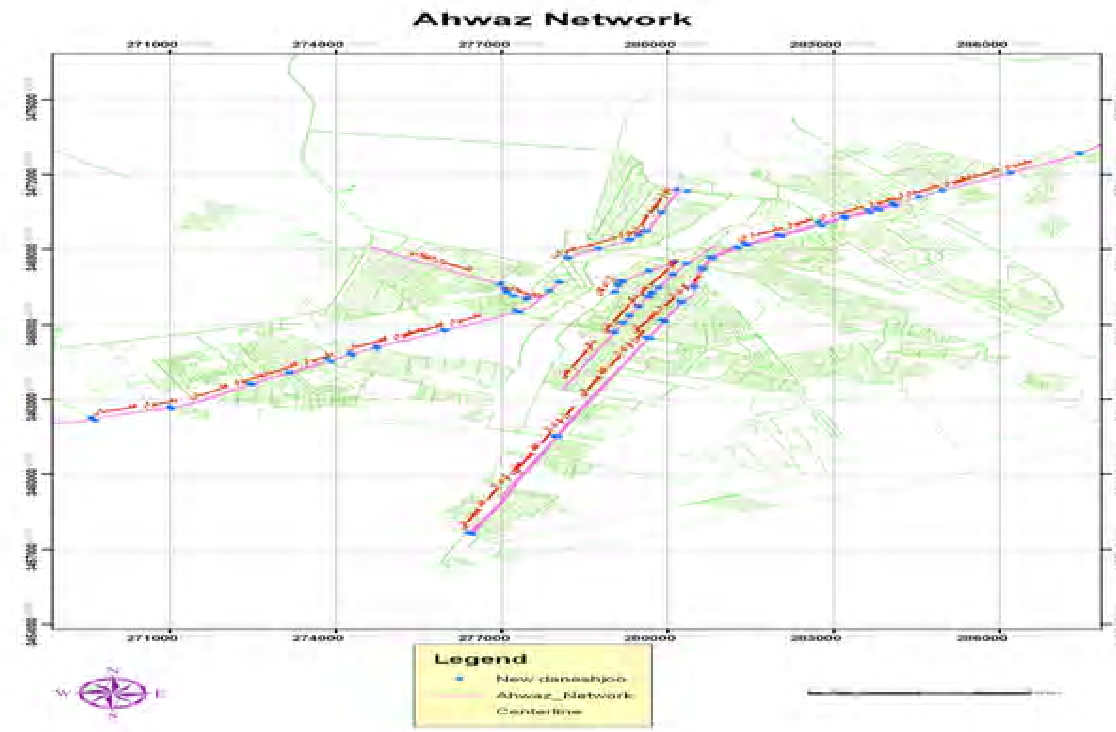


Fig. 1. Measuring stations of noise pollution in highways of Ahvaz city

RESULTS & DISCUSION

Based on the obtained results , the average L_{eq} at all stations is 72.62 ± 2.53 dB_A , also all studied roads, in all measurement periods, showed higher noise levels than standard. Max- Min L_{eq} ranges were 83.44 ± 3.8 dB_A and 65.37 ± 3.36 dB_A , respectively. Statistical analysis showed that among all traffic parameters, passing cars and vans were more than other vehicles in number per hour (2304.34) and their average speed was also more than other vehicles, per hour (34.30 km/h). Trucks and buses were the fewest passages (35.11) with lower average speed per hour compared to other vehicles (25.40 km/h). Among dimension and environmental parameters, the length of the studied area of roads was of highest average (1654.65 cm) and slope was of the lowest average. (0.2 %). Results of Pearson correlation Test, about traffic quantitative datas and dimension and environmental datas with L_{eq} showed that L_{eq} showed that L_{eq} was directly related to all three variables. The highest correlation coefficient among the given variables was for cars, and vans passing per hour(r=1).

According to Regression Analysis Primary results, clarification coefficient between independent variables and L_{eq} was (R^2 = 0.7) which showed scattered datas of high effect. In order to achieve a better clarification coefficient, therefore, data was standardized and refined (From total 1344 measured reassured records, 1135 were selected). In the next steps, analysis was done on the selected records.

