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Noise Mapping and Variance of Road Traffic Noise: Identification of Most Noise Impacting Vehicular Type in an Urban Region

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Urban road traffic noise is a major concern in developing as well as developed countries. Often it is difficult to identify the most noise impacting vehicular type especially in urban region with mixed vehicular flow. Herein, we analysed in a systematic way to identify the most noise impacting vehicular type at Hyderabad city of India. The road traffic noise across the corridor-3 metro line known as the blue line metro was chosen in the present study because, it stretches from north to south connecting 23 stations comprising major residential and commercial locations of the city. The noise levels were analysed as per CPCB guidelines. The noise pollution quantifying parameters such as Noise Climate (NC), Noise Pollution Level (L_{NP}), and Traffic Noise Index (TNI) were analysed across the lane. A systematic analysis revealed that, the two-wheelers are the most noise impacting vehicles in the daytime whereas four-wheelers in the nighttime. Noise map generated using the IDW spatial interpolation method shows the noise impacted regions across the metro lane stretching ~27 km of the city. The methodological pattern in the present investigation can be useful tool in identifying the most noise impacting vehicular type in any region with a mixed vehicular flow.

Keywords: Noise map; Honking; IDW; Hyderabad; India

1 Introduction

Noise is a growing concern especially in an urban area with a fast-growing population and technologies to cater for their need. Several reports were cited on environmental noise and its health effect on urban population starting from mental to physical health conditions[1-14]. Road traffic is the major source of noise pollution in urban areas[15]. Evaluation of traffic noise and noise impacting vehicular type in any urban region is cumbersome as it comprises heterogenic conditions round the clock[16]. Herein, we systematically analysed the road traffic noise to identify the most noise impacting vehicular type pertaining to an urban region with a mixed vehicular flow. The road traffic conditions of the Hyderabad city of India is resemblance to many other urban regions of the county. Moreover, the residential colonies are close enough to get exposed to traffic noises round the clock. There are few studies on Noise pollution assessment at few locations of Hyderabad city and most of the studies[17] are based on the secondary data available on the website of Central Pollution Control Board (CPCB), Govt. of India. Till now there are no comprehensive studies on the traffic noise and the identification of noise impacting vehicular type in Hyderabad city to the best of our knowledge. We aim to predict with the minimal resources *i.e.*, the total number of vehicular count during L_{Aeq} measurement time and the variance of L_{Aeq} values with the segregated vehicular type, one could able to identify the most noise impacting vehicular type in the study region of interest. The noise map was generated using the measured L_{Aeq} in the IDW spatial interpolation method on ArcGIS platform to understand the noise impacted region along the lane with 500m buffer. The methodology and analysis pattern in the present investigation can be a useful tool in identifying the most noise impacting vehicular type in any region with mixed vehicular flow in a given time.

2 Materials and Methods

2.1 Study Area

Hyderabad the capital city of Telangana state of India is one of the fast-emerging and well established metropolitan cities in the country. Greater Hyderabad Municipal Corporation (GHMC) covers 625 sq. km. with five zones (east, west, north, south and central) comprising 30 circles as designated in Fig. 1. The city

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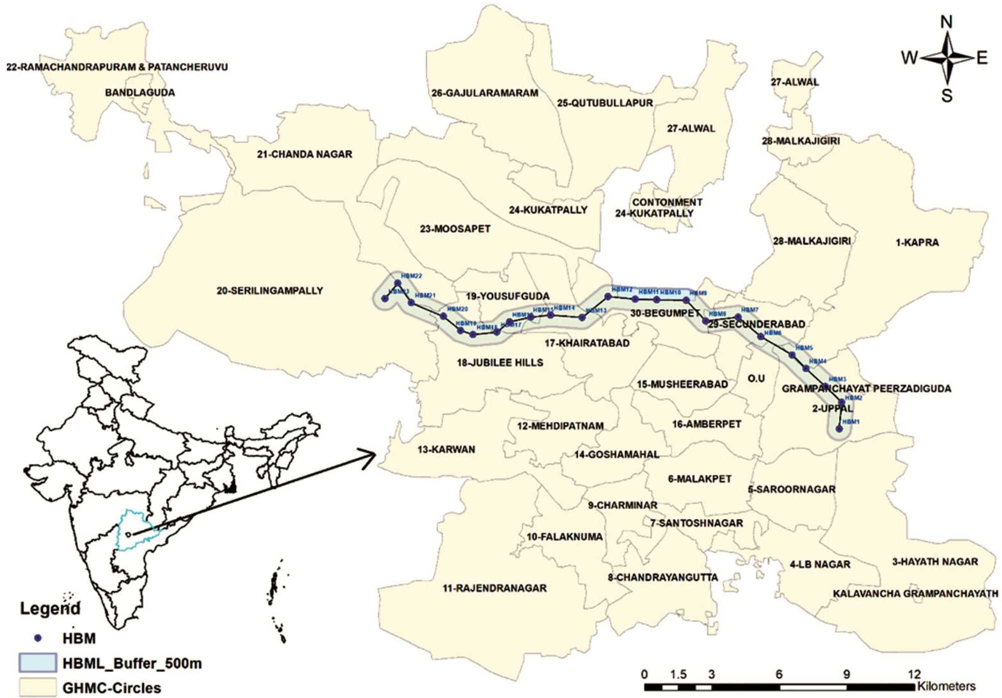

