DOI 10.20544/TTS2021.1.1.21.p43
UDC••504.6:656.121]:303.724(497.115)
Original scientific paper

Traffic noise estimating using multiple regression analysis: A case study Pristina city

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Abstract- **Noise emitted by road traffic is one of the main causes that degrade the standard of the population lives in urban areas. In this paper, is developed a model for the estimating of continuous noise level (L_{eq}) on the two-lane main urban road with medians in the city of Prishtina. Comparison of the results was done through performance indicators. It is found that independent variables have direct impact to dependent variable (L_{eq}) and determination coefficient achieve accuracy close to 94 %. This approach could be applied for predicting traffic noise to different locations with the same category of roads through residential areas.**

Key words- ***Road urban traffic noise, Model, Multiple regression analysis.***

I. Introduction

As is known the growth of economic development is associated with the increase in the number of private owned vehicles and also with the number of trips, [1]. These developments raise noise levels by exceeding established standards and consequently have a negative impact on human health, [2].

The main challenge for Prishtina city (Capital of Kosovo) is the peak hour traffic, respectively the capacity of the available road infrastructure does not meet sufficiently the requirements for travel, thus creating long queues of vehicles in the roads, [3].

As a result of this, there will be an increase of the travel time, environmental degradation and decrease of the level of traffic safety in general. In recent years, with the advancement of technology, there has been a growing interest by researchers in, evaluating, controlling and predicting this problem by development models according to different approaches and methods, [4].

Studies of this nature haven't been realized so far in the city of Prishtina, and this is the main reason that we started to work on this field in the busiest road segments within the urban area of Prishtina city. The main purpose of this paper is to identify the variables that have the greatest impact on the generation of noise emitted by road traffic.

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II. Noise As An Environmental Pollution Factor

Noise is considered as a serious risk to human health causing: hearing loss, speech interference, sleep disturbances and resting conditions, psycho-physiological effects, mental health effects, performance effects, and effects on behaviour with neighbours or pathological reactions, interference with other activities etc., [5].

Noise remains a serious concern for sustainable development affecting ecosystem disruption, disruption of material assets in monuments, interference with normal environmental composition, economic effects, etc. One of the noise level meters is also the SPL (Sound Pressure Level), a function of the ratio of the sound pressure square of any given sound while the SPL unit is "decibel", which in short referred to as dB, [6].

Another indicator that corresponds to the purpose of this paper is environmental noise, [7]. It is common that sources of environmental noise contain substantial infrastructure such as the petrochemical complex. In this type of situation, there are also many resources within the infrastructure that contribute to the overall noise emission process. In the case of noise emitted by road traffic, the source it's composed by vehicles during the traffic flow, [8]. This means that the noise emitted by road traffic is the sum of the noise generated by each vehicle participants in traffic. There are EU directives indicating the permissible noise values in public open spaces as presented in Table I, [9].

Table I
Noise Level Rates According To EU Directives

Acoustic classes	Values during daylight (dB)	Values during night (dB)
Class I – Special areas	50	40
Class II – Residential areas	55	45
Class III – Mixed areas	60	50
Class IV – Areas with intense human activities	65	55
Class V – Mostly industrial areas	70	60
Class VI – Industrial areas	70	70

III. Research Methodology

A. Study area

The main roads within the city of Prishtina were selected based on the traffic load but also their importance passing through the residential areas of the city.

These roads consist of two traffic lanes with 3.5 m wide, medians and a modern surface course (asphalt). The road segments selected for the study are as follows: “Muharrem Fejza”,”Fehmi Lladrovci”,”Road B”, ”Enver Maloku”, which are given in Fig.1.

Fig.1. Study area

B. Study period and methodology

The research was conducted in four locations x two direction = eight sites and different time intervals within weekdays from 08:00-17:00.

Recordings of the noise level (L_{eq}) emitted by road traffic are made on both sides of the road at a distance of 7.5 m from the middle of the traffic lanes and 1.5 m height by base, each of them were measured with a period of 30 minutes by instrument PCE 322 -A, as presented in Fig.2.

All other variables were measured in the same time interval by different instruments as presented in Table II.

