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Various Road Traffic Noise Emission in Urban Microenvironments - an Evidence of Developing Indian city

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ABSTRACT

Urban road traffic noise pollution causes various human health ailments. There is very limited research has been focused on different road traffic noise emission, which is significant to design environmental noise abatement measures. We studied different road traffic noise emission in roadside outdoor and indoor microenvironments, by field noise monitoring, traffic attribute study and meteorological data measurement (Jan-Dec, 2019) near a busiest G.S. road of Guwahati city and SoundPLAN 8.2 based FHWA TNM 2.5 noise modelling. The results depict that the measured noise level at outdoor and indoor were violated the WHO guidelines of 53 dB(A). The modelling study shows that with increasing the building floor level noise was increased up to 60 dB(A) at day and 56 dB(A) at night. The car was found as the leading noise producing vehicle in that study area, which contributed 66.9 dB (A) at day and 61.4 dB(A) at night. However, bike movement mostly contributed 250 Hz noise frequency of about 61.7 dB(A) and truck and bus contributed > 1 kHz noise frequency of > 50 dB(A). The results further showed that nearly 15%, 12%, 8% and 6% exposed people at outdoor could experience the highly sleep disturbances (HSD) due to truck, car, bike and MUV movements. Similarly, 4%, more than and around 3% exposed people at indoor could experience %HSD related to bike, car, MUV and truck movement. This finding could be useful for different noise abatement measures, including Noise Low Emission Zone (Noise LEZ) for controlling the urban noise pollution.

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INTRODUCTION

Traffic noise pollution is an important environmental hazard of urban area and its exposure is omnipresent both in developing and developed countries (Mehdi et al., 2011; Gan et al., 2012; King, 2022;Thompson et al., 2022). Prolonged, traffic noise exposure causes several psychological and physiological health problems, including annoyance, sleep disturbance, stress reactions, hypertension, cardiovascular ailments, metabolic issues and diabetes (Dratva et al., 2010 ; Gelb and Apparicio, 2021;Münzel et al., 2021 ; Prasad et al., 2022 ; Shamsipour et al., 2022; Tortorella et al., 2022; Amini et al., 2024). Noise levels in urban cities are always higher than 55 dB (A), the threshold of different delineating human health hazards (Jiménez-Uribe et al., 2020; Münzel et al., 2021). Near an urban roadway in Surat city, Ranpise and Tandel (2022) observed that the noise level as high as 78.9 dB(A) (Range: 46.1 -114.9 dB (A)), which is way above the WHO recommended standard of 53 dB(A). The traffic flow, horn honking and improper landscape were contributing to the elevated noise levels. In Kanpur city

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of India, the average noise levels were 44.85 - 79.57 dB (A) (Mishra et al., 2021). Jiménez-Uribe et al. (2020) observed that low frequency noise was influenced by different types of traffic throughout a day; however, high frequencies were influenced by heavy vehicles during day and night both. Can et al. (2010) noticed that the slow moving vehicle and accelerating vehicle emit low frequency noise (<1 kHz). Ishiyama and Hashimoto (2000) observed that the reduction of human annoyance perception linked with the reduction of road traffic frequency above 4.8 kHz. Caciari et al. (2013) observed a noticeable difference in hearing threshold at low - mid frequencies (250 Hz - 2000 Hz) of urban outdoor and indoor workers of Italy. Liu et al. (2016) observed the 250 Hz, 1 kHz, 2 kHz, 4 kHz, and 8 kHz occupational noise frequencies influenced the incidence of hypertension to the workers. The 20 dB(A) increase in noise exposure at 4 kHz was related with a 34% higher risk of hypertension (relative risk (*RR*): 1.34; 95% confidence interval (*C.I.*): 1.01-1.77). Guha and Gokhale (2023) shows that the impact of urban road traffic noise pollution on the cardiovascular health of urban workers of Guwahati city. Smith et al. (2022) and Mishra et al. (2021) observed the adverse impact of night time traffic noise on sleep disorders of European and Indian population respectively. Chronic sleep disorders could pose several human health ailments (viz. fatigue, cardiovascular and metabolic ailments).

