Statistical Modeling for Traffic Noise: The Case of Kirkuk City

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Abstract-The auditory system can suffer from exposure to loud noise and human health can be affected. Traffic noise is a primary contributor to noise pollution. To measure the noise levels, 3 variables were examined at 25 locations. It was found that the main factors that determine the increase in noise level are traffic volume, vehicle speed, and road functional class. The data have been taken during three different periods per day so that they represent and cover the traffic noise of the city during heavy traffic flow conditions. Analysis of traffic noise prediction was conducted using a simple linear regression model to accurately predict the equivalent continuous sound level. The difference between the predicted and the measured noise shows that the model's accuracy is 93.93%. The results show the effectiveness of the suggested method and confirm its applicability in developing mitigation plans for both existing and future roadways. To test the effectiveness of the suggested method, the selected location of different road functional classifications of Kirkuk city in Iraq was studied. It was noticed that in all the selected sites, the noise level was observed to be above the permissible noise standard of the World Health Organization (WHO).

Keywords-noise level; traffic noise; road functionality; traffc volume; speed

I. INTRODUCTION

Noise is not only hard on our senses [1], our physical and emotional well-being also are also negatively affected [2]. Exposure to high noise levels, i.e. over 85dBA, for 8 hours or longer may be dangerous [3]. Expansion of cities, industries, and facilities put people's health at risk [4]. Generally, noise has significant effects on human health [5]. Table I shows the recommended noise level standards for several countries and the World Health Organization (WHO) [6]. Noise levels in Kirkuk city have been reported to be high, therefore, the situation requires evaluation. Vehicles are the main source of noise pollution [7]. For reducing the noise pollution caused by transportation in cities, it is necessary to predict traffic noise [8-10]. Research has been conducted to develop a traffic noise model for Surat's main arterial road in India and different variables affecting traffic noise were analyzed in [11]. The survey involved 3 arterial roads based on mixed traffic patterns and a variety of land use patterns. The parameters were measured during peak hours. Multiple linear regression analysis was utilized and the model showed that the variables had a good relationship to the noise. A comprehensive noise prediction model was developed for 8 significant highways in the Indian states of Telangana and Andhra Pradesh in [8]. Each highway was measured for 7h each day. The variables include carriage width, traffic volume, and speed. The 15min interval model produced a negative relation against the 1h interval model. A traffic noise model was developed to measure the noise level of collector roads in Denpasar City, Indonesia in [13]. Measurements were conducted from 6:00 a.m. to 6:00 p.m. and 48 sets of data in total were obtained in 15min intervals. It was shown that if all the other variables remain constant, an increase of 100 motorcycles increases traffic noise by approximately 3dBA. In [14], the noise level was measured on the Asian Highway at the Golestan National Park, Iran. For the analysis of independent variables and noise, 76 sampling locations were selected between 0 and 250m from the road. At each sampling station, monitoring was done for one week with 15min periods between 8:00 a.m. and 8:00 p.m. while SPSS software was used for modeling. A model was developed in [15] to forecast traffic noise on the roadways of the Iranian city Ahvaz. On 7 roads of the city, 1344 observations were performed at 12 stations. During the model development, out of 15 variables, just 9 independent variables were used.

TABLE I. NOISE LEVEL STANDARDS

Noise level standard	Noise level (dBA)	
	Day time	Night time
WHO	55	45
Australia	45	35
Germany	45	35
Korea	50	45
Japan	45	35
India	55	45
Philippines	50	45

II. MATERIALS AND METHODS

To measure traffic noise in Kirkuk, 3 features were selected, road functionality, traffic volume, and speed, and their

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impact on traffic noise was investigated. To measure the noise levels, the 3 variables were examined at 25 locations. At each road, functional classification, traffic volume, and speed survey were conducted and recorded at 15min intervals. Figure 1 displays the process for the suggested model starting with data collection using a sound level meter, variable selection analysis, model development, evaluation, and analysis of the findings. The obtained data include 3 variables: F (functional classification of the road), Q (traffic volume), and V (average speed of vehicles). Statistical analysis was designed to construct a noise level estimation model to highlight the effect of each variable on the noise level.

