Assessment and MLR Modeling of Traffic Noise at Major Urban Roads of Residential and Commercial Areas of Surat City

Ramesh B. Ranpise , **B. N. Tandel, and Chandanmal Darjee**

1 Introduction

The main source of external noise in the world comes mainly from the transportation system [1] and specifically urban road traffic which is increasing with time [2]. There are many unfavorable effects on human health and well-being in urban areas and large cities due to noise pollution, such as speech communication, sleep disturbance, reading, and concentration of mental work, severe physiological and psychological damages [3]. In urban areas, traffic noise could be a keystone for the awareness of imminent conflicts by endanger urban road users [4]. The noise generated from the interaction of vehicular tires and the road surface is a significant contributor to the overall road noise. The main purpose of this study is to assess and model road traffic noise at major urban roads of residential and commercial areas of Surat city. The most widely recognized application is for assessment where a decision is to be made with respect to some future changes to an environmental noise field. In any case, given the reasonable and specialized difficulties in noise measurement strategies, there is an expanding number of circumstances in which predictions complement or substitute for measurement-based noise assessment techniques. Therefore, traffic noise prediction models are required as aids in the design of roads and the assessment of existing, or envisaged changes in traffic noise conditions.

R. B. Ranpise (✉) · B. N. Tandel · C. Darjee
Civil Engineering Department, Sardar Vallabhbhai National Institute of Technology, Ichchhanath, Surat 395007, Gujarat, India
e-mail: ranpiseramesh6588@gmail.com

Table 1 Geometrical/Geographical features of all roads

S. No.	Road	Geometrical features			Land use
		Width	Lane	Service road	
1.	Big Bazaar-Vesu road	14 m (without divider)	2 lane (two way)	Not available	Mixed (residential/commercial)
2.	Swami Vivekananda Marg	14 m (including divider)	2 lane (two way)	Not available	Residential
3.	Bhatar road	14 m (including divider)	2 lane (two way)	Not available	Mixed (residential/commercial)

2 Materials and Methodology

Surat is a city in the Indian state of Gujarat. It used to be a large seaport and is now a center for diamond cutting and polishing. It is the eighth largest city and ninth largest urban agglomeration in India [5]. Also, the city is very well connected by road, rail, and air transport.

Three roads of the same width (14 m) were selected based on a pilot survey carried out on six streets namely Bhatar road (flexible pavement), Swami Vivekananda Road (flexible pavement), and Big Bazaar-Vesu road (rigid pavement) (Table 1).

Noise level readings were collected for continuous day time 16 h (6.00 am–10.00 pm) with noise level meter held at about 1.5 m over the ground close to the edge of the street. Handycam was utilized for vehicular spot speed recordings. Furthermore, after that, the traffic was checked by playing the recordings on the workstation. There were 4–5 individuals associated with the review for different information gathering: (a) Two individuals were there for noise levels data collection. (b) Two individuals collected the traffic speed estimations by utilizing the radar gun. (c) One individual was there with Handycam. After collecting the information, a model has been created utilizing multiple linear regression in MATLAB programming.

3 Data Analysis and Results

After the appropriate execution of a pilot survey of six streets, three streets were chosen, in which two are flexible pavements and one is rigid pavement. Detailed monitoring has been performed for 16 h on every street. Traffic noise readings have been collected continuously for 16 h beginning from 6:00 am morning to night at 10:00 pm.

Traffic composition and graphical representation of traffic noise level and traffic volume count