As this is indicating that road traffic noise has a broad impact on both public health and urban planning, therefore it is crucial to model the road traffic noise for developing mitigation measures. Alam et al. (2021) developed the SoundPLAN based vertical and horizontal 3D noise map for the densely populated busy street of Delhi city. Banerjee et al. (2014) used SoundPLAN based CoRTN model for estimating traffic noise exposure of residents and observed that day-evening-night noise level (L_{den}) > 65 dB(A) for men and L_{den} > 60 dB(A) for women were associated with the occurrence of hypertension. Asensio et al. (2021) studied that the road traffic contribution on environmental noise by developing instantaneous and accumulated dynamic noise map. They have modelled sound pressure level as a function of sound power level and attenuation of sound level during the propagation from source to receiver. They have concluded that estimating the single road traffic noise contribution could play a pivotal role for developing the road traffic noise abatement strategies. Silvaggio et al. (2020) highlighted the controlling of noisiest road traffic for developing the Noise Low Emission Zone (Noise LEZ) in European region. However, there are very limited studies have been focused on characterisation of different road traffic noise emission, which could play a pivotal role for setting up the Noise LEZ in developing cities. Due to the rapid increase in urban population of India (above 1.38 billion in 2021) resulting in 80% increase in traffic population (Verma et al, 2021). The urbanised cities are prone to extreme traffic congestion, resulting in increasing environmental noise problems. Further, the lack of proper urban planning induce the conglomeration of residential, commercial, institutional, and silent areas forming the Central Business District (CBD) in several Indian cities (Gilani and Mir, 2021). That could exacerbate extreme environmental noise pollution in Indian cities (Gilani and Mir, 2021). Therefore, this is essential to control the environmental noise pollution for Indian cities. This paper aims to investigate the contribution of different road traffic on urban environmental noise pollution by field noise study and FHWA TNM 2.5 based SoundPLAN noise modelling in Guwahati city. Also, this study examined the different road traffic noise impacts on highly sleep disturbances (%HSD) of exposed population. The research outcome could be useful for abating noise level such as development of Noise LEZ in developing cities.

METHODOLOGY

Study area

Guwahati city is the gateway of the north-eastern India (NE), which is situated in the Brahmaputra River Valley (BRV) and is surrounded by hills on three sides and the Brahmaputra