- Linear Regression Analysis Results

In order to study effects of each independent variable on L_{eq}, Linger Regression Analysis was applied and results are as Follows:

$L_{eq} = 57.36 + 0.517 \log N_1$ $\quad R^2 = 0.267$
$L_{eq} = 68.855 + 0.417 \log N_2$ $\quad R^2 = 0.147$
$L_{eq} = 67.193 + 0.495 \log N_3$ $\quad R^2 = 0.245$
$L_{eq} = 64.497 + 0.468 \log N_4$ $\quad R^2 = 0.219$
$L_{eq} = 79.64 - 0.224 \log V_1$ $\quad R^2 = 0.05$
$L_{eq} = 78.395 - 0.223 \log V_2$ $\quad R^2 = 0.05$
$L_{eq} = 77.22 - 0.224 \log V_3$ $\quad R^2 = 0.05$
$L_{eq} = 79.164 - 0.22 \log V_4$ $\quad R^2 = 0.043$
$L_{eq} = 72.41 + 0.094\,L$ $\quad R^2 = 0.009$
$L_{eq} = 71.73 + 0.248\,W$ $\quad R^2 = 0.062$
$L_{eq} = 72.21 + 0.045\,H$ $\quad R^2 = 0.002$
$L_{eq} = 72.35 + 0.21\,F$ $\quad R^2 = 0.001$
$L_{eq} = 72.13 + 0.037\,T$ $\quad R^2 = 0.044$
$L_{eq} = 73.42 - 0.181\,RH$ $\quad R^2 = 0.033$

After datas refining range defined, and scattered data eliminated Regression Analysis was performed in several steps regarding clarification coefficient and modeling rules, and the best result was selected to write the best multivariable Regression line equation. It was found that 9 independent variables out of 15

had a meaningful effect on L_{eq}. The best Regression model, therefore, suggested is as follows:
Where L_{eq} (30 min) is predicted for 3 meter distance from roadway. Other variables were introduced previously.

$$L_{eq_{30\,min}}(dBA) = 64.67 + 3.93\log N_1 + 2.69\log N_3 - 1.048\log N_4 - 3.84\log V_1 + 1.71\log V_3 - 0.034RH - 0.042T - 0.011W - 0.04H$$

$R=0.95$, $R^2 = 0.92$

One of the most complete models is a model by federal Highway Administration Model called FHWA designed by Boddy and Reagan (National Cooperative Highway Program) Being under development and expansion, it resulted from National cooperative Highway Program NCHRP. It was later completed and released under the name STAMINA (Zannetti, 1997). Including experimental and analytical contents, the model has been used for all main roads with interrupted traffic, though introduced as Highway Model. It represents traffic flow features as well as environmental and surrounding features of roads and bumps (Zannetti, 1997; Harris Cryril, 1991; Pardina *et al.*, 2003; Stell Campell, 2001). In environmental modeling it was praised as the selected model, being relatively advantageous in L_{eq} estimation for including numerous incomes compared to other models (Zannetti, 1997) In order to match suggested model with FHWA-STAMINA, 7 correctional factors were required to be calculated and included in L_{eq} (ref). Since these 7 factors had no effects on the current study in Ahwaz, and considering the fact that formulas and equations based on them did not result from field study in Ahwaz and were actually derived from models and studies in other countries (Zannetti, 1997; Harris Cryril, 1991; Bell Lewis, 1994). The seven calculation steps were not included. The steps are listed as follows:

1. The effect of distance and earth material shown as $\Delta_{distance}$, this effect is considered on a condition where L_{eq} is required to be defined from a distance longer than standard (3m). Since the distance was considered as standard (3 m). The present study did not need to calculate this value.

2. Relative humidity and temperature effects shown as Δ_{air}. This factor is calculated from a specific table. Since in the present study the above factors were calculated by regression Analysis and the mentioned table was not used, this factor was eliminated.

3. Trees and long grass effects is shown by Δ_g. Due to the lack of such planted areas surrounding the studied sections, this factor was not required to be calculated.

4. Building Block Effect, shown as $\Delta_{housing}$ Since in Ahvaz city, noise level model is true from standard distance (3m) this factor was ignored by avoiding entering building blocks.

5) Short sound barrier effect ($\Delta_{1\,barrier}$)

6) Long and thin sound barrier effect ($\Delta_{2\,barrier}$)

7) Thick or long and wide barriers effect ($\Delta_{3\,barrier}$)

Regarding the fact that there were no sound barriers in the Ahvaz city, steps 5-7 were ignored.

To ensure accuracy and ability of the model, field study data were entered to the model to define correlation between results of suggested model and field study results. This was necessary as modeling was done according to the given clarification coefficient and scattered datas refinement (135 records). Hence the model required to be performed to total 1344 records in order to be able to define difference between predicted values by the model and measured L_{eq} of the field study, In this step the model was performed once without refining datas and once without them. Distribution and correlation coefficient values were checked. For 1344 recordings entered to distribution diagram and correlation coefficient was 0.7 and for 1135 recordings it mounted to 0.9. Diagrams 2 and 3 show the results.