3.1 Bhatar Road (Flexible Pavement)
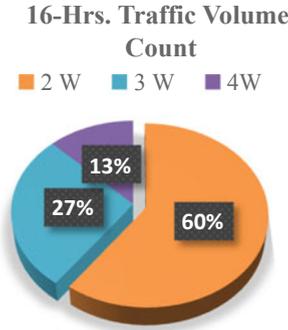
See Figs. 1 and 2; Table 2.

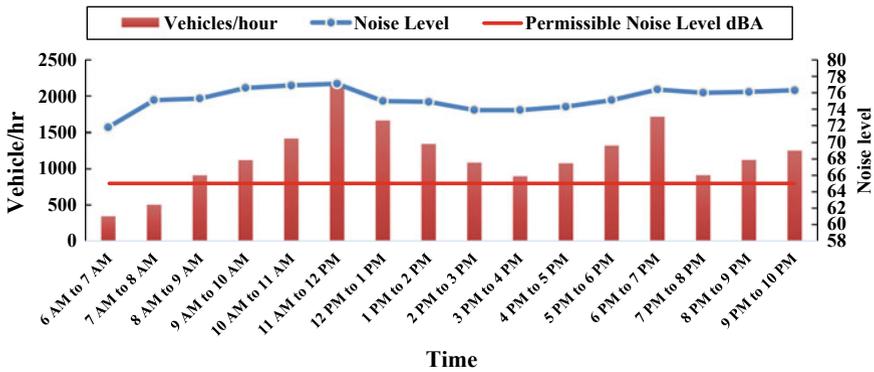**Fig. 1** Traffic compositions at the Bhatar road

Fig. 2 Graphical representation of traffic noise level and traffic volume count at Bhatar road

Table 2 Traffic composition at Bhatar road

Bhatar road		
Type of vehicles	Volume count	
	Numbers of vehicles	Percentage (%)
2 W	11,170	60.10
3 W	5096	27.42
4 W	2321	12.48
Total	18,587	100.00

3.2 *Swami Vivekananda Marg (Flexible Pavement)*
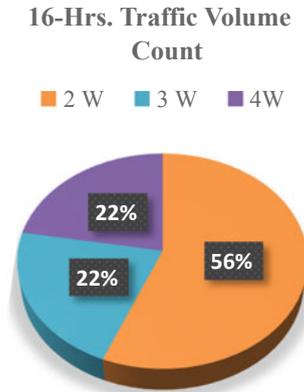
See Figs. 3 and 4; Table 3.

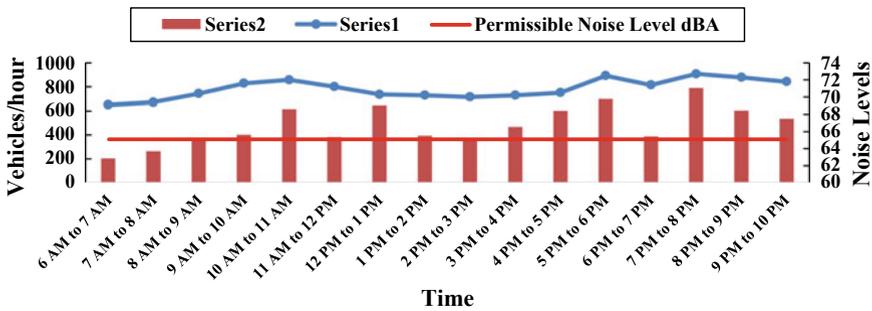**Fig. 3** Traffic compositions at Swami Vivekananda Marg

Fig. 4 Graphical representation of traffic noise level and traffic volume at Swami Vivekananda Marg

Table 3 Traffic composition at Swami Vivekananda Marg

Swami Vivekananda Marg		
Type of vehicles	Volume count	
	Numbers of vehicles	Percentage (%)
2 W	4413	56.15
3 W	1699	21.62
4 W	1748	22.24
Total	7860	100.00

3.3 Big Bazaar-Vesu Road (Rigid Pavement)

The maximum noise level (Leq) measured across all three roads is 77.1 dB(A). It is during morning peak hours (11 am–12 pm) and the road is a flexible pavement (Bhatar road). On this road, the minimum noise level is 73.9 dB(A) during the off-peak hour (2 pm–4 pm) which is still far exceeding the permissible noise level 65 dB(A). There is a significant difference of 3.2 dB(A) in between the maximum and minimum noise levels during the morning peak and off-peak hour. The maximum noise level (L_{max}) measured across all three roads is 107.3 dB(A). It is during evening peak hours (7 pm–8 pm) and the road is a flexible pavement (Swami Vivekananda Marg) (Figs. 5, 6 and Tables 4, 5).

The maximum number of vehicles/hour occurred at Bhatar road during morning peak hour (11 am–12 pm) is 2158 vehicles/hour and the corresponding noise level (Leq) is 77.1 dB(A) which is also maximum. On this road, the minimum number of vehicles/hour occurred during the off-peak hour (3 pm–4 pm) is 897 vehicles/hour and the corresponding noise level (Leq) is 73.9 dB(A) which is also minimum.

