Research Article

Dipeshkumar R. Sonaviya* and Bhaven N. Tandel

Integrated road traffic noise mapping in urban Indian context

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Abstract: Road traffic noise has been recognized as a serious issue that affects the urban regions. Due to urbanization and industrialization, transportation in urban areas has increased. Traffic noise characteristics in cities belonging to a developing country like India are highly varied compared to developed nations because of its heterogeneous conditions. The objective of the research study is to assess noise pollution due to heterogeneous traffic conditions and the impact of horn honking due to un-authorized parked vehicles on the main roadside. Noise mapping has been done using the computer simulation model by taking various noise sources and noise propagation to the receiver point. Traffic volume, vehicular speed, noise levels, road geometry, un-authorized parking, and horn honking were measured on tier-II city roads in Surat, India. The study showed not so significant correlation between traffic volume, road geometry, vehicular speed and equivalent noise due to heterogeneous road traffic conditions. Further, analysis of traffic noise showed that horn honking due to un-authorized parked vehicles contributed an additional up to 11 dB (A), which is quite significant. The prediction models such as U.K's CoRTN, U.S's TNM, Germany's RLS-90 and their modified versions have limited applicability for heterogeneity. Hence, the noise prediction models, which can be used for homogeneous road traffic conditions are not successfully applicable in heterogeneous road traffic conditions. In this research, a new horn honking correction factor is introduced with respect to unauthorized parked vehicles. The horn honking correction values can be integrated into noise model RLS-90, while assessing heterogeneous traffic conditions.

Keywords: Heterogeneity; Horn honking; Horn correction factor; Noise mapping; Un-authorized parking

1 Introduction

A developing nation like India faces serious effects of noise pollution in the last few eras due to substantial growth in the number of vehicles, heterogeneity, horn honking and urbanization [1–3]. Noise pollution due to urbanization and heterogeneous traffic conditions is identified as a major problem in developing nations with many harmful health effects [4–6]. Traffic noise pollution increase due to the composition of vehicular traffic on urban roads, which consists of heavy vehicles, four-wheelers, three-wheelers, two-wheelers, along with slow-moving vehicles such as bicycles [7–9]. The most significant causes of increasing noise pollution in developing nations are heterogeneous vehicular traffic [10, 11]. Several countries have carried out the study of noise pollution and its impact on the surrounding environment [12, 13]. Assessment of traffic noise pollution is not an easy task, it varies with types of vehicles, a dimension of vehicles, speed, horn honking and road geometry [14, 15]. Assessment of traffic is a challenging task in tier-II cities in Indian considering the heterogeneous traffic conditions including the composition of vehicles, vehicles types, vehicle congestion, road conditions, frequently horn honking due to un-authorized parked vehicles and lack of traffic sense [16, 17]. The composition of mixed traffic with varying speeds and vehicular dimensions makes it difficult to maintain lane discipline resulting in more and more honking sounds.

Noise maps can be used to identify the affected area. Much of the noise mapping work using advanced tools and techniques has been done in developed nations. These tools include GIS, AutoCAD, etc. and software includes SoundPLAN, Cadna/A, Lima, etc. There is less documentation on noise mapping research in India. Such studies have been reported only in a few cities of India viz. Chennai, Guwahati, Delhi, Asansol, Chandigarh. Therefore, compared to the noise mapping research work in a developed nation, the scenario of developing nation is quite different.

***Corresponding Author: Dipeshkumar R. Sonaviya:** Environmental Section, Civil Engineering Department, S. V. National Institute of Technology, Surat, India; Email: dipeshsonaviya2589@gmail.com; Tel. +91-90335 77638

Bhaven N. Tandel: Environmental Section, Civil Engineering Department, S. V. National Institute of Technology, Surat; Email: bnt@ced.svnit.ac.in; Tel.: +91-9825553175

