Modeling of Noise Pollution due to Traffic Movement in Mansoura City

نمذجة التلوث الضوضائى نتيجة حركة المركبات بمدينة المنصورة

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الملخص

اهتم البحث العلمي في الماضي وفي الوقت الحاضربتلوث البيئة لما له من اضرار علي صحة الإنسان.ويعتبر التلوث الضوضائي من اخطر انواع التلوث حيث ان الضوضاء تؤدي الي حدوث ارتفاع في ضغط الدم وحدوث اضطرابات في الجهاز الهضمي وانقباض في الأوعيةالدموية . من اهم مصادر التلوث البيئي ذلك الناتج عن حركة المركبات والمواصلات مما دعا الكثير الي ايجاد نماذج رياضيه تربط مستوي الضوضاء باختلاف حالات الطرق والمواصلات.هذه النماذج الرياضية يمكن استخدامها في التنبؤ بمستويات الضوضاء علي الطرق نتيجة حالات الطرق والنقل المختلفة.

هذا البحث نتيجة دراسة تم عملها في ظروف مختلفة للطرق في مدينة المنصورة. حيث تم اختياربعض الطرق المختلفة في مدينة المنصورة وتم قياس مستويات الضوضاء .تم اختيار اربعة طرق في مدينة المنصوره بظروف مختلفه من حيث عرض الطريق و حجم المرور ونسبة كل نوع من انواع المركبات وعرض الجزيره الموجوده بالطريق وتم قياس مستوي الضوضاء الناتج عن هذه الظروف.

في هذا البحث تم تحليل مستويات الضوضاء الناتجة عن حركة المركبات طبقا لظروف الطرق المختلفه وايجاد نموذج رياضي يربط مستوي الضوضاء بعدة عناصر مختلفه هي 1- حجم المرور 2- نسبة المركبات الثقيلة 3- نسبة المركبات المتوسطه 4- عدد الحارات 5– عرض الحاره 6– عرض الجزيره.

من خلال هذا البحث تم الوصول الي معامل ارتباط قوي (R^2 = 0,94) عن طريق نموذج رياضي لمستوي الضوضاء طبقا للعناصر السابقة. لذلك يمكن استخدام هذا النموذج الرياضي للتنبؤ بمستوي الضوضاء علي الطرق المختلفة طبقا للظروف السائده في معظم مدن جمهورية مصر العربيه.

Abstract

Noise is one of the most significant sources of environmental pollution in the metropolitan areas. It negatively affects human health, hearing, sleep and sometimes leads to high blood pressure. Road traffic noise is the main source of environmental noise pollution in urban areas. This paper presents a predictive road traffic noise model for Mansoura city based on field noise measurement and different traffic composition and volume.

The proposed model has six explanatory parameters. These parameters are (total traffic vehicle count (Q), Number of lanes, lane width, median width, percent of medium vehicles, and percent of heavy vehicles).The model yield highly accurate noise predictions with coefficient of determination (R^2 of 0.94).A sensitivity analysis using the proposed model showed that the most significant parameters on predicted noise levels are the total traffic volume and median width. The proposed road traffic noise model can be effectively used as a decision supporting tool for prediction of road traffic noise in Mansoura City and similar cities in Egypt.

Key words

Noise; Traffic volume; Heavy vehicles, Motorcycles; Regression

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Introduction

The noise emitted from all sources except the industrial work places is defined as the environmental noise (World Health Organization, 1999).

Calixto et al. 2003; and Ouis, 2002 reported that the road traffic noise is the most significant source of environmental noise pollution in urban areas. It is increasing at an alarming rate with urbanization and the corresponding increase in number of vehicles in urban areas. In fact the current noise levels in many metropolitan areas exceed the prescribed levels (Jobair and Ahemed, 2001). Vehicle noise is produced from the engine and exhaust system of vehicles, aerodynamic friction, road system, and by the interaction among vehicles (Subramani et al 2012).

Various problems result from noise including hearing loss, stress, sleep disturbance, annoyance, distraction, less productivity, and masking speeches (Rawat et al 2009).This leads to a lower life quality.