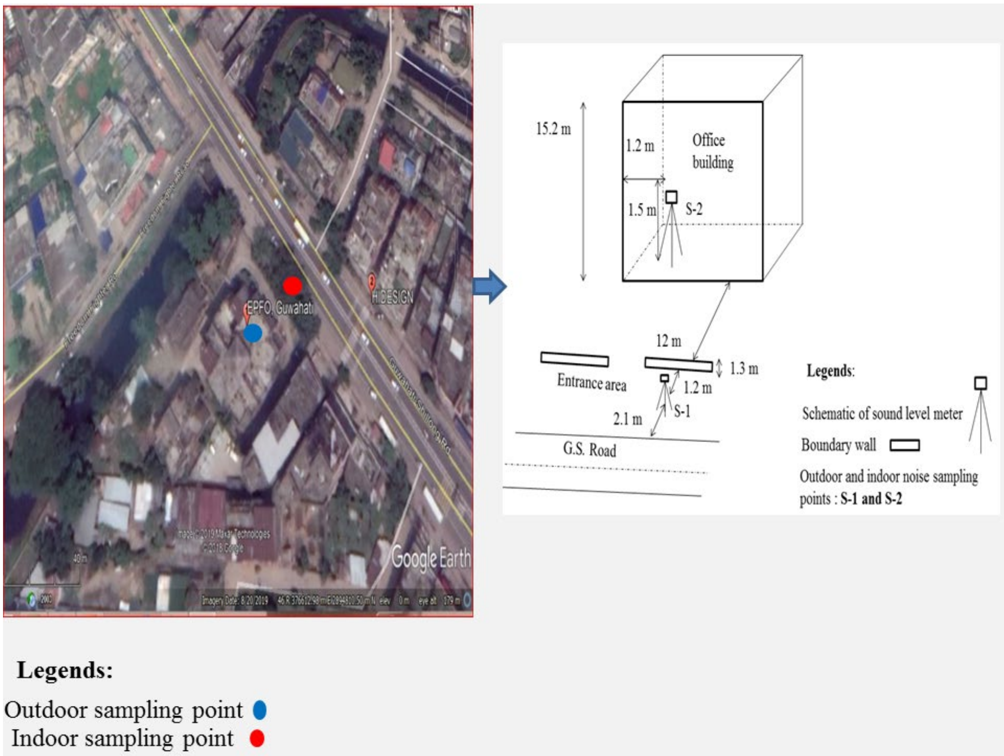


Fig. 1. Study area (Source: Google Earth, accessed on 7th May, 2024) with schematic of noise sampling points

River on one. The city experiences humid weather and hilly fogs for most of the year. The rising urban development of this city has been experiencing intense road traffic activities and densely flanked roadside buildings (e.g. residential and commercial). This research was carried out near the busiest Guwahati-Shillong road (G.S. Road) and inside a public office building (26.1709° N, 91.7673° E) (Fig.1). Through the G.S. road, everyday hourly > 10,000 road traffic movement has been observed. Many individuals use the same stretch of road for living, working, studying, and shopping. There are various commercial, residential, and institutional building types at different heights in both directions of the road at this location. Intense road traffic operations lead to severe acoustic degradation, which significantly induces stress for people frequently exposed to that noise level.

Data collection

The field noise data was collected from Jan-Dec, 2019 on weekdays (Monday-Friday) by Class 1 sound level meter (Brüel & Kjær type 2250) (Make: SVANTEK, Model: 977) near G.S. Road from 10 a.m. to 8 p.m. during day and 12 midnight to 4 a.m. during night time. For the weekdays the noise data was collected in three segmental monitoring hours such as 10 A.M.- 2 P.M., 1P.M.-5 P.M. and 4 P.M.- 8 P.M. However, for weekdays and night time 180 days and 40 days noise sampling was conducted, respectively. The sound level meter was kept at 1.4 m from the road side for outdoor measurements and in the entrance room on the ground floor at 1.2 m from the nearest wall for office indoor noise measurements. The microphone was positioned at 1.5 m above from the ground level for indoor and outdoor noise measurements. Simultaneously with traffic noise monitoring, the road traffic movement was also videotaped and the traffic speed was studied by a radar gun (Make: Bushnell) for 5 min of every 15 min during the study period. The temperature, relative humidity and atmospheric pressure were measured by Vantage Pro weather station in that study area.

Data analysis

Noise data

Raw noise data has been averaged for day (L_d) and night (L_n) time as per the following Eq. (1).

$$L = 10.log\sum_{i=1}^{n} f_i\left(10^{\frac{Li}{10}}\right) \quad (1)$$

where, L is the equivalent noise, f_i the time fraction and L_i is the noise level at each time fraction. The independent sample Student t-test has been studied for day and night time noise data and emitted noise levels from different vehicles.