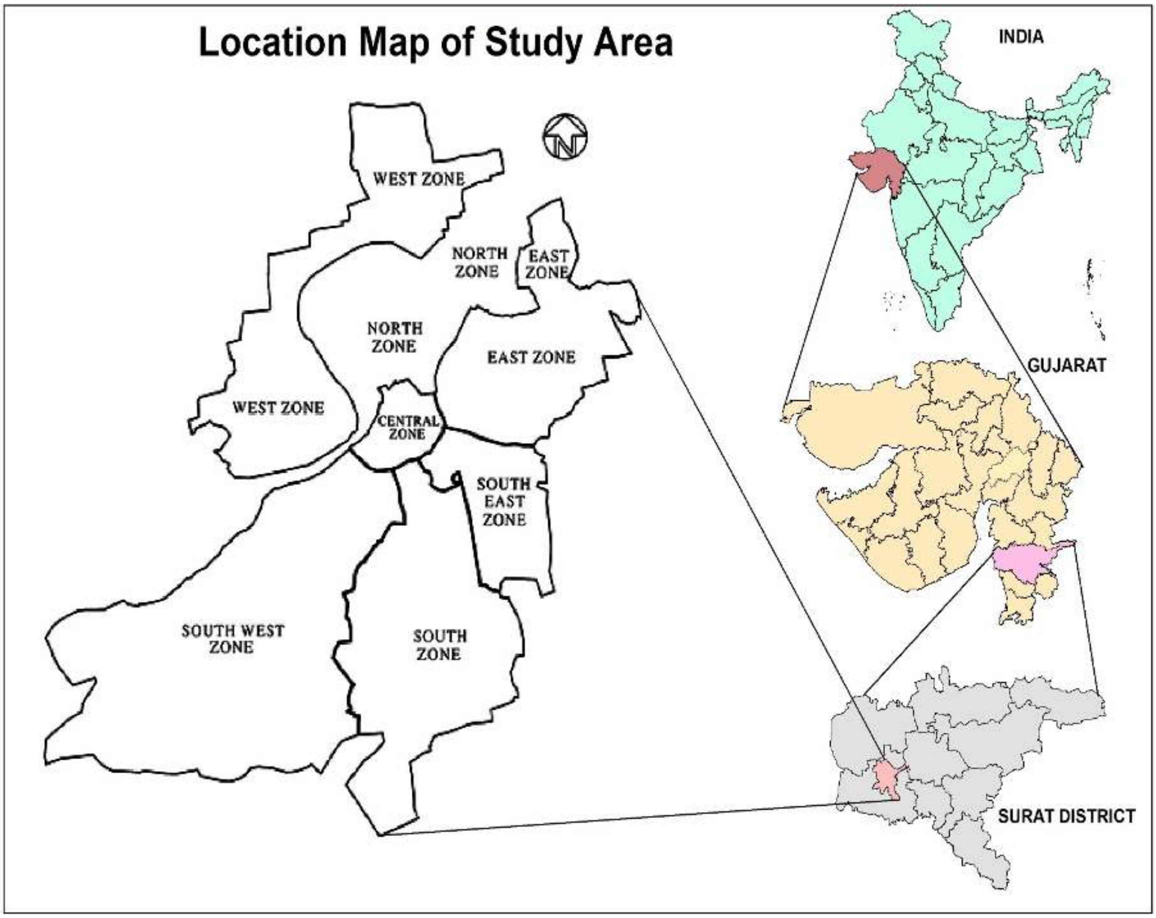

Figure 1: Study area for noise and traffic volume survey

This finding emphasizes the need to develop a map, which is also a prediction noise model, exclusively for heterogeneous Indian conditions. Honking has become a common event in India, which again is a function of un-authorized parking on the main road [18, 19]. The equivalent noise level was increased 2 to 13 dB (A) compared to measured values due to horn honking events while using the standards such as RLS-90, FHWA, CoRTN, in SoundPLAN software [20–22]. These standards have limited applicability for heterogeneity. Therefore, a new model is required to be developed to suit the heterogeneous traffic conditions for noise mapping purposes. Hence, a horn-honking factor is considered in monitoring, assessment, and modelling of traffic noise and planning of noise abatement actions. The objective of this research is to assess and measure traffic noise and the impact of horn honking on the urban environment of Surat city (tier-II), India. The study will help in defining the new 'horn-honking' factor to assess traffic noise.

2 Methodology

The methodology used for the present research study is explained in the following sections.

2.1 Study area

The area selected for entire research is Surat city. Surat is a city located on the western part of India in the state of Gujarat. It is one of the most dynamic city of India with one of the fastest growth rates due to immigration from various parts of Gujarat and other states of India. Surat is regarded as 4^{th} fastest developing cities of India with a bustling metropolitan area home to over 6 million people. According to recent Census of India 2011, Surat has recorded a growth of 63.3% in its population from 2001 to 2011 [23]. Road traffic volume, equivalent noise levels, spot speed, un-authorized parking, and horn honking were measured at two zones namely Central zone and South-West zone of Surat city, Gujarat, India (Figure 1). There are seven zones

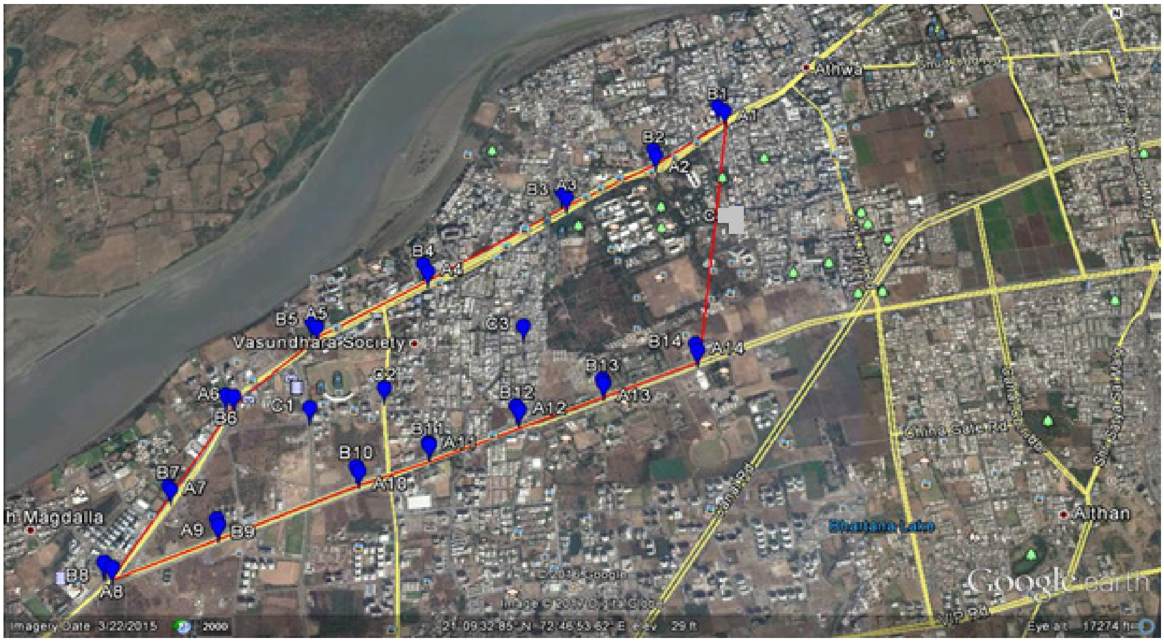

Figure 2: Map of South-West zone of Surat city with monitoring locations

Figure 3: Map of Central zone of Surat city with monitoring locations

in Surat city namely West zone, East zone, South zone, North zone, Central zone, South-West zone, and South-East zone. These seven zones include diversified activities of business, residence, commerce, and industrial. A mixed type of traffic has been observed in these zones.

Different type of land- use pattern has been seen along these zones. Out of the seven zones, the South-West zone and Central zone were selected for the study purpose because these zones include diversified activities of business, residence, commerce. Two study areas from different zones were selected for the survey.

In the South-West zone, nine sq.km. area was selected (Figure 2). These zones contain all type of activities which can be affected by vehicular noise pollution. Noise monitoring was done at thirty-one locations in the South-West zone with traffic volume study and traffic speed study.

In the Central Zone, two sq.km areas were selected (Figure 3). These zones contain all types of activities, which can be affected by vehicular noise pollution. Activity refers to schools, colleges, hospitals, commercial areas, and residential areas. Noise monitoring was done at three locations in the Central zone with traffic volume study and traffic speed study.

2.2 Data collection

Data collection and extraction were done for thirty-one locations of the South-West zone, and three locations of Central zone in Surat city urban roads, with traffic volume, traffic speed, numbers of horn events and un-authorized parking. Residential as well as commercial buildings are located just on the roadside and these buildings are minimum of three storeys and maximum of thirteen storeys. Measurements were carried out from Monday to Friday, the working days. Noise measurements have been taken using the KIMO DB 300/2, automatic sound level meter for a 24-hour duration. Monitoring was divided into two parts as per central pollution control board (CPCB) guidelines, day time 6.00 am to 10.00 pm and night time 10.00 pm to 6.00 am [24]. The vehicles were divided into five categories like 2-wheelers (motorcycle, mopeds), 3-wheelers (autorickshaw), 4-wheelers (cars, bus and truck). The counts of a number of vehicles that crossed the point of measurement from either direction on the road were recorded using a professional camera. Un-authorized parked vehicles and horn events were counted manually. For counting category wise un-authorized vehicles, 4-5 persons were involved. For counting category wise horn events 2-4 persons were involved. The speeds were also monitored with a handheld radar gun along with the noise level. The average A-weighted noise emitted by vehicles traveling the roads under actual conditions of the noise monitoring site was determined at 5 different measurement locations when a single vehicle in each category was passing at its free speed. The data extraction process consists of four parts: namely noise level data, traffic (count & speed), numbers of horns count and un-authorized vehicles count. Noise levels (L_{Aeq}) and other noise indices (L_{10}, L_{50}, L_{90}, L_{95}) stored in the automatic sound level meter, automatically generates a complete data sheet of all necessary noise data and statistics in a user-friendly way. These data sheets are then saved to high-end Windows 7 operating system computer. Classified and total traffic volume count, of each direction, for day time and night time, are recorded using a video camera and transferred to MS Excel direction wise.