Fig. 1 — Study area and sampling points (HBM1 to HBM23) across Hyderabad Blue Line Metro.

comprises national highways NH 44, NH65, NH165 and NH 765 along with state highways and minor roads for transportation. To cater the transport needs of the public, Hyderabad metro project was inaugurated in the month of Nov 2017 aiming to shorten the journey times by 50-70% as well as to reduce carbon emission. Hyderabad Blue line Metro (HBM) passes through East, North, Central and West zones covering major localities which are residential as well as commercial places of Hyderabad. For convenience HBM stations starting from Nagole to Raidurg are serially numbered as HBM1 to HBM23 respectively as shown in Fig. 1. Description about the individual station demographics are described in supplementary information.

2.2 Noise Data Collection

For data collection, the road traffic region was selected along HBM lane of the city which comprises of mixed residential, commercial and silence zones spread in the span of ~27 km. The Traffic noise levels and traffic volume were monitored along the road transportation adjacent to HBM stations starting from Nagole metro station (HBM1) to Raidurg metro station (HBM23) during August 2021 to September 2021 in the peak rush hour timings during the day (8:30 am to 10:30 am), evening (5:30 pm to 7:30 pm) and night-time data after 10 pm to till 6 am. The traffic volume was categorised mainly as two, three, four-wheelers and heavy vehicles to assess their influence on the traffic noise. The vehicular count was conducted manually using the recorded videos during the entire noise data monitoring time for all the three-time slots *i.e.*, day, evening and night. The vehicular traffic noise was monitored as per the standard methods provided by BIS, New Delhi (IS-13099 1998; IS-3028 1998) to the maximum extent.

The sound pressure levels were monitored using a precision integrated sound level meter (Larson Davis Model 831), which is a class 1 environmental noise & building acoustics analyser meeting the IEC 61672-1:2013 (BS EN 61672-1:2013), ANSI S1.4, ANSI S1.43 standards. The instrument is mounted on a tripod or kept hold at the height of 1.5 m above the ground and a distance of 7.5 m away from the centre of the road (depending on the geometry and condition of the road the distance have been varied). The Instrument operated at fast response mode in the 'A' frequency weighting with a 1second data acquisition interval. The noise of the preamplifier is covered with a wind-ball to minimize the wind effects if any. The instrument was calibrated using the Class 1 calibrator CAL200 by Larson and Davis, USA every time before and after the data reading. The L_n statistical values such as L_{10}, L_{50}, and L_{90} in dBA obtained from the instrument were used to evaluate noise parameters such as Noise Climate (NC) is the range over which the sound levels are fluctuating in an interval of time and is assessed by the following equation ($NC = L_{10}-L_{90}$), Noise Pollution Level (L_{NP}) is the amount of noise that is given by the combined effects of the energy average (L_{Aeq}) and the variation characteristics considering as NC ($L_{NP} = L_{Aeq}+NC$), Noise Pollution Index (P_n) or Noise Exceedance Factor (NEF) ($P_n = L_{Aeq}/L_{PEL}$, where L_{PEL} is the permissible exposure limit for different regions set by CPCB, Govt. of India) and Traffic Noise Index (TNI), a method devised in the U.K. to measure annoyance responses to motor vehicle noise ($TNI = L_{90}+4NC-30$)[20].

2.3 Noise Mapping

Noise mapping plays a vital role in the land use pattern of urban cities for the identification of noisy and non-noisy zones for a variety of applications especially land allotment for noise-sensitive areas and structures pertaining to the government regulations. Noise mapping is a useful tool in predicting the noise level spread in the region of interest using the measured noise levels in the minimal region[21]. There are several reports on the generation of noise mapping[22,23] using GIS-based commercial software. In the present study, noise mapping has been generated for 500 m buffer on both sides of the HBM line as shown in Fig. 1 using the IDW interpolation method, a spatial analysis tool of ArcGIS 10.5.1 software to know the spread of noise levels.

3 Results and Discussion

Figure 2 presents the measured L_{Aeq} values of road traffic noise at every metro station along the HBM lane during peak traffic hours on day (8:30 to 10:30 am) and evening (5:30 to 7 pm) times. Night-time noise levels were recorded after 10 pm at all 23 locations. Day and night-time noise levels at all the locations are above the CPCB prescribed values for residential as well as commercial locations across the HBM line as presented in Table 1. A deeper analysis of the L_{Aeq} pattern for day-evening-night time shows an anomalous pattern from station to station across the lane. The maximum difference between day and night L_{Aeq} appeared mostly for pure residential locations like Jubilee Hills (HBM17) with almost 15 dBA variations. However, the L_{Aeq} values for peak traffic hours during the day and evening were recorded with marginal differences at all locations except for HBM8 (Secunderabad East). Secunderabad East is the main train transport location of the state. The daytime higher value at HBM8 might be encountered with train movements.