Furthermore, numerous health problems had been reported including physical and psychological, irritation, human performance and actions hypertension, heart problems, tiredness, headache and sore throat (Fyhri, and Klæboe 2009, Mishra, et al., 2010). Therefore many countries introduced noise emission limits for vehicles and issued other legislations (Abbaspouretal, 2006; Ross, 2001; Stefano2001; Mansouri et al. 2006).

Maximum acceptable level of traffic noise

Traffic noise is a result of a lot of sources which have wide varieties in frequency and severity. Since noise is measured in decibel (dB) units, it was found that the noise produced from rapid motorcycles which have high frequency is equal with that resulting from goods transportation vehicles (Hana 2010). Table (1) presents the maximum noise intensity resulting from movement of some types vehicles at a distance 7.0 m (Shoieb 1997).

Table 1 Maximum Noise Intensity Resulting from Movement of Some Vehicle Types at a Distance 7.0 m (Shoieb 1997)

Type of Vehicle	Noise Level dB(A)
Passenger car	82
Pick up with total weight of 3.5 ton	84
Commercial vehicle with power less than 200 HP	89
Commercial vehicle with power more than 200 HP	91
Passenger train	97

AASHTO has also identified four acceptable levels of noise according to land use and activities as given in Table 2.

Table 2 Permitted Noise Levels According To AASHTO

Land Use	Sound level dB(A)
Services areas which are needed to be quiet.	60 (outdoor)
Residential and recreational areas as well as hotels.	70(outdoor)
Development areas for other activities except those mentioned above.	75(outdoor)
Schools, libraries, music and conferees halls.	55(indoor)

Objectives

The main objective of this research is to develop an accurate road traffic noise predictive model for Mansoura city. This model is expected to help in the geometric design of roads as well as assessing the existing traffic noise conditions and help decision makers.

Review of different literature prediction models

Several models have been developed from fundamental parameters such as traffic flow and speed of vehicles using regression analysis of experimental data (Stefano, 2001). Traffic flow rate and

composition were reported as the most important variables considered in the mathematical noise prediction models (Calixto, 2002, Alves Filho, 1997).
Table 3 summarizes some of the literature traffic noise prediction models.

Table 3 Summary of Literature Prediction Models for Road Traffic Noise

Model	R2	Reference
Leq = Leq(ref) -Δe Leq(ref)=48.48+ΔD+ΔNV Δref)=48.48+ΔD+ΔNVΔNV0. 3 Vp-19.3Log (L/2) Log(1+5b/v)-27 Δref)=48.48+ΔD+ΔNVΔNV0. 3 Vp-19.3Log (L	0.901	Golmohammadi .et al.(2009)
Leq=75.58+0.0024Q–0.0064V+0.0469Ta–0.00451Ts + 0.0306H	0.523	Subramaniet al. (2012)
Leq=54.013+ΔN+ΔV+ΔD Δ54.013+ΔN+ΔV+ΔD+ΔD64 V+0.0469Ta– 0.00451Ts hv+b))+(0.173LogNm) Δ)+(0.173LogNm)gNm)64V+ 0.0469Ta– 0.00451Ts hv+b))+(0.302LogVm) Δ)+(0.302LogVm)gVm)451Ts hv+b))+(0.30	0.913	Golmohammadi .et al.(2007)
Leq=L50+0.079(L10-L90)2	*NA	Griffits,(1968)
Leq=-17.5–10LogQ +30Log V–11.5Logd	*NA	Lamure (1965)
Leq=10Log(Nc+3.7Nhv+ 1.9Nb)+38.2	*NA	NAISS (1997)
Leq= 10.2LogQ + 33.66Log(v+40+500/v) +10.2Log(1+5b/v)-27.302	0.917	Rawatet al. (2009)
Leq=19.92Log[Q(1+0.1Vp)]+12.59	0.927	Kumar et al. (2011)
Leq=7.7 Log[Q (1+0.095*Vp)]+43	0.819	Claxitoet al. (2003)
Leq=-2.862Log(H)+19.495Log (V)-0.694 Mat* Log(V/H)	0.724	Vincenzo et.al. (2006)
Leq=7.04ln Q+0.25V+25.82	0.88	Rodrigues et al. (2003)
Leq= 38+15 Log Q-10Log L	*NA	Josse (1972)
Leq= 55.5+10.2 Log Q+0.3 Vp-19.3Log (L/2)	*NA	Burgess (1977)

