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 un-authorized 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.
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 4th 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
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_{eqen}, 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 congestion, 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 | | | | Night time | | |
|-----------|----------|-------|-------|-------|----------|-------|-------|
|           | $L_{Aeq}$ | Predicted $L_{Aeq}$ | Difference | $L_{Aeq}$ | Predicted $L_{Aeq}$ | Difference |
| A1        | 75.2     | 66.9  | 8.3  | 70.5  | 66.9  | 3.6  |
| B1        | 76.5     | 68.0  | 8.5  | 70.7  | 67.1  | 3.6  |
| A2        | 73.9     | 65.4  | 8.5  | 70.4  | 66.6  | 3.8  |
| B2        | 73.5     | 65.3  | 8.2  | 70.6  | 67.7  | 2.9  |
| A3        | 76.1     | 67.7  | 8.4  | 68.9  | 65.4  | 3.5  |
| B3        | 73.6     | 65.2  | 8.4  | 71.3  | 68.8  | 2.5  |
| A4        | 75.4     | 67.8  | 7.6  | 71.6  | 68.1  | 3.5  |
| B4        | 76.6     | 67.8  | 8.8  | 68.1  | 66.2  | 1.9  |
| A5        | 75.1     | 66.6  | 8.5  | 67.7  | 64.8  | 2.9  |
| B5        | 74.6     | 66.0  | 8.6  | 67.0  | 64.1  | 2.9  |
| A6        | 71.9     | 62.7  | 9.2  | 67.4  | 65.2  | 2.2  |
| B6        | 75.2     | 67.0  | 8.2  | 67.2  | 64.8  | 2.4  |
| A7        | 71.7     | 65.1  | 6.6  | 66.6  | 62.9  | 3.7  |
| B7        | 73.2     | 66.2  | 7.0  | 67.9  | 64.7  | 3.2  |
| A8        | 72.8     | 66.2  | 6.6  | 66.8  | 64.1  | 2.7  |
| B8        | 73.1     | 65.8  | 7.3  | 68.8  | 65.2  | 3.6  |
| A9        | 72.0     | 64.2  | 7.8  | 67.4  | 64.7  | 2.7  |
| B9        | 71.7     | 64.2  | 7.5  | 69.6  | 66.5  | 3.1  |
| A10       | 71.9     | 64.1  | 7.8  | 66.5  | 64.4  | 2.1  |
| B10       | 72.5     | 64.9  | 7.6  | 68.1  | 64.8  | 3.3  |
| C1        | 70.7     | 62.1  | 8.6  | 69.4  | 66.8  | 2.6  |
| A11       | 73.1     | 65.2  | 7.9  | 65.8  | 64.6  | 1.2  |
| B11       | 73.9     | 66.1  | 7.8  | 66.6  | 63.6  | 3.0  |
| C2        | 71.3     | 62.7  | 8.6  | 64.3  | 61.9  | 2.4  |
| C3        | 74.4     | 66.3  | 8.1  | 65.7  | 62.4  | 3.3  |
| A12       | 72.3     | 64.6  | 7.7  | 68.2  | 65.2  | 3.0  |
| B12       | 72.8     | 65.1  | 7.7  | 67.4  | 64.8  | 2.6  |
| A13       | 72.5     | 64.1  | 8.4  | 68.0  | 64.9  | 3.1  |
| B13       | 72.3     | 65.0  | 7.3  | 66.6  | 63.6  | 3.0  |
| A14       | 72.8     | 65.2  | 7.6  | 69.4  | 66.1  | 3.3  |
| B14       | 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 | | |
|-----------|----------|-------|-------|-------|----------|-------|-------|
|           | $L_{Aeq}$ | Predicted $L_{Aeq}$ | Difference | $L_{Aeq}$ | Predicted $L_{Aeq}$ | Difference |
| 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 unauthorized 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) |
|-----------|-----------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| A1        | 5676                        | 4510                                  | 76                                    | 1743                                  |
| B1        | 5488                        | 4320                                  | 65                                    | 1687                                  |
| A2        | 4898                        | 4125                                  | 96                                    | 1621                                  |
| B2        | 4587                        | 3258                                  | 46                                    | 1790                                  |
| A3        | 4898                        | 3423                                  | 61                                    | 1474                                  |
| B3        | 5345                        | 4412                                  | 103                                   | 1569                                  |
| A4        | 4887                        | 3578                                  | 112                                   | 1547                                  |
| B4        | 5404                        | 3534                                  | 98                                    | 1656                                  |
| A5        | 4573                        | 3231                                  | 109                                   | 1256                                  |
| B5        | 6386                        | 5318                                  | 122                                   | 1998                                  |
| A6        | 3064                        | 2568                                  | 76                                    | 945                                   |
| B6        | 2085                        | 2030                                  | 44                                    | 556                                   |
| A7        | 2067                        | 1745                                  | 8                                     | 567                                   |
| B7        | 1802                        | 1890                                  | 12                                    | 453                                   |
| A8        | 2345                        | 2278                                  | 17                                    | 689                                   |
| B8        | 2390                        | 2098                                  | 15                                    | 635                                   |
| A9        | 2060                        | 2598                                  | 23                                    | 667                                   |
| B9        | 2187                        | 2372                                  | 34                                    | 689                                   |
| A10       | 2037                        | 2892                                  | 32                                    | 551                                   |
| B10       | 2189                        | 3001                                  | 43                                    | 556                                   |
| C1        | 2256                        | 2921                                  | 56                                    | 666                                   |
| A11       | 2489                        | 2834                                  | 61                                    | 691                                   |
| B11       | 2391                        | 2387                                  | 37                                    | 623                                   |
| C2        | 1287                        | 1590                                  | 10                                    | 389                                   |
| C3        | 2023                        | 2890                                  | 19                                    | 498                                   |
| A12       | 2620                        | 3112                                  | 56                                    | 569                                   |
| B12       | 2238                        | 3212                                  | 81                                    | 451                                   |
| A13       | 2570                        | 2891                                  | 67                                    | 681                                   |
| B13       | 2078                        | 2423                                  | 54                                    | 502                                   |
| A14       | 2119                        | 2691                                  | 62                                    | 521                                   |
| B14       | 2291                        | 2798                                  | 31                                    | 665                                   |