Nevertheless, HBM8 is always a busy location as described earlier (see also supplementary information). HBM2 (Uppal X road) is recorded second-highest daytime noise. Uppal X road connects the national highway 163 and is one of the main road connecting points to enter the city. The majority of noise data locations recorded higher L_{Aeq} values

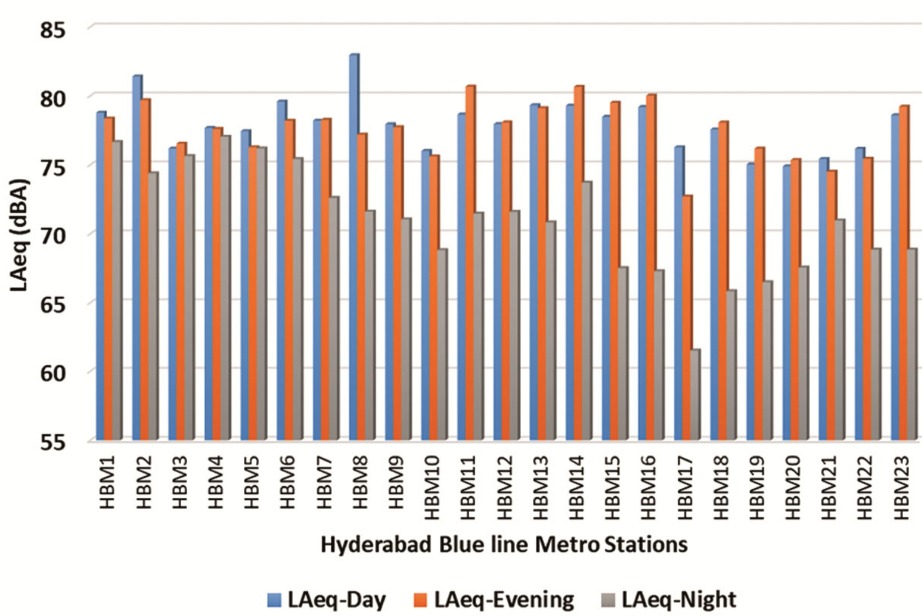

Fig. 2 — Measured L_{Aeq} values of road traffic noise at every metro station along the HBM.

Table 1 — Metro Station locations and corresponding L_{Aeq} values as measured.

Sl. No	Blue Line Metro Station Location Name	Code	L_{Aeq} (dBA) Day (8:30 am to 10:30 am)	Evening (5:30 pm to 7 pm)	Night (after 10 pm to 6 am)
1	Nagole	HBM1	78.8	78.4	76.7
2	Uppal 'X' Road	HBM2	81.4	79.7	74.4
3	Stadium	HBM3	76.2	76.5	75.6
4	NGRI	HBM4	77.7	77.6	77.0
5	Habsiguda	HBM5	77.5	76.3	76.2
6	Tarnaka	HBM6	79.6	78.2	75.4
7	Mettuguda	HBM7	78.2	78.3	72.6
8	Secunderabad East	HBM8	83.0	77.2	71.6
9	Parade Ground	HBM9	78.0	77.7	71.1
10	Paradise	HBM10	76.0	75.6	68.8
11	Rasoolpura	HBM11	78.7	80.7	71.5
12	Prakash Nagar	HBM12	78.0	78.1	71.6
13	Begumpet	HBM13	79.3	79.1	70.8
14	Ameerpet	HBM14	79.3	80.7	73.7
15	Madhura Nagar	HBM15	78.5	79.5	67.5
16	Yusufguda	HBM16	79.2	80.0	67.3
17	Road No-5 Jubilee Hills	HBM17	76.3	72.7	61.5
18	Jubilee Hills Check post	HBM18	77.6	78.1	65.8
19	Peddamma Gudi	HBM19	75.0	76.2	66.5
20	Madhapur	HBM20	74.9	75.4	67.6
21	Durgam Cheruvu	HBM21	75.4	74.5	71.0
22	Hitech City	HBM22	76.2	75.4	68.9
23	Raidurg	HBM23	78.6	79.2	68.9

Central Pollution Control Board, Govt. of India prescribed standards for Noise

Area Code	Category of Area/Zone	L_{Aeq} (dBA) Day (6 am to 10 pm)	Night (10 pm to 6 am)
(A)	Industrial Area	75	70
(B)	Commercial Area	65	55
(C)	Residential Area	55	45
(D)	Silence Zone	50	40

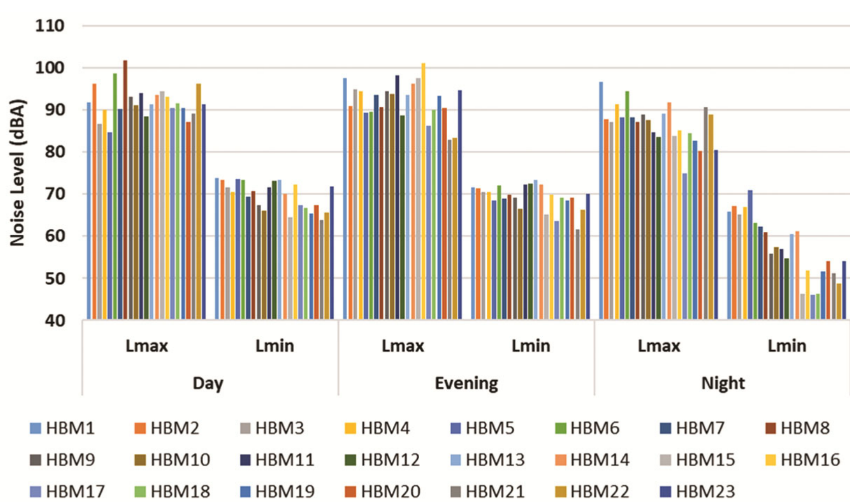

Fig. 3 — L_{max} and L_{min} noise values at every metro station along the HBM.

during evening rush hours and most of them are purely residential areas.