Correlation values of measured L_{eq} were next compared with estimations of models FHWA- TNM (Zannetti, 1997; Stell Campbell, 2001). FHWA-STAMINA (Stell Campbell, 2001) India Model (Pardina et al., 2003) china Model (Benag Li et al., 2002). Turkey Model (Gundogdu et al., 2005), Hong kong Model (Lam William & Tam, 1998), Iran Passage Model ITNP (Golmohammadi, 2007). The results of Pearson correlation test showed that except for Turkey and India models others reported a relatively acceptable L_{eq} for field study datas. The lowest correlation coefficients between measured L_{eq} and estimated L_{eq} among all, were (r=0.304) and (r=0.306) respectively for India and Turkey models, and the highest values were (r=0.788) and (r=0.722) respectively for ITNP and FHWA-STAMINA models. Correlation values for FHWA-TNM model was (r=0.592) and for Hong kong (r=0.462) and china model was (r=0.552). Estimated L_{eq} values for the designed model of the present study (before standardization) had correlation coefficient value of (r=0.702) which mounted to (r=0.95) after standardization. This finding in fact, revealed the necessity of designing a new and comprehensive model for research in the city. Figures 4-10 show the distribution of measured and estimated L_{eqs} from different models.

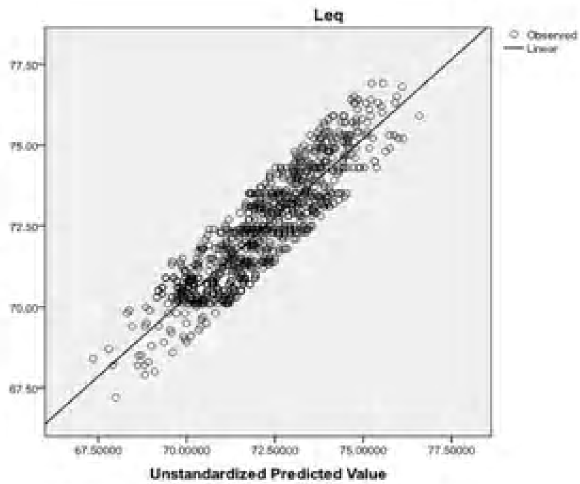


Fig. 2. Distribution of the estimated and measured L_{eq} values by designed model after standardization

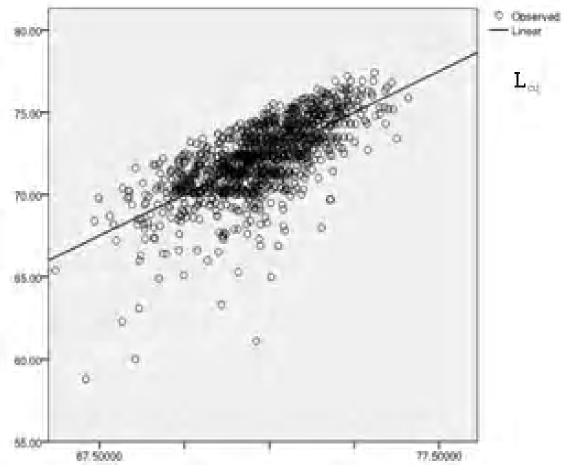


Fig. 3. Distribution of the estimated and measured L_{eq} values by designed model before standardization

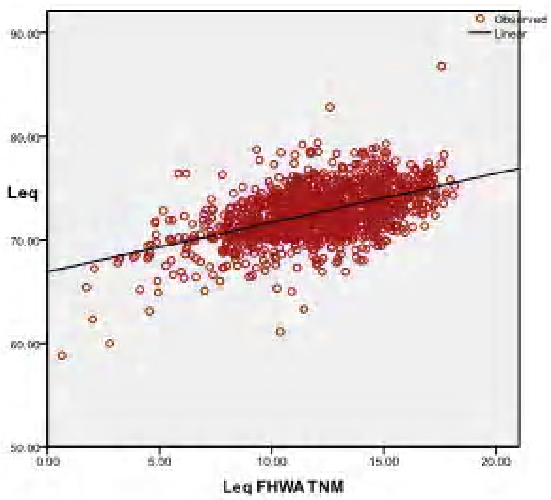


Fig. 4. Distribution of the estimated and measured L_{eq} values by FHWA- TNM model