2.3 Noise mapping

The area selected for noise mapping is Surat city (tier-II city). Figure 4 depicts the methodology used to develop a noise map. Data required for mapping are noise data ($L_{Aeq24hr}$, L_{10}, L_{90}, L_{den}, L_{max}, L_{min}), road inventory data, geometry features of mapping area, category wise traffic counts, category wise vehicles speed, meteorological data such as wind velocity, humidity, temperature, air pressure.

Two inbuilt noise propagation models of SoundPLAN such as CoRTN:88 and RLS-90 were used to develop road traffic noise maps. The reason for selecting CoRTN:88 and RLS-90 noise models was the provision of maximum urban inventory as input variables. The CoRTN:88 is designed for a bituminous surface having vehicular velocity greater than 75 kmph whereas on Indian urban roads such as vehicle speed is never observed. This is reflected in the prediction values given by CoRTN: 88, where day time L_{Aeq} values are underpredicted up to 11 dB (A) as compared to actual values, therefore it is not applicable in Indian urban road conditions [25]. L_{Aeq} values predicted by RLS-90 are nearer to observed (actual) values and having a difference of up to 10 dB (A). Hence, among all available noise propagation models in SoundPLAN software, RLS-90 proved to be the best for homogenous traffic conditions.

Tables 1 & 2 depict the difference of up to 11 dB(A) in the above model when compared to measured data. The results show (Figure 5 to 8) a significant difference from the measured noise levels which are due to the fact that these standards inherently assume homogeneous traffic conditions with higher speeds, wider roads, and no conjunction, whereas Indian traffic conditions are heterogeneous. Due to the widely varying vehicular dimensions & speeds, lack of lane disciplines, and un-authorized parking on road in heterogeneous traffic conditions honking becomes inevitable. It changes the soundscape of the city considerably as compared to other cities of developed countries.

Figures 5 to 8 depict the noise maps of the South-West zone and Central zone using RLS-90 model. The road shown the emission line where noise was generated by vehicles means the main source of noise is vehicles. SoundPLAN can predict noise value at any point on the map. The results of day time noise prediction generated by RLS-90 maps are slightly improved than CoRTN:88 but still having a difference upto 11 dB (A), which may be due to the fact that this inbuilt RLS-90 model of SoundPLAN inherently assume homogeneous traffic conditions with higher speeds, wider roads, and no congestion, whereas Indian traffic conditions are heterogeneous, lesser speeds and narrow roads.

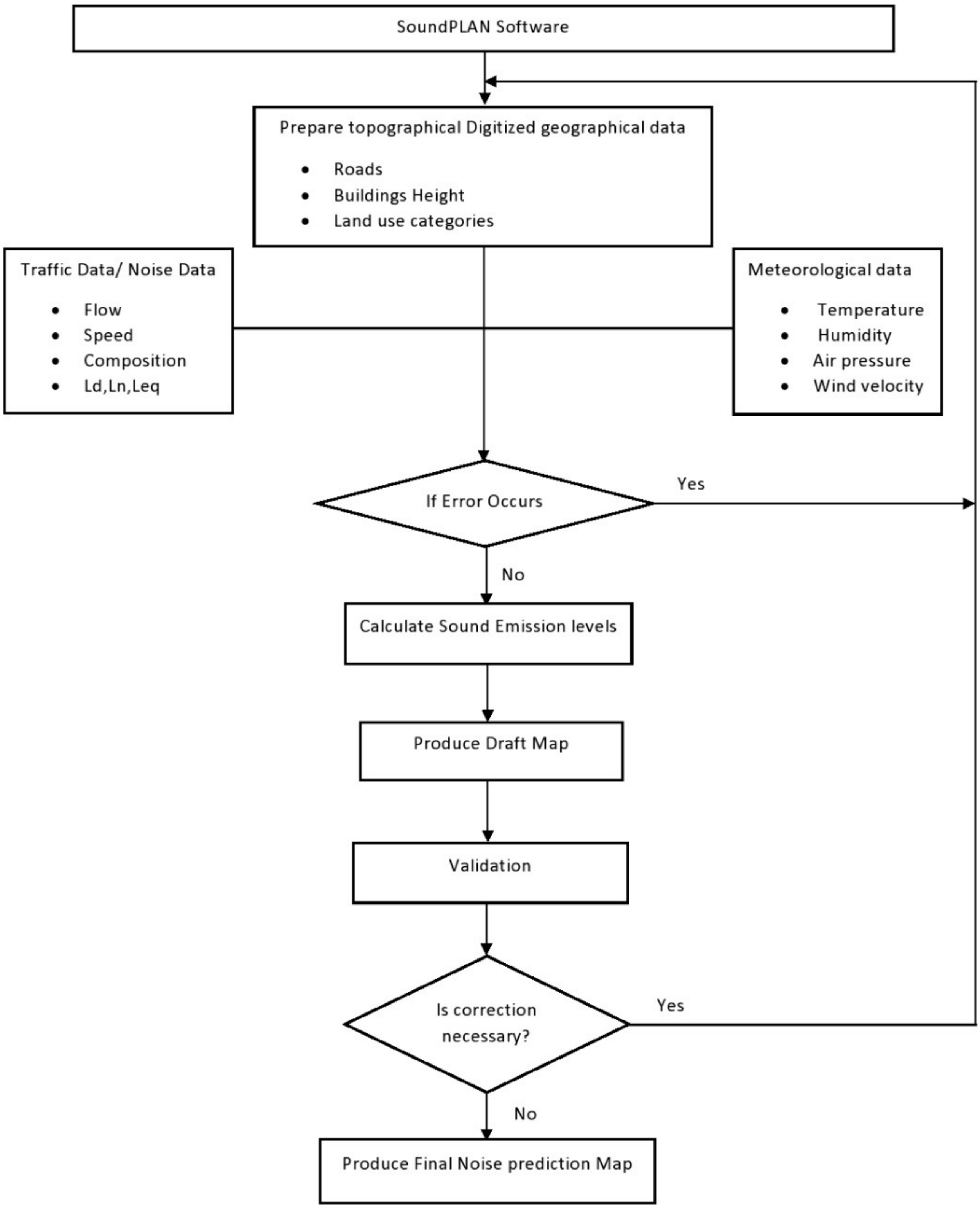

Figure 4: Methodology for noise mapping

Table 1: Difference between Measured L_{Aeq} and Predicted $L_{Aeq-SoundPLAN}$ (South-West zone)