The maximum and minimum L_{Aeq} values measured during the data acquisition time is plotted as L_{max} and L_{min} respectively as shown in Fig. 3 for the three-time slots at every metro location. At most of the locations, the recorded L_{max} values are above 90 dBA for day and evening timings and above 80 dBA during night time. L_{min} values are recorded between 60 to 70 dBA for day and evening times whereas the L_{min} values are recorded at the considerably lower side for a few locations (HBM15, HBM17, HBM18) which are residential areas. It is astonishing to record even the minimum values are still higher than the CPCB prescribed standards.

These anomalous variations were quantified using noise climate (NC) which is the difference between the level of sound exceeded for 10% (L_{10}) to that of 90% (L_{90}) of the total time of measurement. Fig. 4 depicts the noise climate change across the blue line metro locations. As such there are no prescribed standards for NC, however, the higher the value of NC is termed to be the impact of impulse noises are the more dominating sounds. As per the calculation, HBM15 to HBM23 the noise climate is severe, particularly in the nighttime. To further validate, the number of vehicles accounted for the measurement of noise values were examined. Supplementary Fig. S1 shows the total vehicular count during the noise measurement time at every location.

Figure 5(a-c) graphically represents the relation between the measured L_{Aeq} values to that of the total

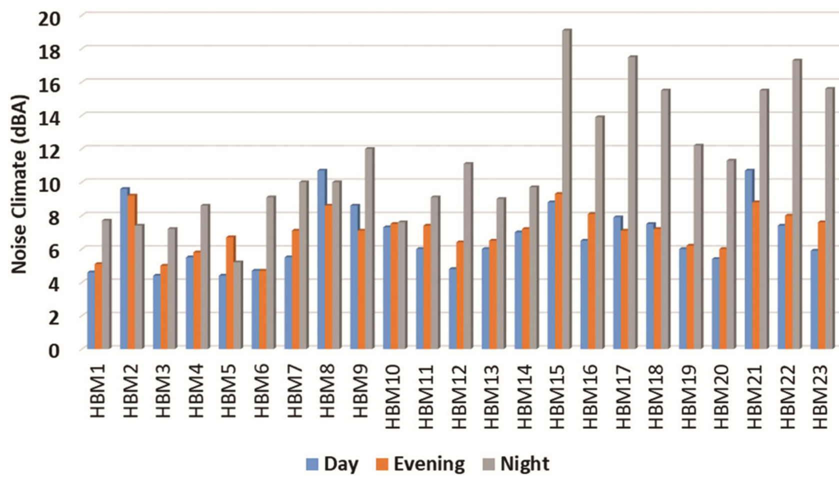

Fig. 4 — Noise Climate (NC).

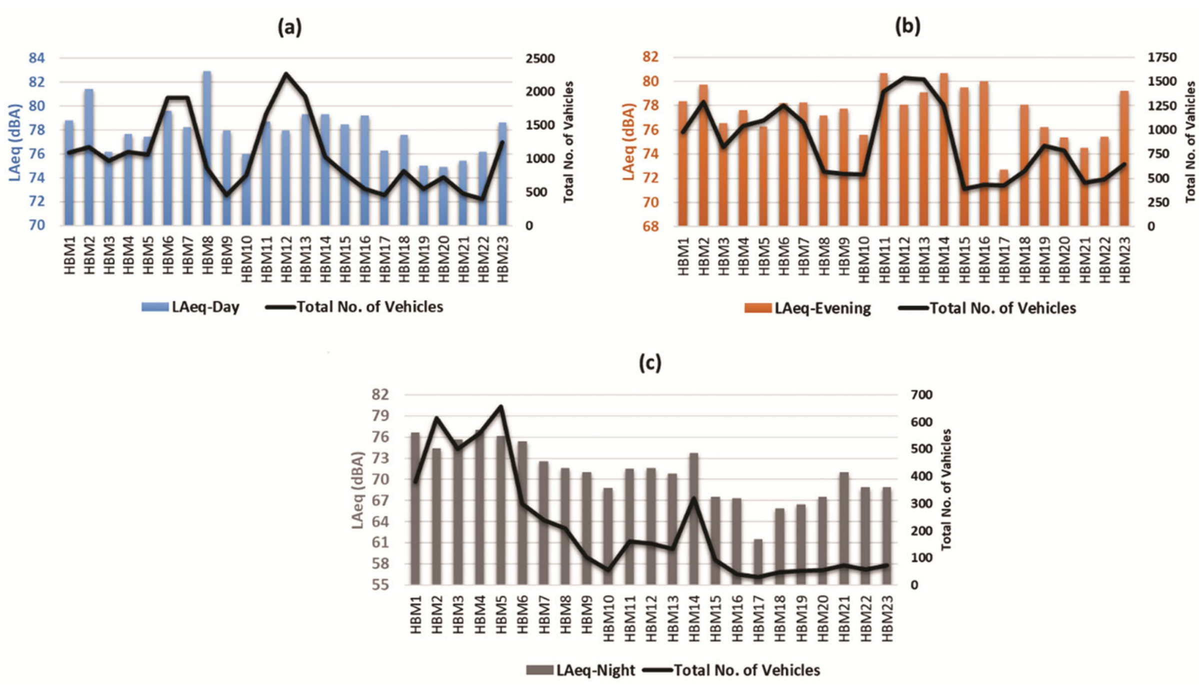

Fig. 5 — L_{Aeq} values and counted Total No of Vehicles during (a) day (b) evening (c) night times.