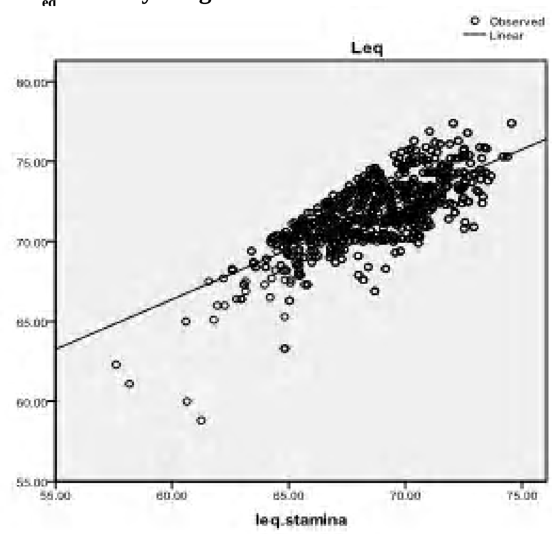


Fig. 5. Distribution of the estimated and measured L_{eq} values by FHWA- STAMINA model

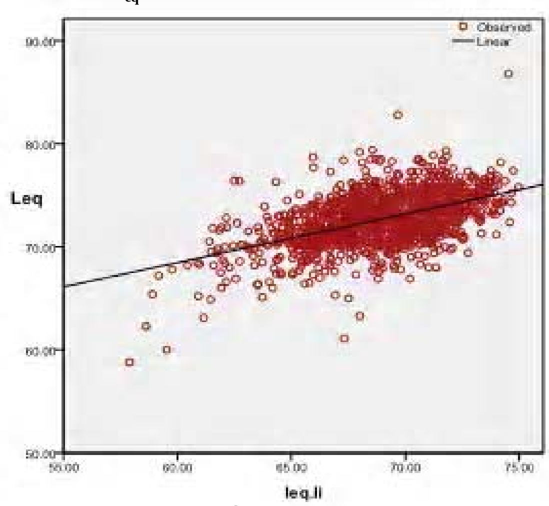
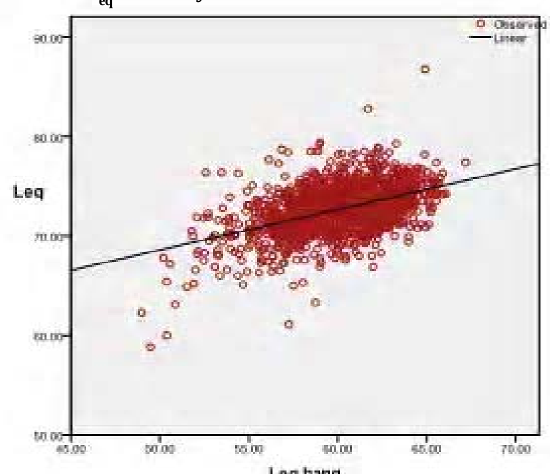


Fig. 6. Distribution of the estimated and measured L_{eq} values by Li model



Leq.Lam & Tam

Fig. 7. Distribution of the estimated and measured L_{eq} values by Lam & Tam model