Locations	Day time			Nigh time		
	L_{Aeq} dB(A)	Predicted L_{Aeq} dB(A)	Difference dB(A)	L_{Aeq} dB(A)	Predicted L_{Aeq} dB(A)	Difference dB(A)
A_1	75.2	66.9	8.3	70.5	66.9	3.6
B_1	76.5	68.0	8.5	70.7	67.1	3.6
A_2	73.9	65.4	8.5	70.4	66.6	3.8
B_2	73.5	65.3	8.2	70.6	67.7	2.9
A_3	76.1	67.7	8.4	68.9	65.4	3.5
B_3	73.6	65.2	8.4	71.3	68.8	2.5
A_4	75.4	67.8	7.6	71.6	68.1	3.5
B_4	76.6	67.8	8.8	68.1	66.2	1.9
A_5	75.1	66.6	8.5	67.7	64.8	2.9
B_5	74.6	66.0	8.6	67.0	64.1	2.9
A_6	71.9	62.7	9.2	67.4	65.2	2.2
B_6	75.2	67.0	8.2	67.2	64.8	2.4
A_7	71.7	65.1	6.6	66.6	62.9	3.7
B_7	73.2	66.2	7.0	67.9	64.7	3.2
A_8	72.8	66.2	6.6	66.8	64.1	2.7
B_8	73.1	65.8	7.3	68.8	65.2	3.6
A_9	72.0	64.2	7.8	67.4	64.7	2.7
B_9	71.7	64.2	7.5	69.6	66.5	3.1
A_{10}	71.9	64.1	7.8	66.5	64.4	2.1
B_{10}	72.5	64.9	7.6	68.1	64.8	3.3
C_1	70.7	62.1	8.6	69.4	66.8	2.6
A_{11}	73.1	65.2	7.9	65.8	64.6	1.2
B_{11}	73.9	66.1	7.8	66.6	63.6	3.0
C_2	71.3	62.7	8.6	64.3	61.9	2.4
C_3	74.4	66.3	8.1	65.7	62.4	3.3
A_{12}	72.3	64.6	7.7	68.2	65.2	3.0
B_{12}	72.8	65.1	7.7	67.4	64.8	2.6
A_{13}	72.5	64.1	8.4	68.0	64.9	3.1
B_{13}	72.3	65.0	7.3	66.6	63.6	3.0
A_{14}	72.8	65.2	7.6	69.4	66.1	3.3
B_{14}	72.3	64.1	8.2	69.8	67.1	2.7

Table 2: Difference between Measured L_{Aeq} and Predicted $L_{Aeq-SoundPLAN}$ (Central zone)

Locations	Day time			Night time		
	L_{Aeq} dB(A)	Predicted L_{Aeq} dB(A)	Difference dB(A)	L_{Aeq} dB(A)	Predicted L_{Aeq} dB(A)	Difference dB(A)
A	74.0	64.8	9.2	66.6	62.9	3.7
B	74.5	64.9	9.6	62.4	58.9	3.5
C	73.2	62.8	10.4	64.7	61.5	3.2

Residential as well as commercial buildings are located just on the roadside and parking space are not available. Therefore, people park vehicles on the main road. This un-authorized parking of vehicles on the road leads to severe horn honking conditions, which is not taken into consideration in inbuilt RLS-90. Therefore, a model is proposed for heterogeneous traffic conditions for developing nations like India, which take into account this significant