*NA = Not available

Where:
Q = the total number of vehicles / hr
Vp= the percentage of heavy vehicles.
Nt= Number of vehicles (v/h)
ΔNV= traffic flow and traffic speed effect
ΔN=Traffic flow factor
ΔV=Traffic speed factor
ΔD=Road dimensions factor
Ta = Average atmospheric temperature in °C,
Ts = Average Surface temperature in°C,
H = Relative humidity in %,
Vti= Mean speed of vehicles (km/h)
V_c=Mean speed of cars (km/hr)
V_{mini}=Mean speed of mini-buses or mini-trucks (km/hr)
$V_{(hv+b)}$ =Mean speed of buses or heavy trucks and buses (km/hr)
V_m=Mean speed of motorcycles (km/hr)
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 (%)
Δ e= Effect of distance, surface, foliage, air temperature, humidity and barriers dB (A)
$Leq_{(ref)}$ = equivalent sound pressure level 3 meters near road side
V= Average speed of vehicles
d= Distance between source and observer.
L= the road width
Mat= Type of road surface (0 normal, 1 acoustic road surface).
N_c = the number of light vehicles / hr
N_m = the number of motorcycles / hr
N_{hv}= the number of heavy vehicles/ hr
N_b = the number of buses / hr
V_{mini}= the number of mini buses or mini trucks / hr
R^2=the correlation coefficient between Leq and L measured
L10= the sound pressure level exceeded in the 10% of the detection time, and *L*90= the sound pressure level exceeded in the 90% of the detection time.
L_{eq} is defined as a continuous sound level that would produce the same effect on the human ear if compared to the actual noise observed during the measurement, with all the variations. (Claxito et al. 2003)

Methodology

The current study was conducted in Mansoura city, the capital of El Dakhlia governorate. It is located in the delta region north of Egypt. Four main urban roads were selected for collecting data. The selected urban roads are El-Gomhoria Street, El-Gish Street, Abd El-Salam Aref Street and Gehan Street. The selected roads are shown in Figure 1. The dots shown in the figure indicted the locations used for data collection. The geometric characteristics of these roads are summarized in Table 4.

Data Collection

Noise Measurements

Noise measurements were performed for the selected roads by using a Digital Sound Level Meter model DSLM407730. The DSLM measures and displays sound pressure levels in the range of 40 to 130 dB. Noise level measurements were recorded with the digital sound level meter placed at a distance of 1.0 m from the outer edge of traffic lane and at a height of 1.0 m from the ground level. For each location, noise measurements were taken in 5different week days (Saturday to Wednesday) from 07:00 AM to 09:00 AM and from 02:00 PM to 04:00 PM. Readings were recorded every 2 minutes.