number of vehicles counted for the measurement time at every data station. Most of the time especially when measuring road traffic noise, the vehicular count follows a linear trend with observed L_{eq} values[20,24]. But, the scenario is entirely different when assessing an urban area, it varies vastly between time intervals due to its heterogenic traffic conditions[25,26] and the effect of honking. Here too, the observed L_{Aeq} values followed non-linear behaviour concerning the total number of the vehicular count at majority locations for the day as well as evening peak rush hours as shown in Fig. 5(a-c). Whereas the nighttime L_{Aeq} values follow the linear trend with total vehicular count comparatively. Supplementary Figs. S2, S3 and S4 show the trend of linear fitting for the day, evening and night time LA_{eq} values with that of the total vehicular count. As said earlier, a relatively good fit can be observed for nighttime data for most of the locations. The average width of the road is around 30 m with a divider across the blue line metro lane, and the average speed of the vehicles is between 40-50 kmph due to congested traffic conditions and speed limits posed by the government regulations (however vehicles exceeding 50 kmph have been noticed in most of the locations). Other than vehicular speed, contribution of honking is the major source of noise that was observed during day and evening times. This might be one of the reasons to observe the non-linear behaviour of the L_{Aeq} values with Total vehicular count.

In a further deeper analysis, we segregated the vehicular type to see the variance of the L_{Aeq} pattern for three-time slots. Out of the total number of vehicular count during the noise monitoring time, the percentage of two-wheelers (2W) and four-wheelers (4W) are occupying more than 85% in all the measured time slots. Fig. 6(a-c) presents the insights of L_{Aeq} variation with that of %2W and %4W for all time slots. Compare to the total number of vehicles, the %2W is in close aggregation with the trend of measured L_{Aeq} values in most of the locations for day and evening times whereas %4W is in close alignment with night time measured L_{Aeq} values. Supplementary Figs. S5-10 shows the variance of linear fitting related to L_{Aeq} to that of 2W and 4W vehicular count for the day, evening and night times. Though a relatively good trend has been observed for L_{Aeq} values with %2W for day and evening times, a poor linear fitting has been noticed compared to nighttime data. Nevertheless, the locations can be identified (labelled as numbers) which are close to the linear fit in terms of the type of vehicular count. It is indeed practically impossible to segregate and identify the road traffic noise contributing factor in busy metropolitan cities especially in India known for its diversified heterogenic conditions which vary from

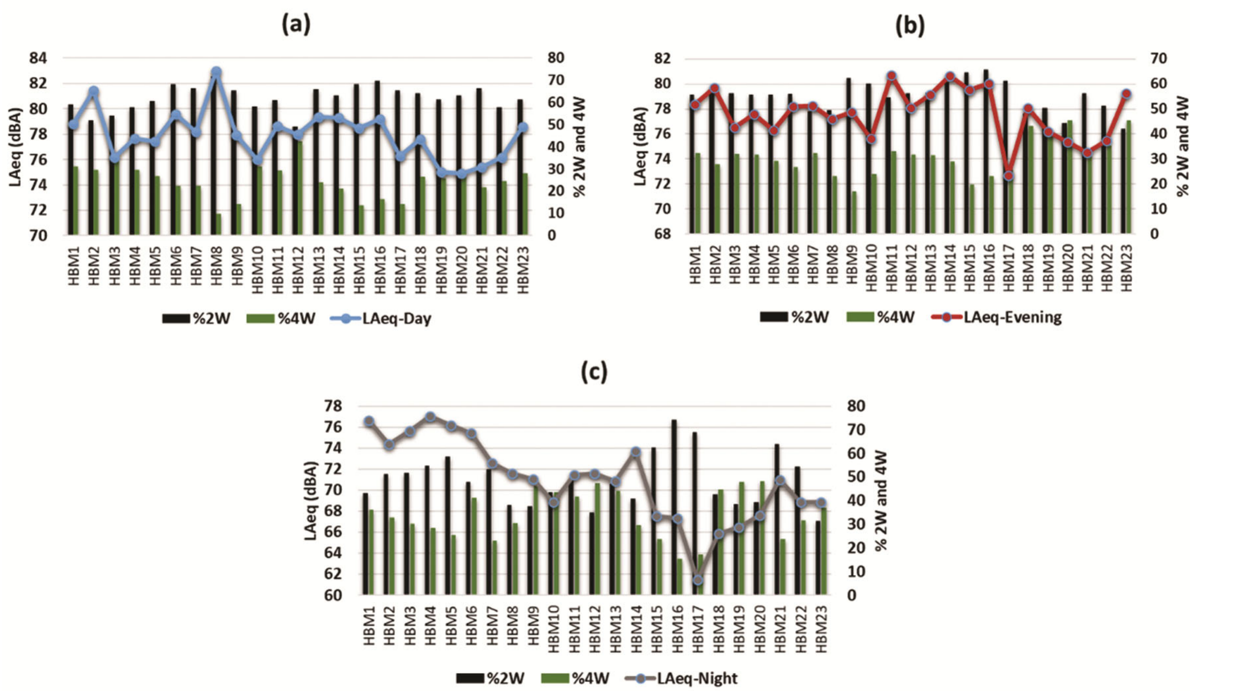

Fig. 6 — L_{Aeq} values and %2W and % 4W Vehicles during (a) day (b) evening (c) night times.