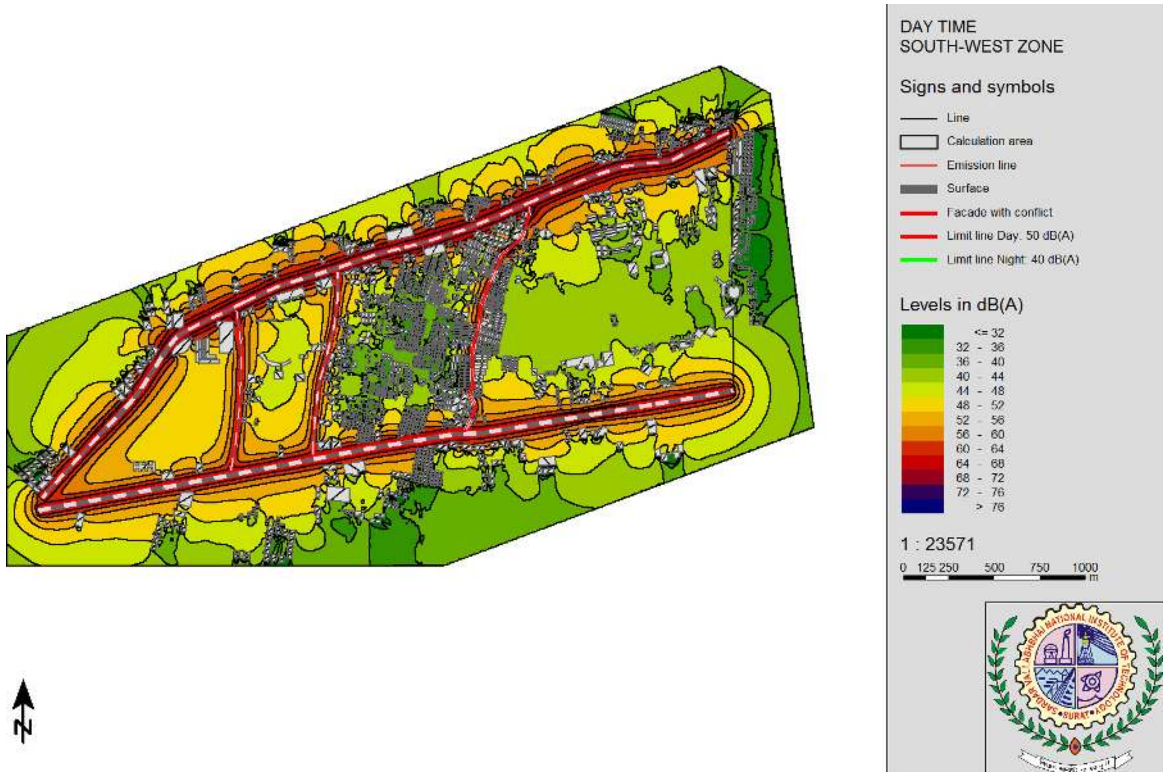

Figure 5: Day time noise map of South-West zone using RLS-90

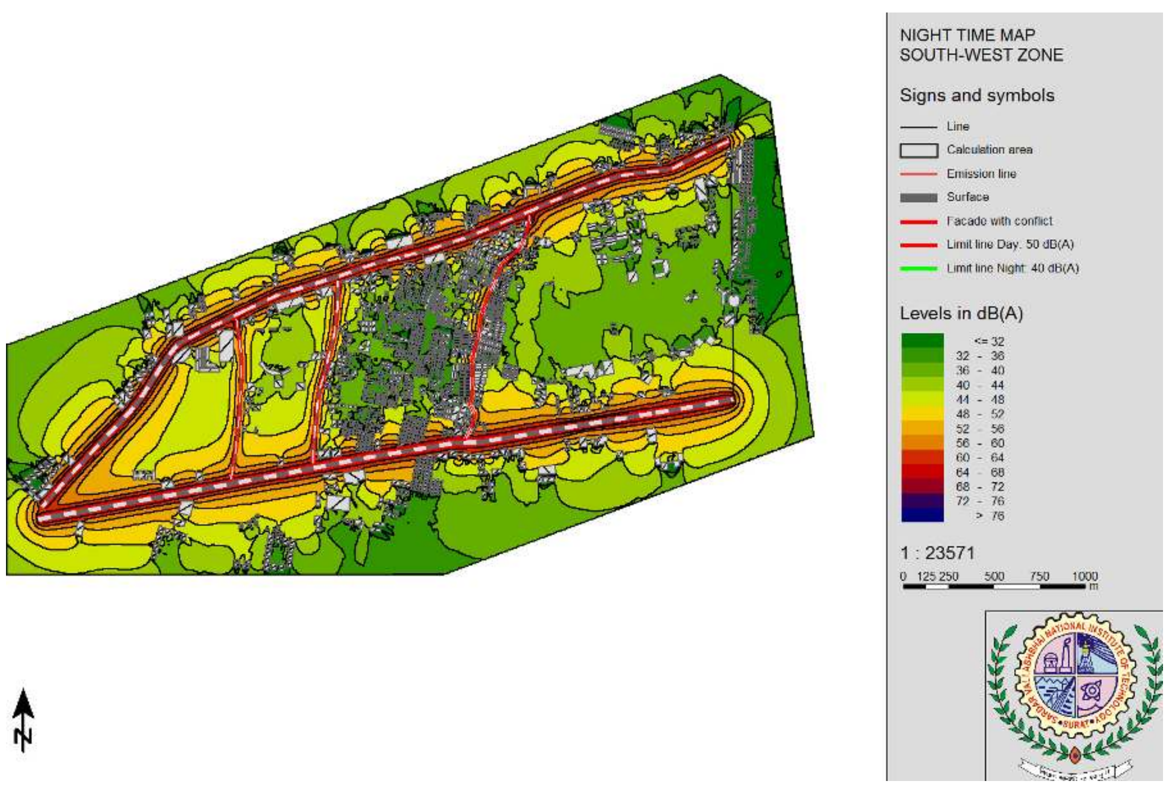

Figure 6: Night time noise map of South-West zone using RLS-90

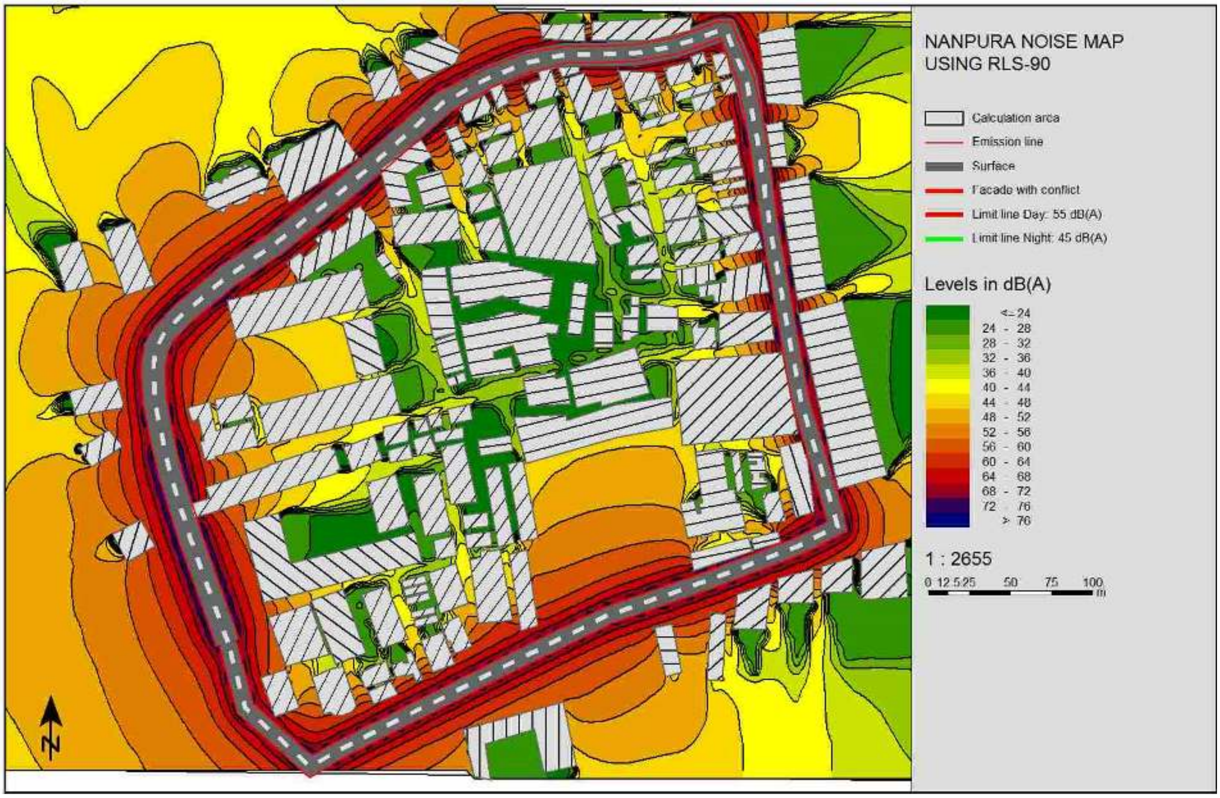

Figure 7: Day time noise map of Central zone using RLS-90

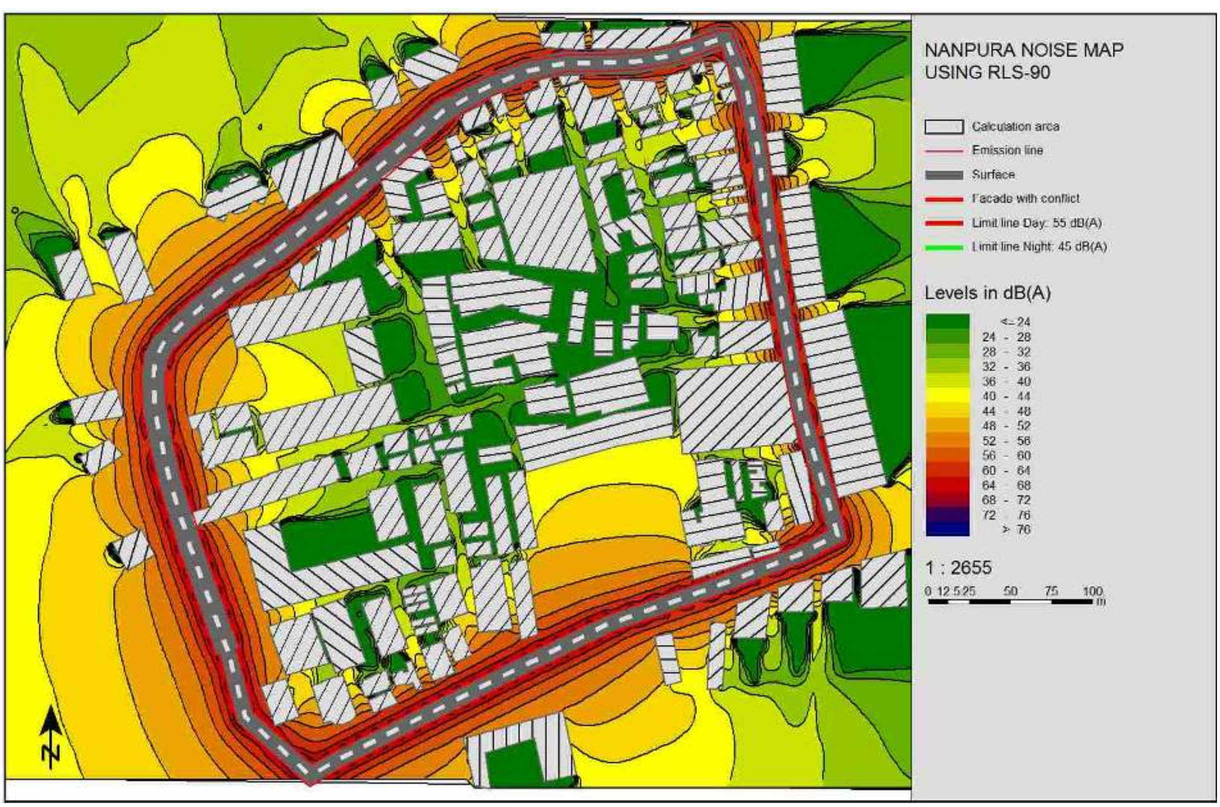

Figure 8: Night time noise map of Central zone using RLS-90

Table 3: Number of horn and un-authorized parked vehicles of South-West zone of Surat city

Locations	Total number of horn events	Un-authorized parked 2-wheelers (2W)	Un-authorized parked 3-wheelers (3W)	Un-authorized parked 4-wheelers (4W)
A_1	5676	4510	76	1743
B_1	5488	4320	65	1687
A_2	4898	4125	96	1621
B_2	4587	3258	46	1790
A_3	4898	3423	61	1474
B_3	5345	4412	103	1569
A_4	4887	3578	112	1547
B_4	5404	3534	98	1656
A_5	4573	3231	109	1256
B_5	6386	5318	122	1998
A_6	3064	2568	76	945
B_6	2085	2030	44	556
A_7	2067	1745	8	567
B_7	1802	1890	12	453
A_8	2345	2278	17	689
B_8	2390	2098	15	635
A_9	2060	2598	23	667
B_9	2187	2372	34	689
A_{10}	2037	2892	32	551
B_{10}	2189	3001	43	556
C_1	2256	2921	56	666
A_{11}	2489	2834	61	691
B_{11}	2391	2387	37	623
C_2	1287	1590	10	389
C_3	2023	2890	19	498
A_{12}	2620	3112	56	569
B_{12}	2238	3212	81	451
A_{13}	2570	2891	67	681
B_{13}	2078	2423	54	502
A_{14}	2119	2691	62	521
B_{14}	2291	2798	31	665

input variable, viz. un-authorized parking and horn honing.

3 Horn honking correction factor-based noise prediction model