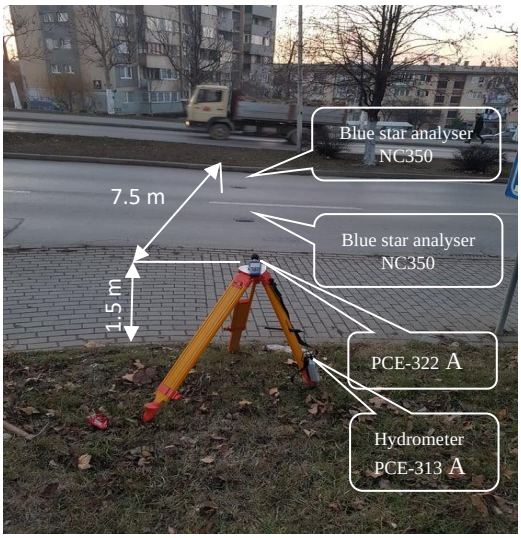

Fig.2. Methodology of measurement

C. Parameters and instruments for measurement

Based on the purpose of the research for analysis, the variables as presented through Table II were taken into account. Recordings of the rates of these variables were made through calibrated instruments.

TABLE II
VARIABLES AND INSTRUMENTS

Observed variable	Symbol	Instrument
Noise level in dB(A)	L_{eq}	PCE 322-A 
Average atmospheric temperature in ^oC	T_a	Hydrometer PCE-313 A 
Relative Humidity in %	H_r	
Dew point in ^oC	D_p	
Total traffic volume	Q_t	NC350 Bluestar traffic analyser 
Average spot speed of vehicles in km/h	S_p	
Average pavement surface temperature in %	T_s	
Average headway in second	H_a	

Based on the data collected and on the manufacturer's instructions, a data set of 240 units was gathered as the starting point for model building through the Multiple Linear Regression (MLR) method as presented in Table III.

For development the noise prediction model L_{eq} emitted from uninterrupted traffic flow on two-lane roads passing through residential areas, respectively, to investigate the relationships between the dependent variable "y_i" and the independent variables "x_{ik}", the MLR method was used, [10].

The general form of the equation for MLR is given in Eq. (1):

$$y_i = \beta_0 + \beta_1 \cdot x_{i1} + \beta_2 \cdot x_{i2} + ... + \beta_k \cdot x_{ik} + \varepsilon_i \qquad (1)$$

where are:

y_i - *dependent variable,*
$ß_0$ - *intercept,*
$ß_1$, $ß_2 ... ß_k$ – *coefficients of regression,*
x_{ik} - *independent variable,*
$\mathcal{E}_i$ -*error.*

TABLE III
DATA SET FOR ANALYSIS

Measurement	L_{eq} (Observed)	T_a	H_r	D_p	S_p	Q_t	T_s	H_a
1	63.1	3.3	49.8	0.0	42.9	17	15	6.3
2	63	3.9	50.1	0.3	30.7	8	15	11.4
3	64.8	3.7	50.3	0.2	40.0	16	14.5	6.7
4	64.6	3.3	50.1	0.0	36.0	10	14.5	9.9
5	64.2	3.5	50.8	0.1	40.2	16	14.5	6.6
6	64	2.8	52.0	-0.4	35.4	11	14.5	9.1
7	64.1	3.7	50.6	0.2	44.3	13	14.5	7.9
8	64.7	3.9	49.4	0.3	37.7	11	14.5	9.2
9	64.1	4.5	50.2	0.8	36.5	16	14.5	6.7
…	…	…	…	…	…	…	…	…
240	60.5	10	33.9	3.8	30	4	16.5	12

Initially correlation analysis was performed between the dependent variable and independent variables as well as between the independent variables themselves, from which it was found that each of the individual "*k*" variables ($x_1 \ldots x_7$) has an impact on the dependent variable "y_i", and that with each of them we can build a single linear regression model. For this reason, all variables are taken into account in model build. Then, the normality of the data for each variable was performed through the Klomogorov statistical test, where it emerged that all variables experience a normal distribution and those can be directly incorporated into the model without applying any additional transformations such as "log", "sqrt" etc., [11]. In this case, all variables are of the metric type. It is also shown graphically that all independent variables "x_{ik}" have a satisfactory correlation with the dependent variable "y_i".The identification of the independent variables that influence traffic noise emission is made after a preliminary research of various papers in this field of international publications, [12]. Also, descriptive statistics were performed for all variables involved in the model development as presented in Table IV.