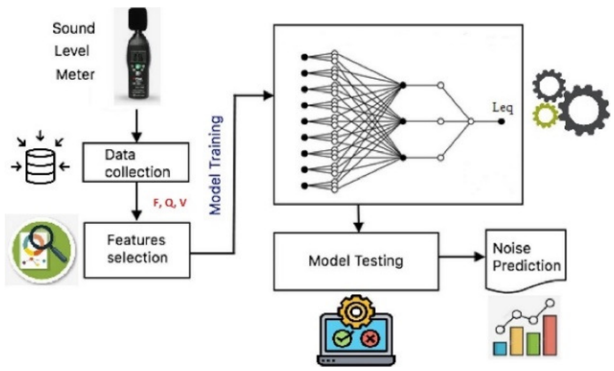

Fig. 1. Pipeline of the proposed model.

III. TRAFFIC NOISE DATA

The sound level meter (Figure 2) was used to measure the sound levels during peak hours. The average of maximum and minimum noise levels was calculated and plotted in a normal graph with respect to time. A tripod supported the device at 1m height and kept it at 6.5m away from the middle lane of the road as depicted in Figure 3.

Fig. 2. The sound level meter.

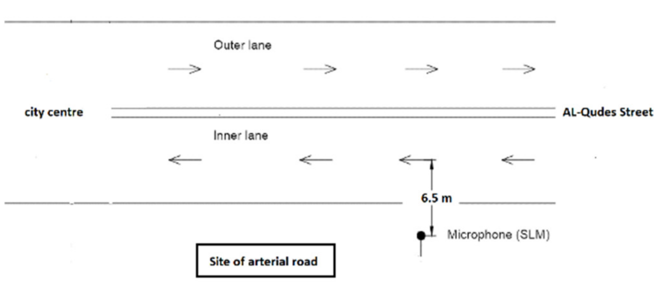

Fig. 3. A schematic diagram of the monitored site.

IV. SITE SELECTION

Kirkuk, located in the north of Iraq, was selected as a typical representative modern city to carry out the study on the aspect of traffic noise. Kirkuk witnessed extensive urban development over the past decades to become a node for commercial activity characterized by modern and beautiful buildings and modern sites. Traffic noise measurements were conducted at 25 locations on the main streets of Kirkuk, representing the classes of roads and zone types as shown in Figure 4. The data have been taken during 3 different periods of the day so that they may represent and cover the traffic noise of the city during heavy traffic flow conditions. The periods were: 8:00 a.m. to 9:00 a.m. (supposed to be the peak traffic hour density of the day), 1:00 p.m. to 2:00 p.m. (supposed to be the end of the governmental staff working hour), and 6:00 p.m. to 7:00 p.m. (time of the evening marketing). Measurements of the traffic count and speed were not taken during holidays [16, 17].

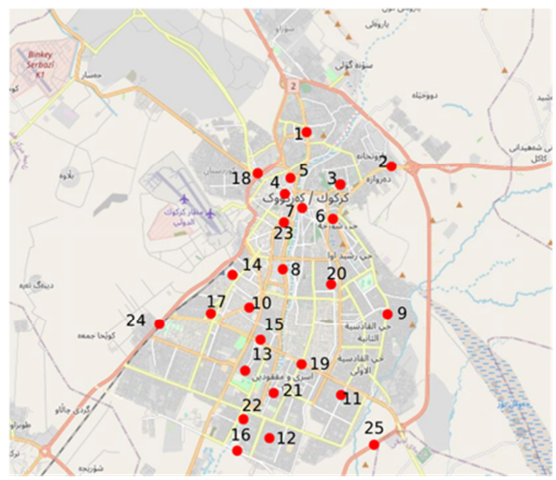

Fig. 4. Locations of data collection sites on Kirkuk city.