Tables 3 & 4 show the relationship between un-authorized parking and number of horn events for a duration of 16 hours, which is arrived at based on the field data collection, with one slot being considered of 15 minutes. From the Figure 9 and 10, it is clearly understood that the horn events increase proportionally with un-authorized parked vehicles.

The horn honking condition arising due to un-authorized parking is not taken into consideration in RLS-90. A new horn correction factor (ΔL_{UAP}) is developed to improve the accuracy of the noise map and prediction model. The new correction factor, ΔL_{UAP} is derived to reduce the error between predicted and measured noise levels. If noise in dB (A) (ΔL_{UAP}) is the dependent variable, then it majorly depends on independent variables, un-authorized parked vehicles, and a number of horn events. These variables were intra and inter correlated and findings showed strong correlation amongst and between

Table 4: Number of horn and un-authorized parked vehicles of Central zone of Surat city

Locations	Total number of horn events	Un-authorized parked 2-wheelers (2W)	Un-authorized parked 3-wheelers (3W)	Un-authorized parked 4-wheelers (4W)
A	16275	2836	128	2406
B	10673	5320	453	2459
C	14107	4533	184	4675

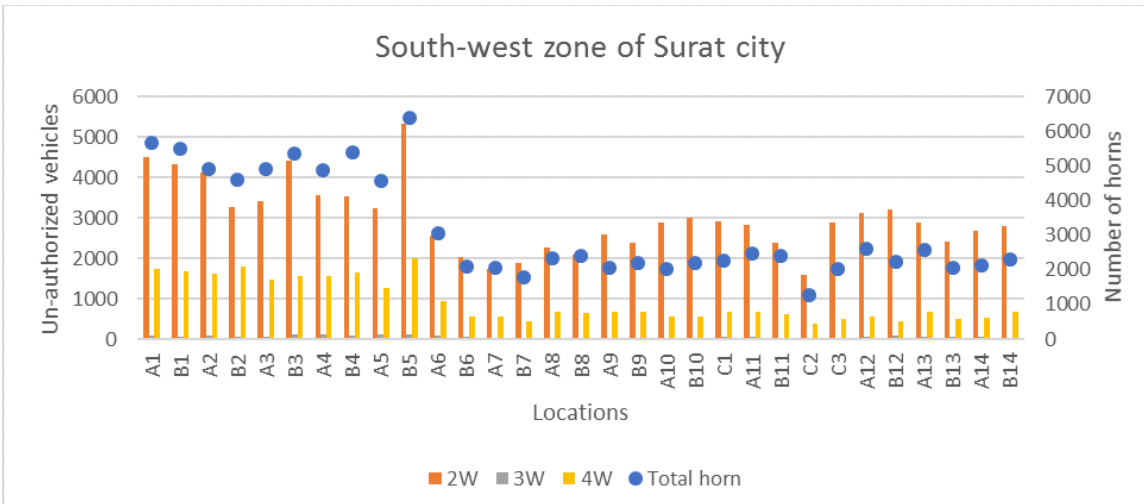

Figure 9: Correlation between un-authorized vehicles and number of horn event (South-West zone of Surat city)