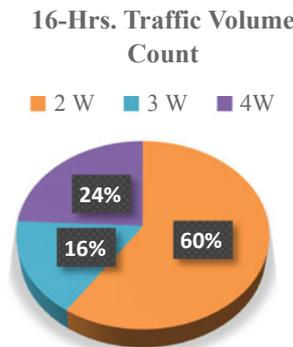**16-Hrs. Traffic Volume Count**

■ 2 W   ■ 3 W   ■ 4W

24%

16%

60%

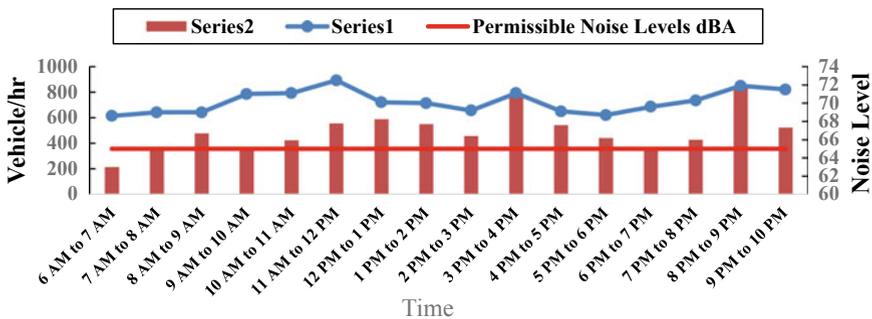**Fig. 5**   Traffic compositions at Big Bazaar-Vesu road

Fig. 6   Graphical representation of traffic noise level and traffic volume count at Big Bazaar-Vesu road

Table 4 Traffic composition at Big Bazaar-Vesu road

Big Bazaar-Vesu road		
Type of vehicles	Volume count	
	Numbers of vehicles	Percentage (%)
2 W	4622	59.42%
3 W	1274	16.38%
4 W	1883	24.21%
Total	7779	100.00%

Table 5 Traffic noise level (Leq) at each location

Location	Noise levels dB(A)		
	Peak (9 am–1 pm) or (5 pm–9 pm)	Off-peak (1 pm–5 pm)	Difference (Leq)
Bhatar road	77.1	73.9	3.2
Swami Vivekananda Marg	72.7	70.0	2.7
Big Bazaar-Vesu road	72.5	68.7	3.8

Among all three roads, Bhatar road has the highest aspect ratio (H/W), i.e., 2.5. The corresponding noise level (Leq) is 75.5 dB(A) which is maximum among all three roads and the aspect ratio for Big Bazaar-Vesu road is 1.64 and the corresponding noise level is 70.3 dB(A) which is minimum among all three roads. Based on this variation of equivalent traffic noise level concerning the aspect ratio, it is clear that when the aspect ratio is increasing for a particular road then the equivalent traffic noise level is also increasing due to the reverberation effect of noise (Table 6).

The maximum and minimum noise level among all rigid pavement under detailed study is 72.5 dB(A) and 68.6 dB(A), respectively. For flexible pavement, the maximum and minimum noise level is 77.1 and 69.1 dB(A). The significant finding here is that minimum noise levels are almost the same for both types of pavement, viz. rigid and flexible. But the maximum noise is more in a flexible type of pavement, by 4.6 dB(A).

Also, it is seen that the 2 W is contributing the maximum (55–60%) in the generation of equivalent traffic noise levels for all three roads.

Table 6 Variation of traffic noise level concerning aspect ratio (H/W)

Location	Noise level dB(A)	Aspect ratio (H/W)
Bhatar road (A)	75.5	2.5
Swami Vivekananda Marg (B)	72.0	2.14
Big Bazaar-Vesu road (C)	70.3	1.64

4 Model Developments

In this research, SPSS STATISTICS 22 programming is utilized for the generation of a multiple linear regression equation which can be represented as below:

$$Y = A + B_1 X_1 + B_2 X_2 + B_3 X_3 + \ldots + B_n X_n \tag{1}$$

where

Y = Dependent variable
Leq = 16 h day time equivalent noise level
X_1, X_2, X_3, and so on = Independent variables (2-W, 3-W, 4-W count)
A = Intercept
B_1, B_2, B_3, and so on = Coefficients of independent variables (Table 7).