V. ROAD FUNCTIONAL CLASSIFICATION (F)

The road functional classification of a city is a channel for communication between the city's various parts and with nearby cities and urban areas. Factors like traffic volume and average speed are related to functionality. Therefore, functionality is associated with traffic noise [18]. The functionality variable was applied and 4 types of roads were considered according to their functionality: highway, arterial, collector, and local road. The highways and arterial roads recorded the highest noise level measurements since they are characterized by very congested traffic volumes and faster speeds.

VI. TRAFFIC VOLUME (Q)

The vehicles were counted within each time span of sound level measurement during observation. The traffic count was conducted manually by using a video camera [19] or by utilizing sensors on roads [20].

VII. VEHICLE SPEED (V)

It is the average measured speed of the cars. Vehicle speed can be manually measured by estimating the travel distance of a car per second or by a velocity speed gun [21]. Bushnell 101911 (Figure 5) was used to detect the spot speed of passing vehicles. The gun was directed at the passing vehicle. The gun was designed to measure the speed in km/h. It delivers signals to moving objects and can detect any object running faster than 20km/h.

Fig. 5. The Bushnell speed gun.

VIII. NOISE LEVEL DESCRIPTOR (LEQ)

The traffic noise statistical descriptors used in this study is the equivalent continuous sound level. Leq is often used in noise measurements [22]. The dBA is the most often used unit for sound measurement. Table II lists the independent variables (F, Q, and V) as well as the measured dependent variable (Leq) in relation to the sample values.

TABLE II. DATASET SAMPLE VALUES

F	Q	V	Leq
Highway (Erbil principal)	1424	80	78.19
Arterial (King Qazi street)	1309	63	78.86
Collector (University street)	895	53	76.52
Local (Iskan street)	122	31	68.27

IX. RESULTS AND DISCUSSION

As the road type is considered one of the primary noise sources, each road was statistically analyzed for noise response. The analysis revealed that the noise is very dependent on the functional classification of the road, especially the highway and arterial class, since they are designed to accommodate high speeds and are utilized in large-scale movements. There is a relationship between traffic volume and noise [23]. The noise level is more dependent on traffic volume followed by the road functional class. The study investigated the characteristics of traffic noise and found that traffic noise is closely related to traffic volume. The distribution of traffic noise in different regions is determined by the kinds of vehicles in the area and the density of a road network [24].

The speed variable also affects noise levels [25]. Reducing speed could decrease noise, moreover, noise reduction is achievable by traffic calming policies because it prevents forceful accelerations [26]. Both these claims are accurate in terms of producing sound pressure levels that the vehicles moving at a slower speed would produce less noise. Figures 6-9 show the relationship between each variable and the noise level (the plotted points refer to the average value of multiple readings).

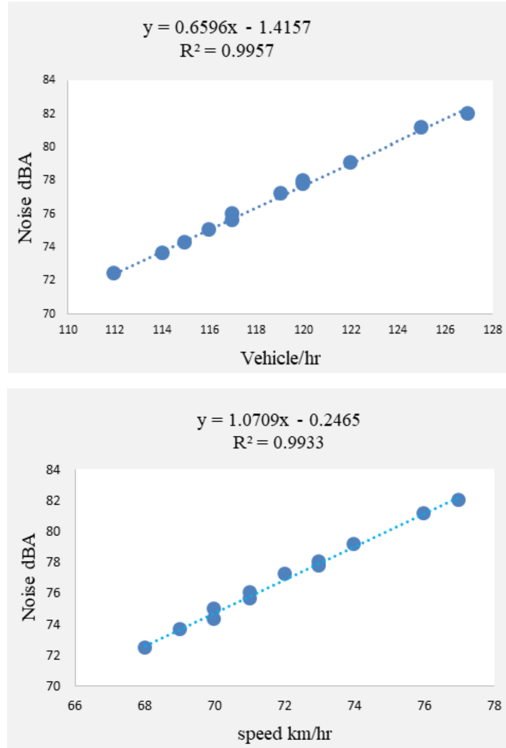

Fig. 6. Noise of the principal road (Erbil highway).