time to time and location to location. However, we tried to analyse the data to identify the most probable noise creating vehicular type along with the Hyderabad blue line metro locations.

Although vehicular speed is one of the main factors along with engine type and road conditions, honking is also one of the major factors of noise contribution, especially in busy and peak rush hours during day and evening times in the urban area. There are few studies on the honking impact on traffic noise in urban traffic environments[25,27-30] in India. In reality megacities like Hyderabad, it is practically impossible to count the honking frequency and number of honking to validate or quantify the impact of honking on traffic noise during peak hours of traffic. Considering the similar road conditions and average similar speed, and also knowing the type of vehicular flow, the impact of honking, to some extent could be predicted from the difference of impulse L_{AIeq} to that of L_{Aeq} of the measured noise data. Fig. 7 depicts the (L_{AIeq}-L_{Aeq}) variance across the traffic lane at every location. The noisiest locations for daytime were recorded at HBM2, HBM8 and HBM22 with above 5dBA difference and for evening time HBM11, HBM14-16, HBM19 and HBM23. For night time the difference is comparatively less except at HBM16, HBM18 and HBM21. The higher difference in the nighttime can be purely termed to vehicular speed and it has been observed over speeding of vehicles in those residential locations during the measurement time.

Accordingly, The Traffic Noise Index (TNI) was estimated and it shows a similar trend as that of L_{AIeq}-L_{Aeq} for all the time slots. As shown in Fig. 8, the higher TNI values can be observed for nighttime starting from HBM15 (Madhura Nagar). With the number of late-night restaurants and pubs are situated in these locations, it is observed that vehicular moments specially 4W are the major noise creating

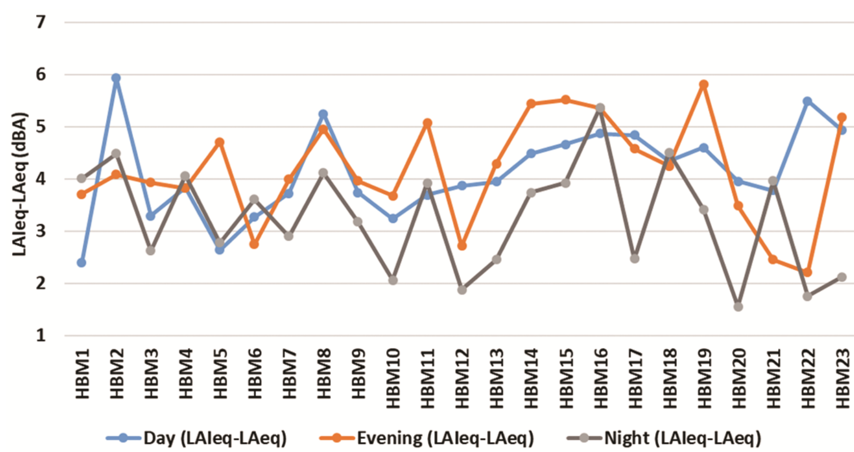

Fig. 7 — (L_{AIeq}-L_{Aeq}) variations during three times slots at every location.

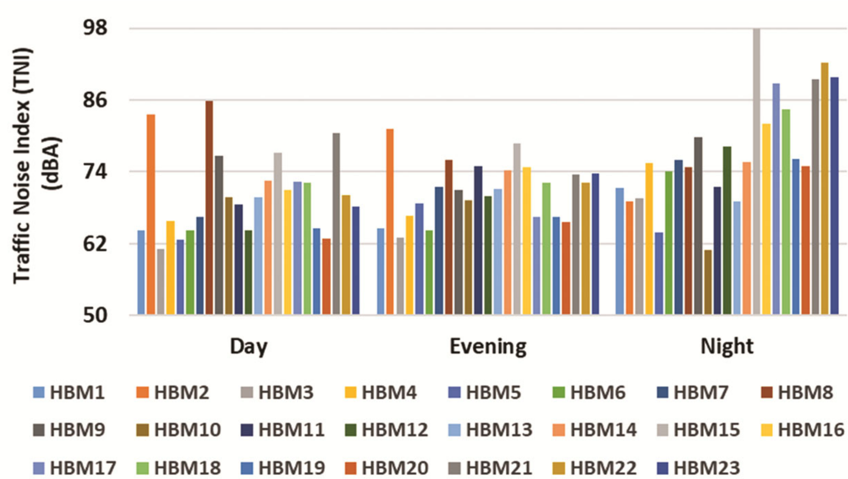

Fig. 8 — Traffic Noise Index (TNI) for the day, evening and night times.

sources. This has been observed from the linear fitting of L_{Aeq} values with the number of 4W showing a better regression coefficient (Supplementary Fig. S10).