From all the above results of the MLR model, we can say that when the number of three-wheeler is increasing for a road then the equivalent noise level is also increasing for that particular road. For Bhatar road, when the number of four wheelers is increasing the equivalent noise level (Leq) is decreasing, and for Big Bazaar-Vesu road, when the number of two wheelers is increasing the equivalent noise level is decreasing.

4.1 For All Three Roads

Developed multiple linear regression model for all three roads is as follows:

$$Y = 30.212 - 2.132 \, X_1 + 2.156 \, X_2 + 1.6 \, X_3 + 25.671 \, X_4 \tag{2}$$

where X_4 = Average Height of buildings.

From Eq. (2), it is seen that equivalent traffic noise level (Leq) is increasing with the numbers of the three-wheeler, four-wheeler, and average building heights, and it

Table 7 Multiple linear regression equation for three roads

Location	MLR equation	R^2	Avg. percentage % error
Bhatar road	$Y = 64.562 + 3.573 \, X_1 + 1.184$ $X_2 + 1.567 \, X_3$	0.086	1.804
Big Bazaar-Vesu road	$Y = 61.129 - 3.05 \, X_1 + 3.101$ $X_2 + 2.315 \, X_3$	0.253	2.065
Swami Vivekananda Marg	$Y = 63.840 + 3.379 \, X_1 + 0.181$ $X_2 + 2.143 \, X_3$	0.172	2.272
All roads (combined)	$Y = 30.212 - 2.132 \, X_1 + 2.156$ $X_2 + 1.6 \, X_3 + 25.671 \, X_4$	0.511	2.273

is decreasing with the increment of numbers of the two-wheeler. In the MLR model for all three roads, the coefficient for average building height is also obtained because the average building height for all three roads is not constant.

5   Results and Discussion

As per Fig. 7, it is observed that the estimation of the coefficient of determination (R^2) is 0.086 which is less noteworthy. The mean percentage error as indicated by Fig. 8, it is observed that the estimation of the coefficient of determination (R^2) is 0.253 which is additionally less, yet more prominent than the R^2 for Bhatar street, the greatest and least supreme blunder is 5.23 and 0.01% individually. The normal outright blunder is 2.06%. Swami Vivekananda Marg: As indicated by Fig. 9, it is observed that the estimation of the coefficient of determination (R^2) is 0.172 which is likewise exceptionally less yet more noteworthy than the R^2 for Bhatar Street, the most extreme and least total mistake is 9.35 and 0.07% individually. The mean percentage error is 2.27%.

For all three roads according to Fig. 10, it is seen that the value of the coefficient of determination (R^2) is 0.511 which is higher than all the three roads. The maximum and minimum absolute errors are 12.86% and 0.0%, respectively. The mean percentage error is 2.27%.

After the interpretation of the outputs from MLR, it was found that the value of mean square error is higher and the value of the coefficient of determination (R^2) is low. It is a clear indication that the model obtained from the MLR is weak and not adequate. Among the prediction in three urban roads, the predicted output result from

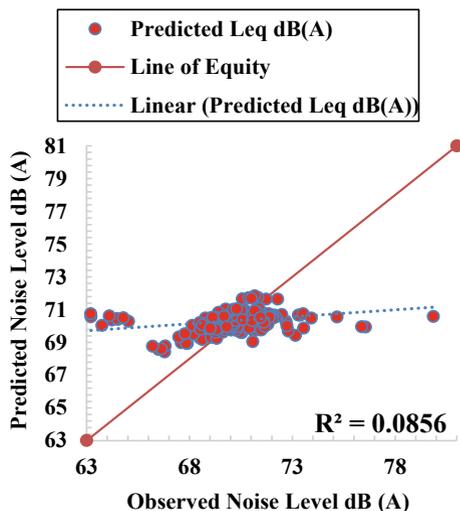**Fig. 7** Observed versus predicted traffic noise level (Leq) for Bhatar road