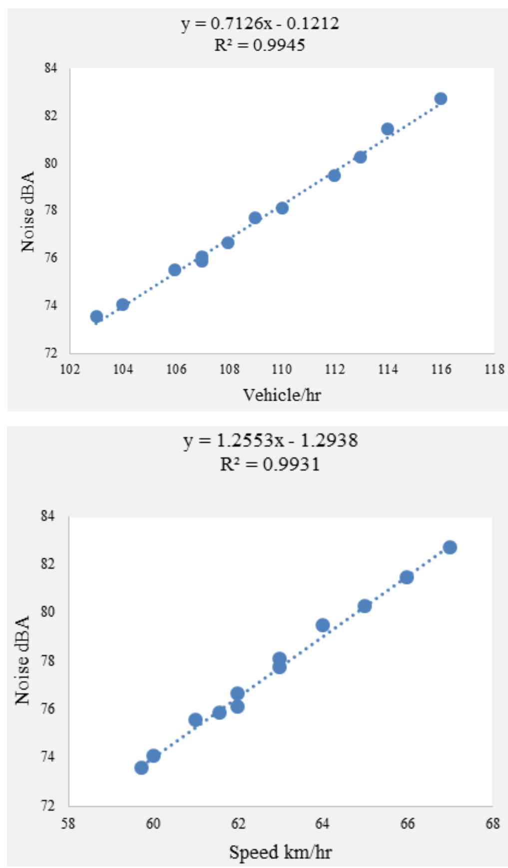

Fig. 7. Noise of the arterial road (King Qazi street).

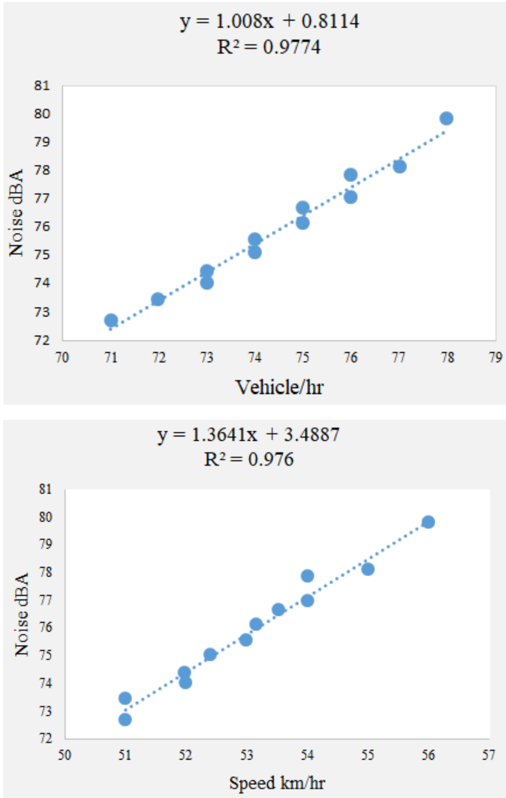

Fig. 8. Noise of the collector road (University street).

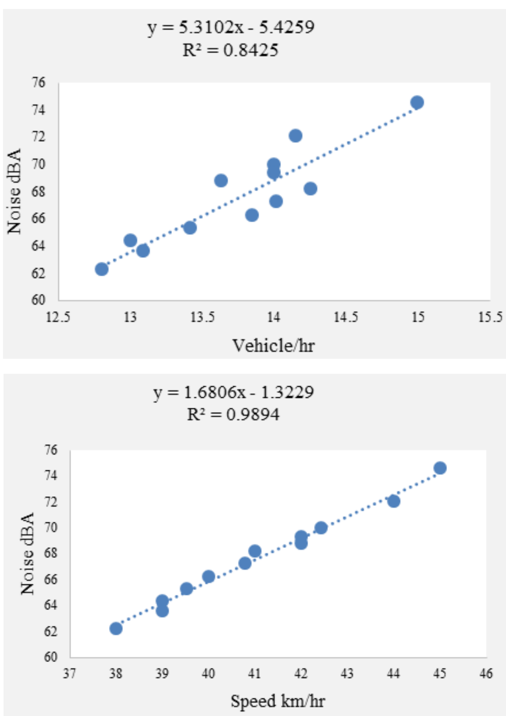

Fig. 9. Noise of the local road (Iskan street).