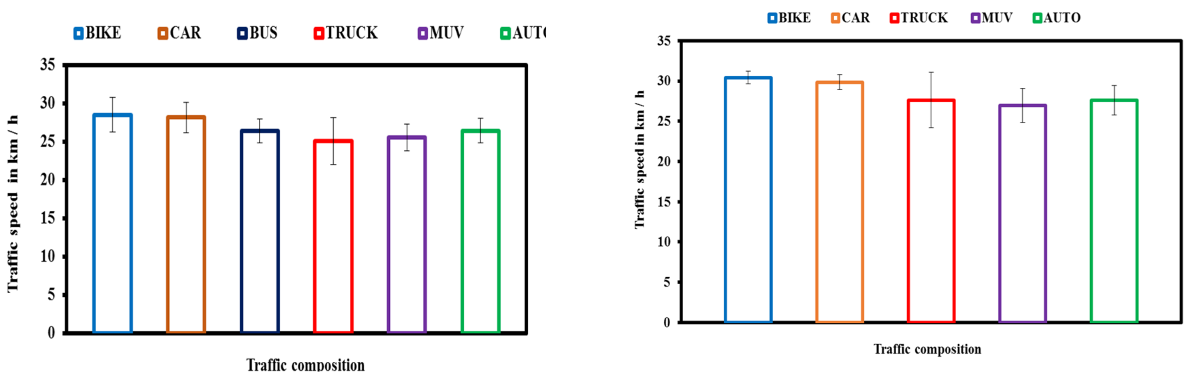
Characteristics of traffic and meteorological attributes

The traffic data videotaped at the study area along with the speed monitoring throughout the study duration have been analysed for traffic flow, composition, and speed. The traffic counts are categorised into light vehicle (bike, car, multi-utility vehicle (MUV), auto) and heavy vehicle (bus, truck). Fig. 2(a) shows that in that study duration (10 a.m. - 8 p.m.), observed speed of different traffic including bike, car, bus, truck, MUV and auto were, 28.5 ± 2.2 km/h, 28.2 ± 2 km/h, 26.4 ± 1.6 km/h, 25.1 ± 3.1 km/h, 25.6 ± 1.8 km/h and 26.4 ± 1.6 km/h, respectively. While, at midnight (12 a.m. - 4 a.m.), the observed speed of bike, car, truck, MUV and auto were 30.4 ± 0.8 km/h, 29.8 ± 0.9 km/h, 27.6 ± 3.5 km/h, 26.9 ± 2.1 km/h, 27.6 ± 1.8 km/h respectively (Fig. 2 (b)).

Out of 101,865 of total traffic, 45 % of bike, 36 % of car, 3% of bus, 0.29% of truck, 6% of MUV (multi utility vehicle), 10% of auto was observed throughout the study hour (10 a.m. - 8 p.m.). While during 12 a.m. - 4 a.m. midnight out of 6144 of total traffic, 30 % of bike, 56 % of car, 5 % of truck, 4 % of MUV and 5 % of auto was observed. This finding indicate that bike and car were the dominating traffic in the fleet and both of these were moved with relatively faster speeds than other traffic. Thakre et al. (2020) observed similar trend of traffic fleet in Indian road. The data analysis indicated that the average ambient temperature, relative humidity and atmospheric pressure were 27±4.29 ˚C, 73.84±14.85% and 722.84 ±3.91 mm Hg, respectively. Spearman-rho correlation analysis was performed between meteorological parameters and noise indices to explore the impact of meteorological parameters on noise indices.

Road traffic noise modelling

The traffic noise propagation has been modelled by SoundPLAN (version 8.2), using traffic



(a) (b)

Fig. 2. Traffic speed (a) at 10 a.m. - 8 p.m. and (b) at 12 a.m. – 4 a.m. of different traffic in the fleet

Table 1. Input cum configuration variables for SoundPLAN modelling

Input cum configuration variables	Characteristics of input cum configuration variables
Geographical attributes	• **Coordinate system and coordinate** : Universal Transverse Mercator (UTM) and Northern hemisphere • **Reference system** : World-wide GPS geocentric (GS84) • **Zone**: 46 • **Latitude and Longitude** : 26.1709 ˚ N and 91.7673˚ E
Pavement	Average grade asphaltic bitumen
Building attributes	Height (H) = 16.90 m, Length (L) = 14.85 m, Width (W) = 5.75 and, floor height (h) = 2.65 m, floor slab thickness (t) = 0.65 m and Number of floor :4 Façade material : Brick work Door : Double glazed glass door Window : Sliding glass window
Calculation Settings	• **Time intervals**: Two (6 a.m.-10 p.m.; 10 p.m. - 6 a.m.) • **Frequency bands**: 1/1 octave frequency • **Weighting**: dB(A) • **Receiver property for point receiver**: Distance between road and receiver at 2.1 m ; receiver height 1.5 m • **Indoor receiver property**: Receiver height 1.5 m from floor and distance between receiver and adjacent indoor wall 1.4 m • **Receiver position for FNM**: Centre of each façade • **Grid property for GNM**: 5 m spacing with height of the 1.3 m elevation from ground. • **Reflection order**: 1 • **Reflection loss**: 1 dB(A) • **Field size**: 9 m × 9 m