TABLE IV
DESCRIPTIVE STATISTIC FOR ALL VARIABLES

Variable	N	Min	Max	Mean	Std.dev	Impact
L_{eq}	300	49.00	74.30	65.99	5.284	----
T_a	300	-0.30	12.20	6.10	3.446	-
H_r	300	24.40	85.30	50.34	13.472	-
D_p	300	-1.90	6.90	2.10	2.199	+
S_p	300	0.00	73.30	40.04	15.827	+
Q_t	300	0.00	29.00	13.25	6.520	+
T_s	300	2.50	17.00	11.40	3.645	-
H_a	300	3.90	60.00	11.15	9.705	+

IV. RESULTS AND DISCUSSION

TABLE V
MODEL SUMMARY OF STATISTICAL PARAMETERS

Model Summary[a]						
Model	R	R^2	Adjusted R^2	Std. Error		D.Watson
1	0.937	0.879	0.836	1.34256		0.877
ANOVA						
Model	SumSquares	Df.	Mean Square	F		Sig.($p<0.05$)
Regression	3064.318	4	766.080	425.017		0.000
Residual	423.580	235	1.802			
Total	3487.898	239				
Coefficients[b]						
	B	Std.Err	t	Tolerance	VIF	Sig.($p<0.05$)
Constant	82.613	1.312	62.982			0.000
T_s	-1.349	0.046	-29.239	0.564	1.772	0.000
Q_t	0.122	0.015	8.276	0.800	1.250	0.000
S_p	0.027	0.009	3.101	0.389	2.574	0.002
H_r	-0.030	0.012	-2.567	0.303	3.303	0.011

a. *Dependent Variable: Noise Level (L_{eq})*
b. *Predictors : (Constant), Ts, Q_t, S_p, H_r*

The rate of the impact of each variable is raised on the context of this study and the empirical studies of the various authors, as presented through the symbols "+" and "-" in Table IV.

For the development and evaluation of the significant model, the "stepwise" technique is selected which functions as a forward or backward procedure within the SPSS software, [13]. As a result, was created the most suitable model presented in Table V.

The model results show that the dependent variable has a strong correlation with the independent variables according to the coefficient of determination at the level of $R^2 = 0.937$ or 93.7%. Whereas in our analysis $R^2 = 0.879$, which indicates that 87.9% of the dependent variable is explained by the independent variables. Adjusted R^2=0.836 indicates that 83.6% of the variance of the dependent variable is explained by the variation of the independent variables. At first glance based on these values of R^2 and Adjusted R^2, impression is gained that the model is not suitable. However, this does not mean that a model with high value of R^2 should necessarily be suitable and a model with low value of R^2 is unsuitable.

In such cases the model evaluation should be done if the coefficients before the variables are statistically significant, [14]. From the results given in Table V, it can be seen that the values of the coefficients near to the variables T_s, Q_t, S_p and H_r are all statistically stable because they fulfill the criteria of Sig. ($p<0.05$).

Also, the pre-signs near the coefficients of the significant variables are in line with the expectation of impact according to Table IV. The value of the collinearity coefficients near to each significant variable has range to be VIF<10, indicating that the phenomenon of multicollinearity does not occur, [15].

Model testing by ANOVA (F-test = 425.017) with 95% confidence level (Sig.= 0.000 <0.05) indicates that all coefficients together are statistically significant and different from *zero.* Therefore, based on data collected for different days and time intervals and the equivalent level of noise (L_{eq}), applying the MLR method the mathematical model is obtained by expressing the interrelationship between the variables included in the model.

The general form of the equation for equivalent level of noise (L_{eq}) in dB (A) is given by Eq. (2):

$$L_{eq}=82.613-1.349\cdot T_S+0.122\cdot Q_t+0.027\cdot S_p-0.030\cdot H_r \qquad (2)$$

As seen from Eq. (2), traffic volume (Q_t=0.122) and speed (S_p=0.027) have the greatest impact on the increase in noise level, while the average asphalt temperature (T_s=-0.1349) and relative humidity (H_r=-0.030) has an effect on its reduction.