A statistical model was constructed to fit these parameters and connect them to the noise level. Simple linear regression was used for formulating the model (using Minitab 21) and the output is the following model:

$$\text{Noise (dBA)} = 43.34 + 0.282\ V + 0.000690\ Q + 3.87\ F \quad (1)$$

The noise level was reasonably predicted by the model, as shown in Figure 11. The model's effectiveness can be seen in the difference between the predicted and the measured noise. Plotting was done for the additional statistical indicators which show very good potential for prediction as depicted in Figure 12. It demonstrates the reliability of the predicted noise level within a given range. The accuracy of the model is important because it can then be used to plan noise abatement measures. The current study can be further expanded by adding additional features to these 3 variables.

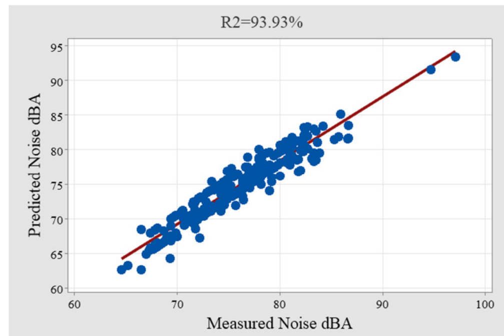

Fig. 10. Scatter of Leq dBA (measured vs predicted).

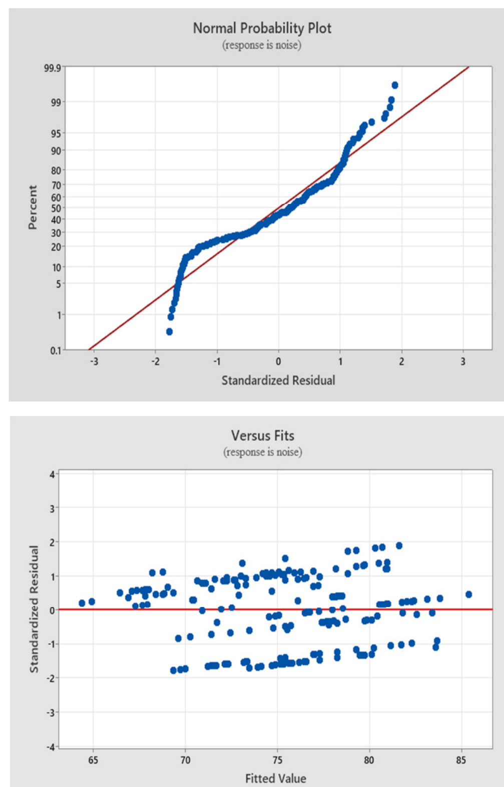

Fig. 11. Statistical indicators of the model.

X. CONCLUSION

Analysis of traffic noise prediction is carried out in the present work using a simple linear regression model to precisely predict the equivalent continuous sound level. The suggested method predicts the Leq dBA at various locations of Kirkuk city using 3 independent variables: road functionality, traffic volume, and average vehicle speed as essential features that affect the level of noise. It was confirmed that these variables are the main factors that influence the increase in noise level. The traffic noise can be predicted by using the formulated model with the aid of the suggested methods without using sound level devices. The output Leq value can be estimated with perfect accuracy by using the values of input variables. The model has predicted the level of noise with high accuracy (93.93%). This scenario implies an exact prediction that ranges within the bounds of the actual values. Measurements of traffic noise levels generally show levels above 70dBA at collector, arterial, and highway roads. These levels are generally higher than the accepted standard criteria of WHO. Moreover, Leq in the local streets of Kirkuk exceeded the limit recommended by the WHO for residential areas, except in relatively quiet locations during the off-peak hours.

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