attribute (traffic count and traffic speed), building attributes, receiver properties (receiver height), pavement characteristics and meteorological input. SoundPLAN process the georeferenced data through its' in built geographic data processing module and it creates the digital ground model (DGM) by converting the 3D contour lines into elevation lines. The necessary topographical features (building, road) were incorporated. Thereafter by defining the acoustic receptors and aforementioned model input, SoundPLAN 8.2 modelled the traffic noise pollution, in terms of day time (L_d) and night time (L_n) noise level as per the Federal Highway Administration Traffic Noise Model (FHWA TNM 2.5). Based on the model input (Table 1), different noise propagation scenarios have been developed and validated with the observed noise data and different traffic source contribution has been characterised. Model output could be categorised as, noise level at single receiver point, façade noise map (FNM) and grid noise map (GNM).

Traffic noise was modelled for single point receiver at outdoor locations (1.4 m from the curb side) and at the façades of the building where the study was conducted. And, at the building indoors receiver assumed at 1.4 m distance from the adjacent walls and furniture and at 1.2 m height from the floor level. Noise level has been modelled using Eq. (2) (FHWA TNM, 1998).

$$L_{Aeq\,1h} = EL_i + A_{traffic\,i} + A_d + A_s \tag{2}$$

where, L_{Aeq1h} is the hourly equivalent noise level, EL_i is the vehicle noise emission level for the ith vehicle type, $A_{traffic\ i}$ is the adjustment for traffic flow, volume and speed for the ith vehicle type, A_d is the adjustment for distance between the roadway and receiver and for the length of the roadway, and A_s refers to the adjustment for all shielding and ground effects between the roadway and the receiver.

For indoor noise model, SoundPLAN 8.2 used the building-acoustic module (BA module), which uses the noise input from outdoor façade of any building to estimate the indoor noise level by assessing the permissible indoor noise limit.

RESULTS

Noise indices

Fig. 3 shows that at outdoor ambient environment due to intense road traffic and other anthropogenic activities leads to the noise level of 77.21±1.7 dB(A) which exceeded the WHO prescribed limit of 70 dB(A). Kalawapudi et al.(2020) observed similar increase in noise level in Mumbai city. However, inside the office the observed day time noise level of 68.60±3.7 dB(A) which also exceeded the 53 dB(A) of WHO allowable level (WHO, 2018). During office hour along with the ingress of outdoor noise, the operation of wall mounted fans and workers' activities leads to that high indoor noise level. However, at night the outdoor roadside and inside the office the observed noise level were 66.80±0.61 dB(A) and 65.68±5.09 dB(A), respectively. The night time bike and car movement were mainly causing that high noise level at both microenvironments. The similar findings was observed by Pirrera et al.(2014) in the Brussels-Capital Region.