Fig. 8 Observed versus predicted traffic noise level (Leq) for Big Bazaar-Vesu road
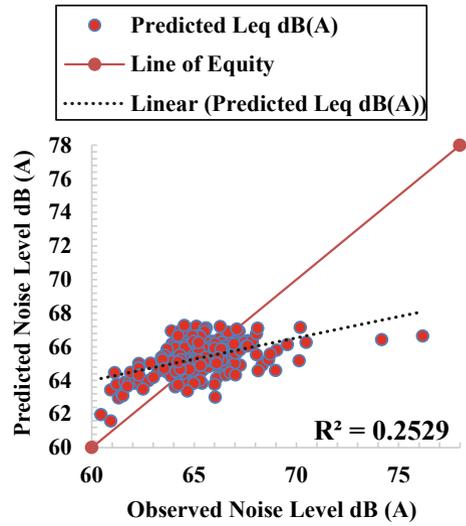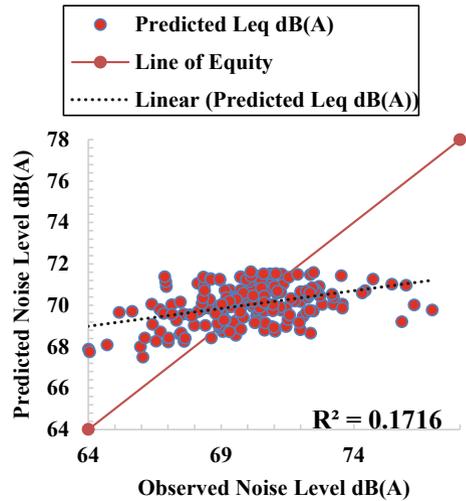

Fig. 9 Observed versus predicted traffic noise level (Leq) for Swami Vivekananda Marg

the MLR model showed not much correlation with a mean percentage error of 2.065 and an R^2 value of 0.25. But with the combined road, there is a significant change in average absolute % error 2.27, with R^2 value 0.51. The factors not considered in this study, but contributing to the generation or absorption of noise are speed of the vehicles, vegetation along the roadside, and the number of heavy vehicles passed through the road from 1:00 pm to 5:00 pm.

Fig. 10 Observed versus predicted traffic noise level (Leq) for all three roads
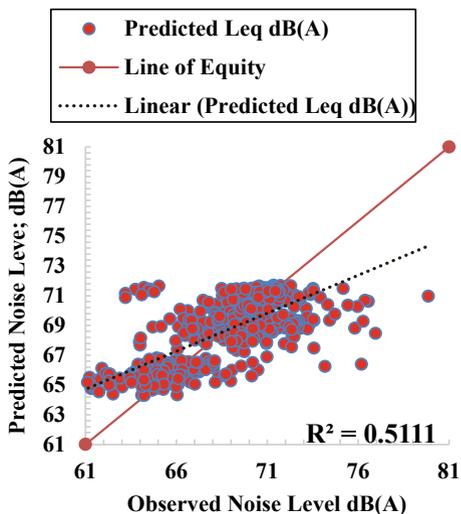
6 Conclusion and Recommendations

In this study, noise and traffic information has been collected for continuous 16 h the span at three distinct streets of Surat city. Two streets have flexible pavement surface, and one street has rigid pavement. Multiple regression model has been created by utilizing information gathered during the itemized study in MATLAB R2013b and SPSS Statistics 22 programming. Among all three roads understudy, the noise level during day time and night time is above the permissible limit of Noise Pollution (Regulation and Control) Rules, 2000. It was also found that the maximum noise level obtained on the flexible pavement road surface during the morning peak hours which is 4.6 dB(A) higher than the maximum noise level (Leq) obtained on the rigid pavement road surface during the morning peak hours. Hence, among all the three individual prediction model results, it is found that the Bhatar road and Big Bazaar-Vesu road have approximately the same value of the coefficient of determination and average absolute percentage error. The model developed for these two roads is better than the Swami Vivekananda Marg.

As the equivalent noise level is not linearly dependent upon independent variables traffic count and average building height, the MLR models developed are weak and not reliable. To overcome this problem, road traffic noise prediction models may be developed using evolutionary computing tools like genetic algorithm, neural networks, etc. Also, only two independent variables, viz. vehicular count and building height have been taken into consideration, but generation or reduction of noise also depends largely upon vegetation along roads, types of pavement, speed of the vehicle, etc.

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