Noise pollution level is estimated to be above 80 dBA in every location irrespective of the time slot as shown in Fig. 9. Also, the Noise pollution index shown in Fig. 10 is close to 1 indicating the severity of noise pollution in Hyderabad city.

The sound waves are estimated to be effective till 300m from the source point, accordingly, to know the spread of noise levels, noise mapping has been generated using Inverse Distance Weighting (IDW) spatial interpolation method on Arc GIS 10.5.1 software platform[22,30-34]. As mentioned in the Noise mapping section, a buffer layer of 500m was created across the HBM lane for noise map generation. Fig. 11-13 shows the mapped noise levels across HBM for peak hours during the day, evening times and non-peak hours after 10 pm. Daytime and evening noise levels are predicted to be above 73 dBA across the metro lane. The intense noise locations can be identified through the mapping. Nighttime noise levels are predicted to be higher side for HBM1 to HBM6 might be due to heavy vehicular (heavy vehicles are allowed inside the city after 10 pm only) movement connecting to highways. Although the noise map shows the overall noise spread levels, the practical constraints such as buildings, trees and noise barriers are not considered in the mapping.

Along with the blue line metro, the number of silent zones like hospitals, schools, colleges and research organizations are situated within 500 m from the metro lane. The noise levels measured within the silence zone are exceedingly higher than the CPCB prescribed limits which were again reflected through noise mapping. The road traffic noise mapping

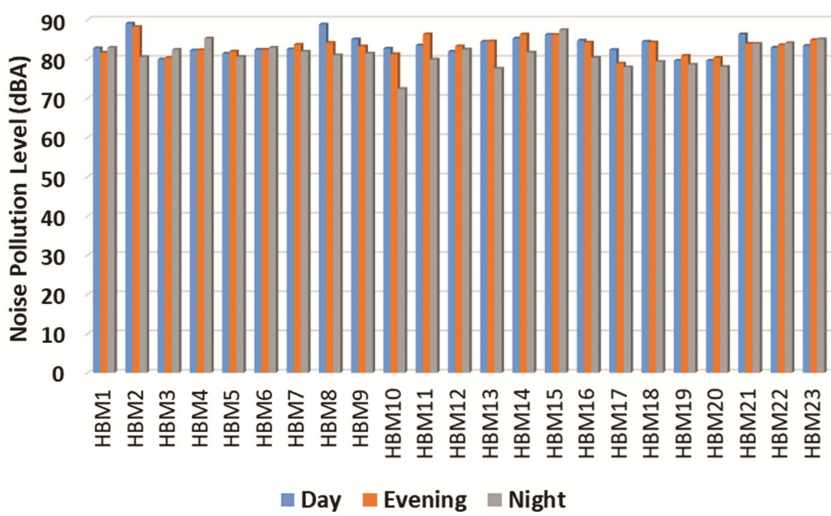

Fig. 9 — Noise pollution level at every location during the day, evening and night times.

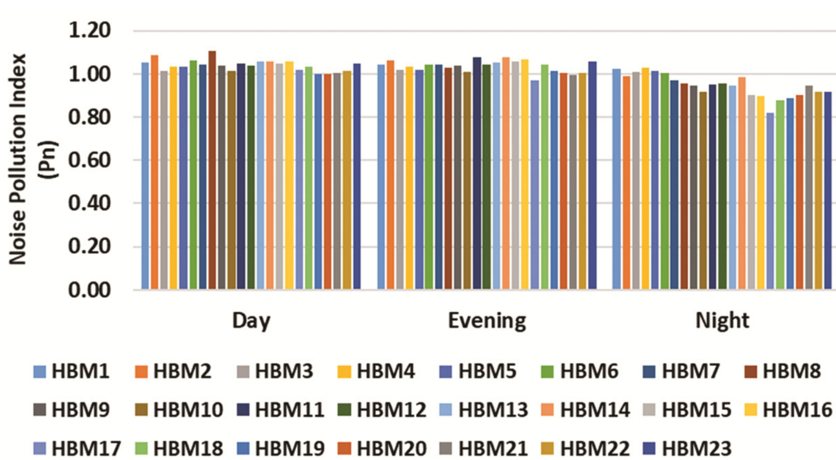

Fig. 10 — Noise Pollution Index at every location during the day, evening and night times.