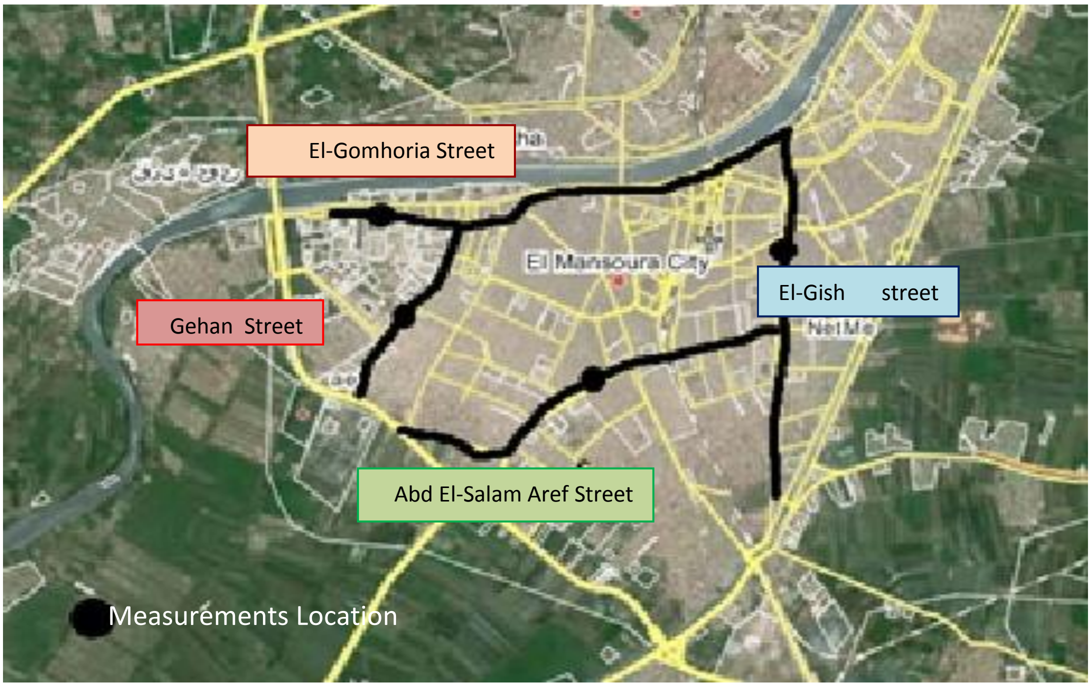

Figure 1 Location of the investigated urban roads.

Table 4Geometric Characteristics of the Selected Urban Roads

Road	No. of Directions	Divided/ Undivided	Lane Width (m)	Median Width (m)	No. of Lanes
El-Gomhoria Street	One way	undivided	3.45	0	4
El-Gish Street	Two way	divided	3.20	1.6	6
Abd El-Salam Aref Street	Two way	divided	3.20	2.5	6
Gehan street	Two way	divided	3.25	0.6	6

Traffic Volume Count

The number of vehicles passing through a fixed section on the road was recorded by a digital video camera. The vehicles were classified into four categories:

1. Passenger Vehicles (cars): This category includes normal passenger vehicles, microbuses, Pickups and taxis.

2. Medium Trucks (MT): This category includes delivery vans, single unit trucks and minibuses.
3. Heavy Trucks (HT): This category includes large tow trucks, long vehicles, cement mixers and large buses.
4. Motorcycle: This category includes two and three wheels vehicles such as motorcycles, tricycle, and tuktuk.

The following section summarizes the steps to analyze the noise level measurements and development of the proposed model.

Results and analysis

The collected data was used to develop a traffic noise predictive model for Mansoura city. The collected data for each street was used separately to develop a model for each street. Then data for all streets were combined in one database and used to develop a general model for Mansoura city. Regression analysis using the least square method was used for the model development. After many trials, the following model which yielded the highest coefficient of determination (R^2 of 0.939) and lowest percent of S_e/S_y of 0.247 (S_e is the standard error of predicted noise levels and S_y is the standard deviation of observed noise levels)

$$L_{eq} = 55 + 2.205\, Q^{0.338} + 0.17\, (\%MV+\%HV)^{1.241} + 0.156 * W - 1.7895 * M$$

Where:

Q = total traffic volume (vehicle/15 min)

%MV = percent of medium vehicles

%HV = percent of heavy vehicles

W = carriage way width (m)

M = median width (m)

The relationship between the predicted and measured noise levels is presented in Figure 2. The goodness of fit statistics is also shown in the figure.