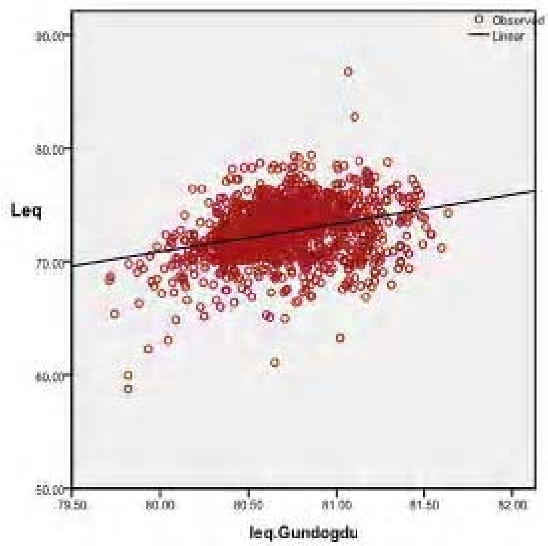
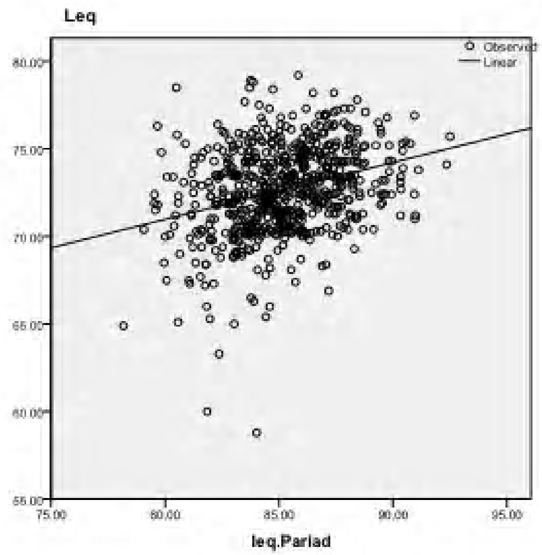
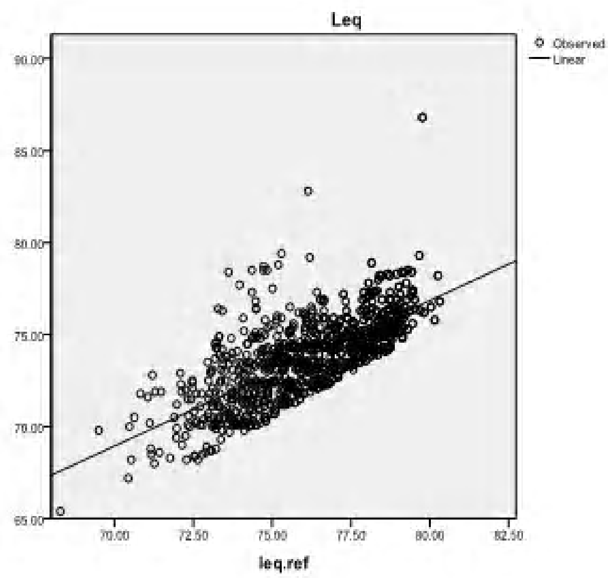


Fig. 8. Distribution of the estimated and measured L_{eq} values by Gundogdu model



Leq. Pardina
Fig. 9. Distribution of the estimated and measured L_{eq} values by Pardina model



Leq. ITNP
Fig. 10. Distribution of the estimated and measured L_{eq} values by ITNP model

Also, the difference between average estimated L_{eq} values of the model and those of above models were measured and it showed this difference for the designed model
(-1.5 dB_A) to be a desired value, compared to other models including Turkey (with average difference of – 6.4 dB_A). India (with average difference of – 8.2 dB_A), FHWA – STAMINA (with average difference of +2.08 dB_A) ,FHWA-TNM (with average difference of -3.97 dB_A), ITNP (with average difference of -2.38 dB_A) Hong kong (with average difference of +5.2 dB_A) and china (with average difference of -3.8 dB_A). This difference of the estimation from various models with that of the present model, considering various modeling strategies, traffic condition, distribution level, passage features etc. This difference also showed that the above models valid only to their own conditions and not suitable for a field study like the present one. The results as well as showed preference of FHWA-STAMINA and ITNP to other models for the present field study. Aside from these differences, the difference between average measured values and estimated values by the designed model, was- 1.5 dBa which showed

the priority of results from the designed model to other models. Also The number of this model inputs allows important traffic features to be put to predict the most real value possible. As the studied models by Stell Campbell (2001) stated, the highest input number was for FHWA which did not consider dimension, except for distance from midline on passage (Stell Campbell., 2001). However, the present model, considers surrounding buildings and heights as an effective factor to be a complementary additional factor to the above parameters.

CONCLUSION

The present study is based on data colleted from 1344 traffic noise and measurements of effective factors in Ahwaz city. Sampling included measurement of 6 traffic factors at each station at same time, 8 records of traffic load and speed, 2 records of climate condition, 3 records of dimensions, and 2 records of environmental factors. The total number of records for 112 stations was 28224 which is the strength point of the present study. For designing the model and selecting the effective parameters on traffic noise, Multi – Variable Regression Analysis and SPSS were used, respectively. The model was eventually designed with 9 inputs of high clarification coefficient (R^2=0.920 and correlation coefficient of R=0.95) for the city.

Due to the accuracy and precision in designing this model and considering effective factors, as well as the large number of inputs, accounting of main parameters of traffic, dimension and environment parameters of roads under study and its expandability, the present model could be an appropriate one to predict L_{eq} 30 minutes in Ahwaz, also could be Practical for estimation of traffic noise pollution of the city. The model can be developed by defining variable such as wind speed and gradient effect , calculation of absorption and reflection, level by construction materials, absorption level by plant species, designing a model based on results from field studies performed in four seasons of the year, as well as on all days of the weak, and in two day period (DL) and night period (NL) are suggestible.

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