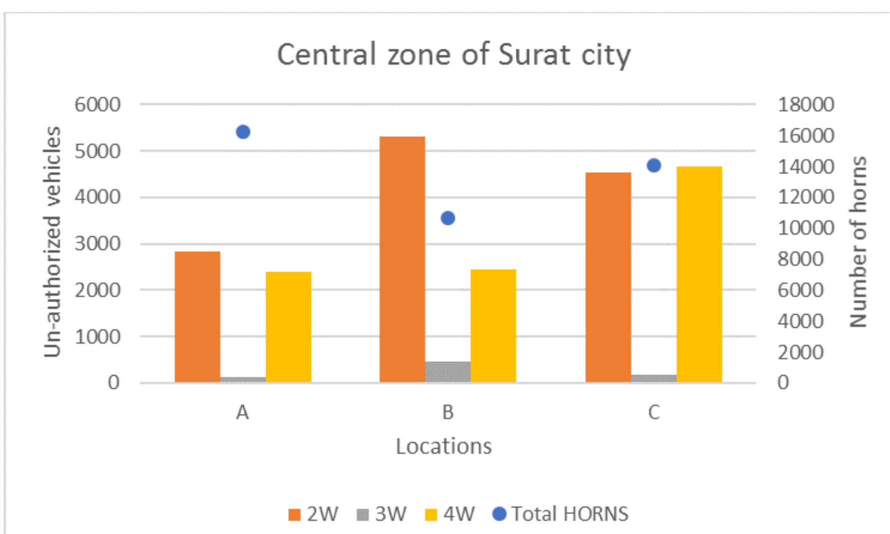

Figure 10: Correlation between un-authorized vehicles and number of horn event (Central zone of Surat city)

them. It can be concluded that noise as a dependent variable is having a linear relationship with un-authorized parked vehicles and a number of horn events. Therefore, multiple linear regression model is prepared which is an addendum/modification to RLS-90 model.

16 hours daytime and 8 hours night time (as per CPCB protocol) data collected from all locations of similar landscape and land use activity is already reported in the data collection section. RLS-90 gave a mathematical model in the form of noise maps for day time but with high error up to 11 dB (A).

Table 5: Horn honking based correction models

Sr. no.	Number of hours	R Square value	Equations
1.	4 hrs	0.270	$\Delta L_{UAP} = 6.350 - 1.290\log X_1 - 1.7851\log X_{2(2W)} + 2.473\log X_{3(3W)} + 0.433\log X_{4(4W)}$
2.	8 hrs	0.334	$\Delta L_{UAP} = 5.280 + 1.201\log X_1 - 1.650\log X_{2(2W)} + 1.955\log X_{3(3W)} + 2.819\log X_{4(4W)}$
3.	16 hrs	0.754	$\Delta L_{UAP} = 3.084 + 1.552\log X_1 - 0.461\log X_{2(2W)} + 0.578\log X_{3(3W)} + 0.943\log X_{4(4W)}$

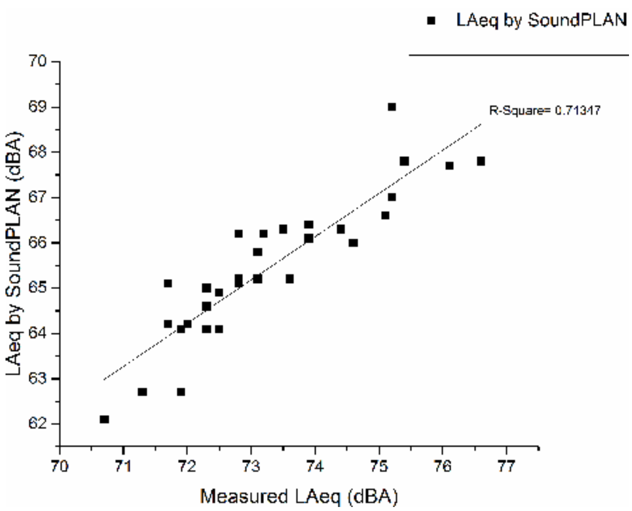

Figure 11: Measured L_{Aeq} vs $L_{Aeq-SoundPLAN}$ without horn correction

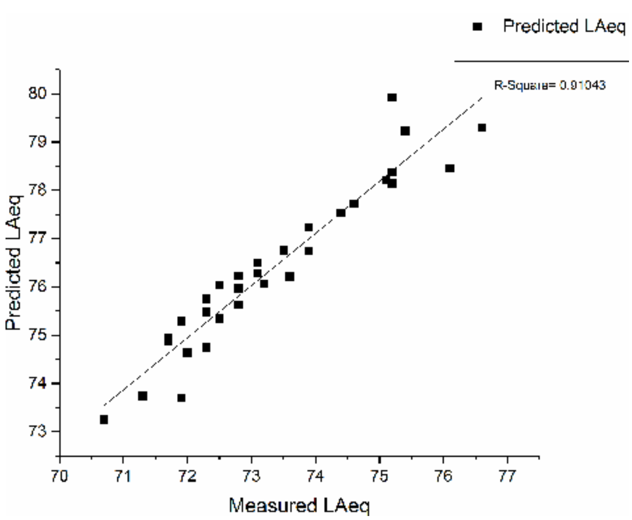

Figure 12: Measured L_{Aeq} vs $L_{Aeq-Predicted}$ with horn correction

As explained above, a new correction factor exclusively for daytime ΔL_{UAP} was derived using 4 hours, 8 hours, and 16 hours data. Accuracy of each model derived for 4 hours, 8 hours, and 16 hours are tabulated in table no. 9.1.

Here, it is categorically mentioned that such nighttime correction factor is not required because of the following two reasons:

1. As compared to day time prediction model, the error is significantly lesser that is as low as 3 to 4 dB (A).
2. Night time as defined by CPCB is 10.00 PM to 6.00 AM, where except for the first one to one-half hour un-authorized parking and horn honking was not observed.

Multiple linear regression equations were developed for 4 hours data, 8 hours data, and 16 hours data. From Table 5 it is seen that 16 hours data have good R^2 value.

The basic noise equation has arrived in the form of multiple regression equations with the independent variables such as Number of horns (X_1) and un-authorized vehicles (X_2,X_3,X_4) and the dependent variable is MASE (difference of measured LAeq and Predicted LAeq by SoundPLAN).

Therefore, the new prediction Leq, taking into consideration the horn correction factor (ΔL_{UAP}) is given as below:

$$LAeq\text{-}_{Predicted} = L_{SoundPLAN} + \Delta L_{UAP}$$

$L_{SoundPLAN}$ is predicted noise level by SoundPLAN,
ΔL_{UAP} is predicted noise level by a horn correction factor.

Data that were collected were regressed in SPSS software, where un-authorized parked 2W, 3W, 4W, and a number of horn events were independent variables and ΔL_{UAP} is an equivalent noise dependent variable. Detailed statistics output of linear regression of each 4 hours data, 8 hours data, and 16 hours data is presented in Table 6 to 8.

Figure 12 shows measured L_{Aeq} VS predicted L_{Aeq} with a horn correction factor. The R^2 value obtained is 0.9104 and from the t-test, it is observed that all coefficients are statistically significant.