Whereas the other variables T_a, D_p and H_a did not appear statistically stable and as such were not taken into account. It has also been confirmed for the variables that resulted significant, residual analysis shows that residuals are normally distributed by zero mean and constant variance. In addition to the coefficient analysis, to determine the accuracy of the noise level estimation model for L_{eq} (Observed) and L_{eq} (Calculated) values, are utilized performance indicators such as: Relative Error (RE), Mean Error (ME), and Root Mean Squared Error (RMSE) [16].

This is accomplished by comparing the calculated data (F_i) with the observed data (A_i) so that the errors should be as small as possible [17], using equations Eqs.(3), (4) and (5).

$$RE=\frac{1}{n}\cdot\sum_{i=1}^{n}\left(\frac{F_i-A_i}{A_i}\right)\cdot 100 \qquad (3)$$

$$ME=\frac{1}{n}\cdot\sum_{i=1}^{n}(F_i-A_i) \qquad (4)$$

$$RMSE=\left[\sum_{i=1}^{n}(F_i-A_i)^2/n\right]^{\frac{1}{2}} \qquad (5)$$

Results are given in Fig. 3.

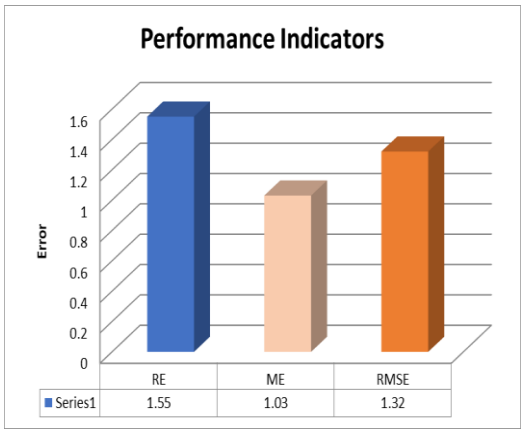

Fig. 3. Performance comparisons betwen indicators of model

From the results of Table VI, it seems that the model according to MLR gives small prediction error referring to the indicator in percentage RE = 1.55% and indicators with numerical values ME = 1.03 and RMSE = 1.32.

Also, the results of this paper show that the average value of traffic noise for the study locations is L_{eq} = 66.71 dB (A) with standard deviation σ=3.82 dB (A), which exceeds the allowable value at limit 55 dB (A) for Class II- residential area according to Table I.

V. Conclusion

This paper presents the development of an appropriate model using the Multiple Linear Regression (MLR) method

for estimating road traffic emission noise (L_{eq}) on two-lane roads with median passing through residential areas in the Prishtina city. The recordings were carried out in four locations in two directions of traffic flow with a total of eight sites. At each of these sites, data were measured through sophisticated and pre-calibrated equipment for all variables included in the model over a 30-minute time interval, based on 240 values of dataset.

To develop the model, the noise emitted by the traffic as a dependent variable (L_{eq}) and seven independent variables were taken into account, of which only four (T_s, Q_t, S_p and H_r) were significant. While, two of them (Q_t and S_p) have positive impact until two others ($-T_s$ and $-H_r$) have negative impact.

Significance of the model was done through statistical tests (R, R^2, Adjusted R^2, F-test, t-test, DW, VIF etc.), all of which resulted in acceptable values according to statistical theory. To verify the predict error, the calculated data (F_i) was compared with the observed data (A_i) through the performance indicators RE, ME, RMSE. The results showed that the values of all three indicators are quite low and within the allowed error limits for prediction.

In order to achieve the model with even better performances, more different locations within the road network in the urban area of Prishtina should be included. Also, recordings should be made at intervals longer than 30 minutes taking into account the peak hours of traffic flows thus creating a dataset on a larger number of recorded values.

Due to the small rates of error in predicting, this model can be used to predict the noise emitted by traffic on two-lane urban roads with medians (uninterrupted traffic flow) in the urban area of Prishtina in the time interval only during the day and for roads that pass through residential areas.

The obtained results showed that the mean value of the traffic emitted noise for the study locations was L_{eq} = 66.71 dB (A) with standard deviation σ = 3.82 dB (A), which exceeds the acceptable value at the limit of 55 dB (A) for Class II- residential area. Therefore, this is an indication that responsible authorities should take actions to prevent respectively to reduce the level of noise emitted by traffic to an acceptable limit level. This study can also serve as a starting point for future studies of this nature such as: overnight intervals, different classes of roads, different climatic conditions, different locations within urban areas, etc.

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