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

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 ($\Delta L_{UAP}$) is developed to improve the accuracy of the noise map and prediction model. The new correction factor, $\Delta L_{UAP}$ is derived to reduce the error between predicted and measured noise levels. If noise in dB (A) ($\Delta L_{UAP}$) 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          | \[\Delta L_{UAP} = 3.084 + 1.552 \log X_1 - 0.461 \log X_{2(2W)} + 0.578 \log X_{3(3W)} + 0.943 \log X_{4(4W)}\] |

As explained above, a new correction factor exclusively for daytime \(\Delta L_{UAP}\) 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 \((\Delta L_{UAP})\) is given as below:

\[LA_{eq-Predicted} = L_{SoundPLAN} + \Delta L_{UAP}\]

\(L_{SoundPLAN}\) is predicted noise level by SoundPLAN, \(\Delta L_{UAP}\) 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 \(\Delta L_{UAP}\) 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 LAeq VS predicted LAeq 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 unauthorized 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) | $\Delta L_{UAP}$ 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 |                                 |                                             |                                               |                         |            |
| A1        | 66.9                                   | 11.4                                        | 78.3                                          | 75.2                    | 3.1        |
| B1        | 68                                     | 11.3                                        | 79.3                                          | 76.5                    | 2.8        |
| A2        | 65.4                                   | 11.3                                        | 76.7                                          | 73.9                    | 2.8        |
| B2        | 65.3                                   | 11.2                                        | 76.5                                          | 73.5                    | 3.0        |
| A3        | 67.7                                   | 11.2                                        | 78.9                                          | 76.1                    | 2.8        |
| B3        | 65.2                                   | 11.4                                        | 76.6                                          | 73.6                    | 3.0        |
| A4        | 67.8                                   | 11.4                                        | 79.2                                          | 75.4                    | 3.8        |
| B4        | 67.8                                   | 11.4                                        | 79.2                                          | 76.6                    | 2.6        |
| A5        | 66.6                                   | 11.2                                        | 77.8                                          | 75.1                    | 2.7        |
| B5        | 66                                     | 11.7                                        | 77.7                                          | 74.6                    | 3.1        |
| A6        | 62.7                                   | 10.8                                        | 73.5                                          | 71.9                    | 1.6        |
| B6        | 67                                     | 10.2                                        | 77.2                                          | 75.2                    | 2.0        |
| A7        | 65.1                                   | 9.9                                         | 75.0                                          | 71.7                    | 3.3        |
| B7        | 66.2                                   | 9.8                                         | 76.0                                          | 73.2                    | 2.8        |
| A8        | 66.2                                   | 10.2                                        | 76.4                                          | 72.8                    | 3.6        |
| B8        | 65.8                                   | 10.1                                        | 75.9                                          | 73.1                    | 2.8        |
| A9        | 64.2                                   | 10.1                                        | 74.3                                          | 72                      | 2.3        |
| B9        | 64.2                                   | 10.3                                        | 74.5                                          | 71.7                    | 2.8        |
| A10       | 64.1                                   | 10.1                                        | 74.2                                          | 71.9                    | 2.3        |
| B10       | 64.9                                   | 10.2                                        | 75.1                                          | 72.5                    | 2.6        |
| C1        | 62.1                                   | 10.4                                        | 72.5                                          | 70.7                    | 1.8        |
| A11       | 65.2                                   | 10.5                                        | 75.7                                          | 73.1                    | 2.6        |
| B11       | 66.1                                   | 10.3                                        | 76.4                                          | 73.9                    | 2.5        |
| C2        | 62.7                                   | 9.5                                         | 72.2                                          | 71.3                    | 0.9        |
| C3        | 66.3                                   | 9.9                                         | 76.2                                          | 74.4                    | 1.8        |
| A12       | 64.6                                   | 10.4                                        | 75.0                                          | 72.3                    | 2.7        |
| B12       | 65.1                                   | 10.3                                        | 75.4                                          | 72.8                    | 2.6        |
| A13       | 64.1                                   | 10.5                                        | 74.6                                          | 72.5                    | 2.1        |
| B13       | 65                                     | 10.2                                        | 75.2                                          | 72.3                    | 2.9        |
| A14       | 65.2                                   | 10.3                                        | 75.5                                          | 72.8                    | 2.7        |
| B14       | 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 un-authorized 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 (ΔLUAAP).

Results obtained show that R² 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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