Table 6: Regression variable results for 4 hours

Model	Coefficients	Std. Error	t	Significant values ($p < 0.05$)
(Constant)	6.350	3.573	1.497	0.1420
NOH	1.290	0.582	2.216	0.0320
U2W	−1.785	1.400	−1.275	0.2090
U3W	2.473	1.082	2.286	0.0270
U4W	.433	3.750	0.115	0.9090

Table 7: Regression variable results for 8 hours

Model	Coefficients	Std. Error	t	Significant values ($p < 0.05$)
(Constant)	5.280	1.180	1.932	0.0570
NOH	1.201	0.266	4.522	0.0001
U2W	−1.650	0.582	−2.834	0.0060
U3W	1.955	0.618	3.161	0.0020
U4W	2.819	1.168	2.414	0.0180

Table 8: Regression variable results for 16 hours

Model	Coefficients	Std. Error	t	Significant values ($p < 0.05$)
(Constant)	3.084	0.449	6.872	0.0001
NOH	1.552	0.086	18.053	0.0001
U2W	−0.461	0.191	−2.413	0.0160
U3W	0.578	0.260	2.227	0.0270
U4W	0.943	0.394	2.396	0.0170

4 Critical analysis and validation

Regression analysis is one of the important methods in which the statistical technique is used to build a mathematical model to relate dependent variable to independent variable [26]. The collected data was divided into two parts in the ratio 1:5. 80% of the data were used for formulating the model and the remaining 20% were used for model validation. Results obtained after MODIFIED noise prediction model with horn correction factor are improved as compared to model given by SoundPLAN essential 4.0 software.

Table 9 shows the comparison of measured noise levels with predicted noise levels (with and without horn honking correction). The result shows that the horn honking correction factor improves the accuracy from 11 dB (A) error to less than 4 dB (A) error. Figure 11 is the scatter plot of predicted values without horn honking correction factor, having R^2 value 0.7134. Figure 12 shows the improved R^2 value by considering the horn honking correction factor.

Multiple regression model was developed for Indian traffic condition. The parameters for variables decided for multiple linear regression analysis of Surat city are sound pressure level Leq difference between measured L_{Aeq} and predicted $L_{Aeq-SoundPLAN}$ in 15 min interval, number of horns in 15 min interval, and un-authorized parking calculated in 15 min interval. SPSS was used to developed MLR model. From Figure 12, R^2 value is to be observed as 0.9104. From the t-test, it is observed that all coefficients are statistically significant.

Table 9: Measured L_{Aeq} VS $L_{Aeq-Predicted}$ after modelling

Locations	L_{Aeq} without Horn Correction dB(A)	ΔL_{UAP} Horn Correction factor dB(A)	$L_{Aeq-Predicted}$ With horn correction dB(A)	Measured L_{Aeq} dB(A)	MASE dB(A)
			Central zone		
A	64.8	12.4	77.2	74	3.2
B	64.9	12.4	77.3	74.5	2.8
C	62.8	12.6	75.4	73.2	2.2
			South-West zone		
A_1	66.9	11.4	78.3	75.2	3.1
B_1	68	11.3	79.3	76.5	2.8
A_2	65.4	11.3	76.7	73.9	2.8
B_2	65.3	11.2	76.5	73.5	3.0
A_3	67.7	11.2	78.9	76.1	2.8
B_3	65.2	11.4	76.6	73.6	3.0
A_4	67.8	11.4	79.2	75.4	3.8
B_4	67.8	11.4	79.2	76.6	2.6
A_5	66.6	11.2	77.8	75.1	2.7
B_5	66	11.7	77.7	74.6	3.1
A_6	62.7	10.8	73.5	71.9	1.6
B_6	67	10.2	77.2	75.2	2.0
A_7	65.1	9.9	75.0	71.7	3.3
B_7	66.2	9.8	76.0	73.2	2.8
A_8	66.2	10.2	76.4	72.8	3.6
B_8	65.8	10.1	75.9	73.1	2.8
A_9	64.2	10.1	74.3	72	2.3
B_9	64.2	10.3	74.5	71.7	2.8
A_{10}	64.1	10.1	74.2	71.9	2.3
B_{10}	64.9	10.2	75.1	72.5	2.6
C_1	62.1	10.4	72.5	70.7	1.8
A_{11}	65.2	10.5	75.7	73.1	2.6
B_{11}	66.1	10.3	76.4	73.9	2.5
C_2	62.7	9.5	72.2	71.3	0.9
C_3	66.3	9.9	76.2	74.4	1.8
A_{12}	64.6	10.4	75.0	72.3	2.7
B_{12}	65.1	10.3	75.4	72.8	2.6
A_{13}	64.1	10.5	74.6	72.5	2.1
B_{13}	65	10.2	75.2	72.3	2.9
A_{14}	65.2	10.3	75.5	72.8	2.7
B_{14}	64.1	10.2	74.3	72.3	2.0

5 Conclusion

In this research, a new correction factor was developed using a mathematical model for prediction of road traffic noise for heterogeneous traffic conditions. Noise data, road traffic data, road width, pavement type, average building heights, number of horn events, un-authorized parked vehicles, and meteorological data were recorded. Two zones of Surat city were mapped namely South-West zone and Central zone. All the noise maps of day time and night time were generated using RLS-90 mathematical model inbuilt in SoundPLAN essential 4.0 software. L_{Aeq} prediction values obtained were under predicting up to 4 to 11 dB (A).

In developing countries like India, residential as well as commercial buildings are located just on the roadside and less parking spaces are available. Hence, people park vehicles on the main road. Also, due to the widely fluctuating vehicular dimensions, diversified composition, and speed of vehicles, lack of lane discipline and unauthorized parking on main roads, horn honking becomes imperative.

Amongst many reasons for horn honking, these authors after the actual observations on Indian urban roads found out that the major reason for horn honking is the occupancy of un-authorized parked vehicles on roadside kerbs. Therefore, an integrated noise prediction model based on multiple linear regression approach is developed for Indian heterogeneous traffic condition, considering both noise maps prediction and horn honking correction factor (ΔL_{UAP}).

Results obtained show that R^2 vale of the integrated noise prediction model improved to 0.9104 as compared to 0.7134 without horn correction factor. Also, from the t-test, all coefficients are found to be statistically significant. The horn honking correction factor improves the accuracy of RLS-90 mathematical model from 11 dB (A) error to less than 4 dB (A). Modified RLS-90 mathematical model can be incorporated in SoundPLAN essential 4.0 software, which can be readily used for Indian urban road traffic condition.

From the findings of current research, Municipal corporation authorities and citizens can get a clear warning of noise levels exceeding the permissible norms for residential and commercial zones from the black spots (red color) in noise maps. The effect of a proposed new road can be assessed and suitable noise mitigation measures can be adopted to minimize its impact at the planning stage itself. For existing grey areas (yellow color) in noise maps, suitable noise mitigation strategies such as proper traffic planning, use of porous asphalt pavements or designing low-cost noise barriers can be implemented.

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