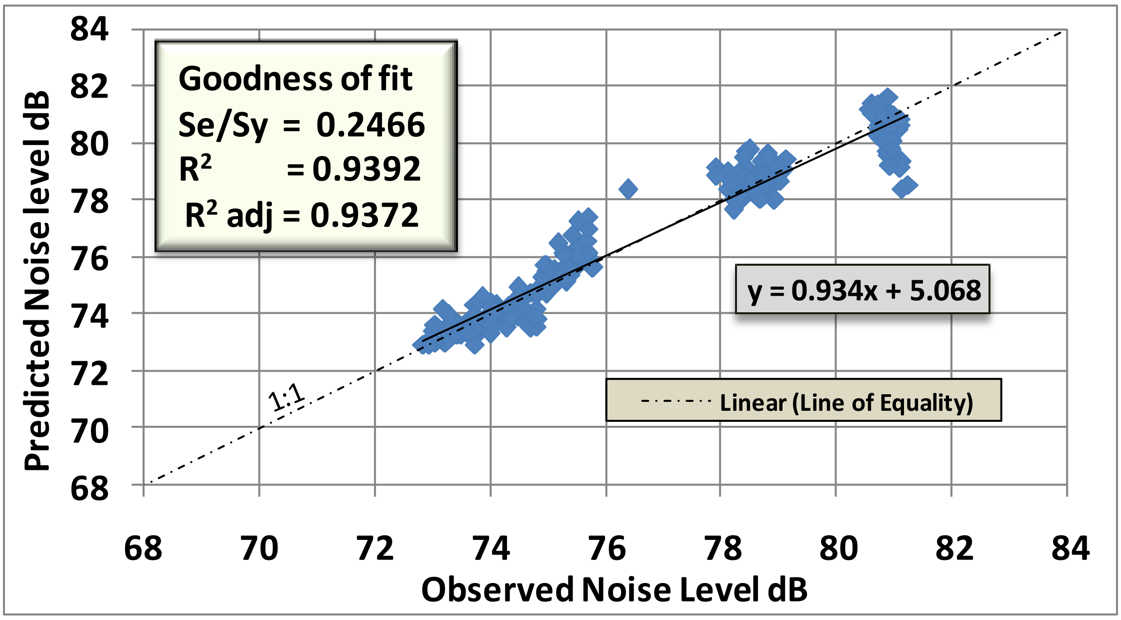

Figure 2 Observed versus Predicted Noise Level

Model precision and bias

Figure 2 along with the goodness of fit statistics of the model show very low scatter and highly accurate predictions. Bias is defined as the systemic difference between observed and predicted values. The bias in the model predictions was evaluated statistically. A linear regression on the measured and predicted noise levels was conducted and the following hypothesis tests at a significance level of 5 percent (α= 0.05) were performed.

Hypothesis 1: Determines whether the linear regression model developed using measured and predicted noise level has an intercept of zero by testing the following null and alternative hypotheses:

H_o: Model intercept = 0; and

H_A: Model intercept ≠ 0.

A rejection of the null hypothesis (p-value < 0.05) would imply the linear model had an intercept significantly different from zero at the 5 percent level of significance. This means biased model predictions especially at the low noise levels.

Hypothesis 2: Determines whether the linear regression model developed using measured and predicted noise level has a slope of unity by testing the following null and alternative hypotheses:

H_o: Model slope = 1.0; and

H_A: Model intercept ≠ 1.0.

A rejection of the null hypothesis (p-value < 0.05) would imply that the linear model has a slope significantly different from 1.0 at the 5 percent level of significance and thus the model systemically yields biased predictions especially for noise levels outside the measured data used for the model development.

Hypothesis 3: A paired t-test was done to determine whether the measured and predicted noise level represented the same population.

H_o: Mean measured noise level = Mean predicted noise level; and

H_A: Mean measured level ≠ Mean predicted level.

A rejection of any of the three null hypotheses (p-value < 0.05) would imply that predicted noise level model results are biased predictions. If the model passed all three hypotheses tests successfully, the model predictions are not biased. The results of the conducted hypotheses tests are summarized in Table 5.

Table 5Statistical Comparison of Measured and Predicted Noise level Data

Hypotheses	df*	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
(1)Ho: Intercept=0	1	0.1266	1.398	0.0905	0.9279	-2.6303	2.8834
(2)Ho: slope = 1.0	1	0.9983	0.0181	1.3858	0.1736	0.9626	1.0341
(3)Ho: Mean Measured = Mean Predicted noise level	191	-	-	-	0.9913	-	-

*df = degrees of freedom

Sensitivity Analysis

The predicted model was usedto test the sensitivity of predicted traffic noise levels to each parameter. The results of the sensitivity analysis are illustrated in Figures 3 to 6.