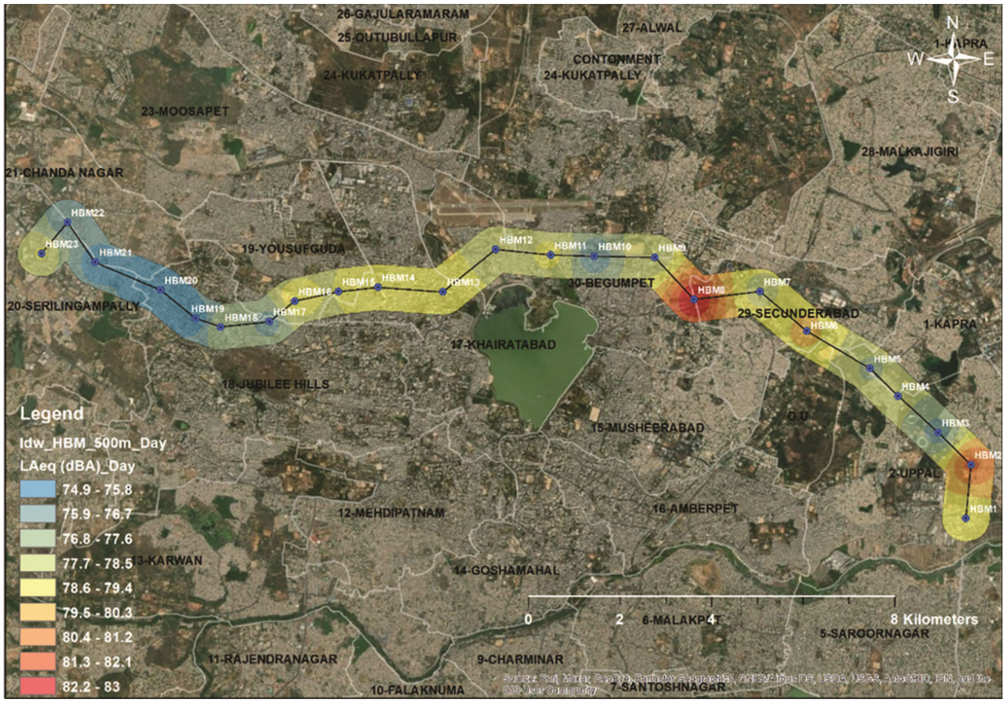

Fig. 11 — Noise mapping for day time peak rush hours.

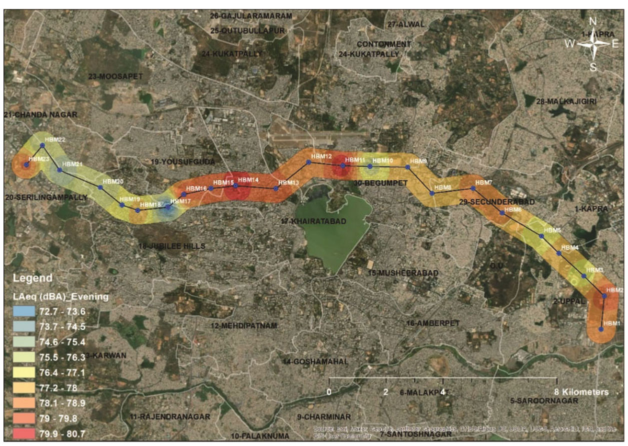

Fig. 12 — Noise mapping for evening time peak rush hours.

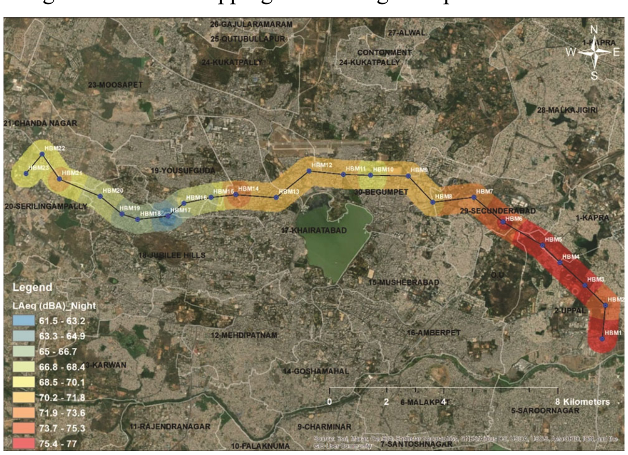

Fig. 13 — Noise mapping for nighttime.

luminously showed the noise pollution around the blue line metro lane using less data, which is of great significance for the evaluation of urban road traffic noise.

4 Conclusions

In the present study, the noise levels during the day and night times are estimated to be exceedingly higher side across the blue line metro lane of Hyderabad city which comprises mixed residential, commercial and silence zones. Although traffic and noise are naturally related, urban traffic poses heterogenic conditions and has been observed the non-linearity of noise levels to that of total vehicular count in the present study. The most noise impacting vehicular type on road traffic has been identified to be two-wheelers during peak rush hours of day time and four-wheelers during night time. Impulse noises created in the process of honking is the main noise source during daytime rush hours. Whereas, vehicular speeding is the major source during night times across the blue line metro regions. Noise mapping generated using the IDW interpolation method shows the intensely affected regions across the metro lane due to road traffic. The present methodology and analysis pattern can be used as a tool to identify the most noise impacting sources in a given time especially in a heterogenic urban conditions across the globe.

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Conflict of Interest

Authors don't have any conflict of interest in publishing the generated data.

Author Contribution

Dr Sathravada Balaji has generated and executed the idea completely right from data acquisition, compilation and manuscript formulation and finalization. Pragati Tiwari has contributed to study area description, data acquisition, compilation, and manuscript formulation. Ampolu Suresh, Dimple Sharma, G V Santosh Kumar, Ch Hemadhri Veera JagannadhaRao Rao, Abhijeet Mondal have contributed to data acquisition, compilation and manuscript formulation.

Supplementary Information

Supplementary data contains short description about every location and Supplementary Fig. S1 to Fig. S10 which are marked in the relevant area of the main text.

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