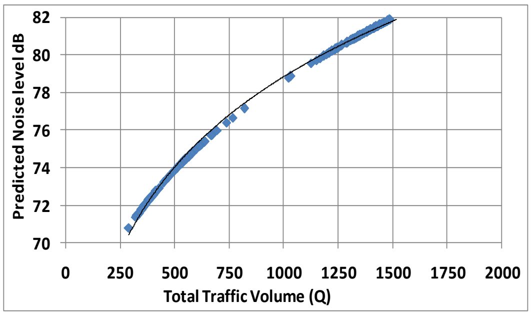

Figure 3 Total traffic Volume versus Predicted Noise Level

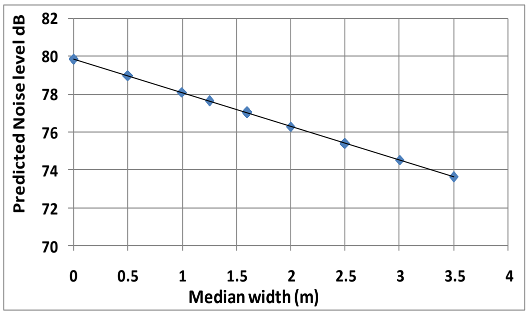

Figure 4 Median width versus Predicted Noise Level

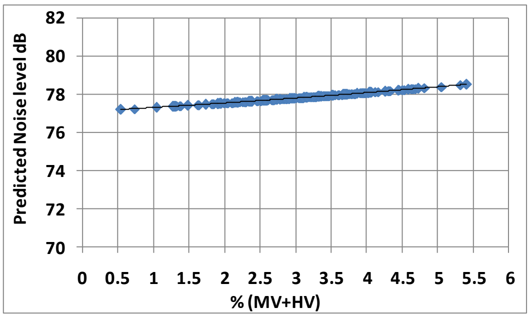

Figure 5 Percent of (Medium +Heavy) Vehicles versus Predicted Noise Level

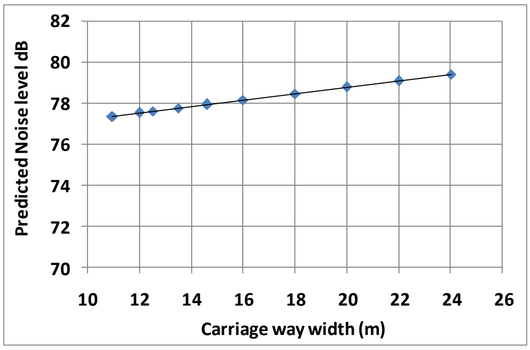

Figure6Carriage way width versus Predicted Noise Level

The sensitivity results in the above figures show that, the effect of changing traffic volume on the predicted noise level is more significant than all other variables.

Figure 4 shows that as the median width increase, the predicted noise levels significantly decrease. The effect of the percentage of medium and heavy vehicles in the traffic mix was not found to have a very significant influence on predicted noise levels. The reason for this fining is the low percentage for these types of vehicles in the city. Finally, as the lane width increase, the capacity of the road increase and then the traffic volume increase. However, the effect of increasing the lane width on the predicted noise level is not significant.

Summary and conclusions

The present study was conducted in Mansoura city. Four main roads of the city were selected. The collected data were noise levels, traffic volume and composition, and the geometric characteristics of the selected roads. Based on the collected data, a traffic noise predictive model for Mansoura city was developed. This model predicted the noise level model as a function of total traffic volume, percent of medium vehicles, percent of heavy vehicles, roadway width and Median width. The model showed excellent prediction accuracy with R^2 of 0.94 and S_e/S_y of 0.247. The results of the conducted hypotheses tests showed that the model predictions are not biased. The sensitivity study of the model identified that traffic volume and median width as key factors affecting the predicted traffic noise levels.

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