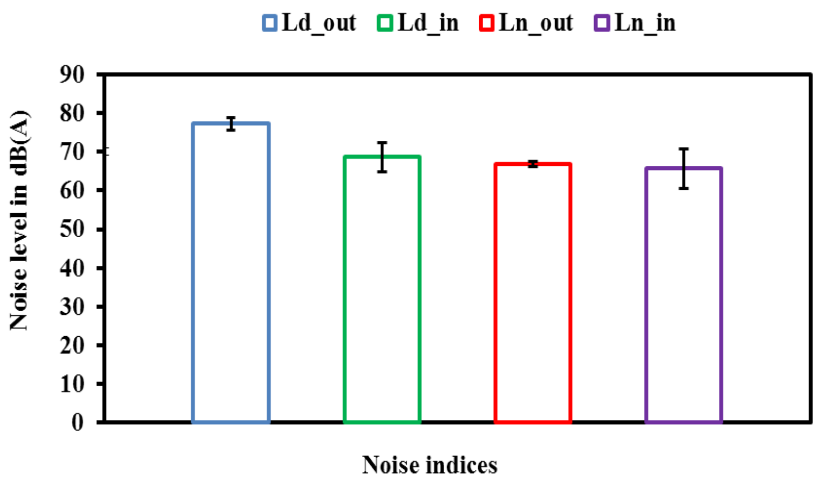


Fig. 3. Measured noise indices at day and night in different microenvironments

Table 2. Independent sample t-test statistics for day and night outdoor noise level

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig.	Mean Difference	Std. Error Difference	95% CI LL	95% CI UL
Equal variances assumed	15.21	.00	10.00	78	.00	8.77	0.87	7.02	10.52
Equal variances not assumed			10.00	49.84	.00	8.77	0.87	7.01	10.53

Table 3. Independent sample t-test statistics for day and night indoor noise level

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig.	Mean Difference	Std. Error Difference	95% CI LL	95% CI UL
Equal variances assumed	5.25	.02	16.52	78	.00	15.38	0.93	13.52	17.23
Equal variances not assumed			16.52	74.13	.00	15.38	0.93	13.52	17.23

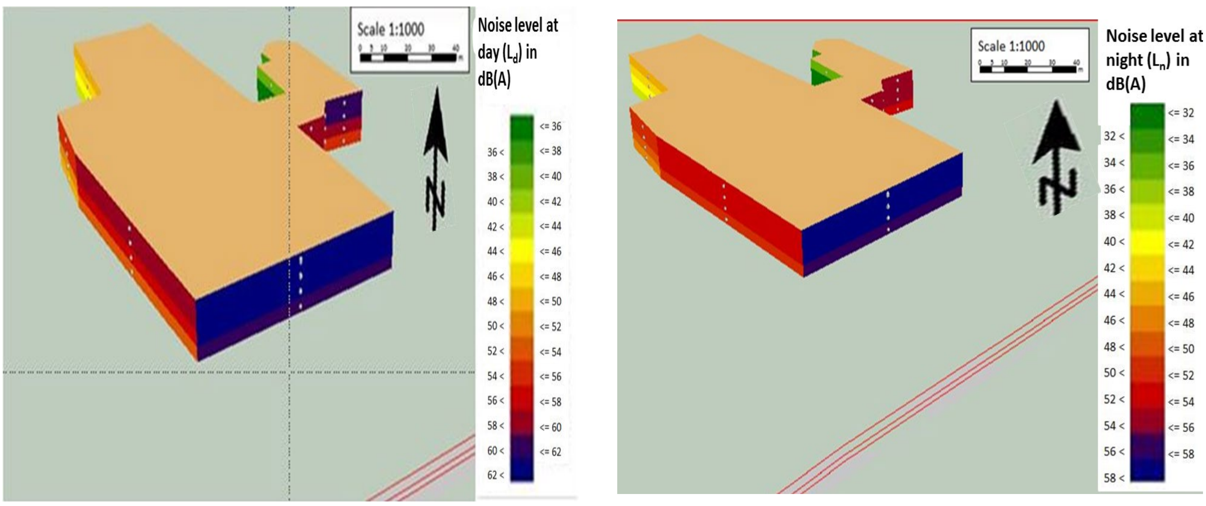
Relationship between day and night time noise levels and noise from different vehicle

Independent sample t-test has been carried out for day and night time noise levels from different vehicles for outdoor and indoor microenvironments. The results show that the mean and variance of day and night time indoor and outdoor noise are observed as significantly different (Table 2 and Table 3).

Modelled noise level

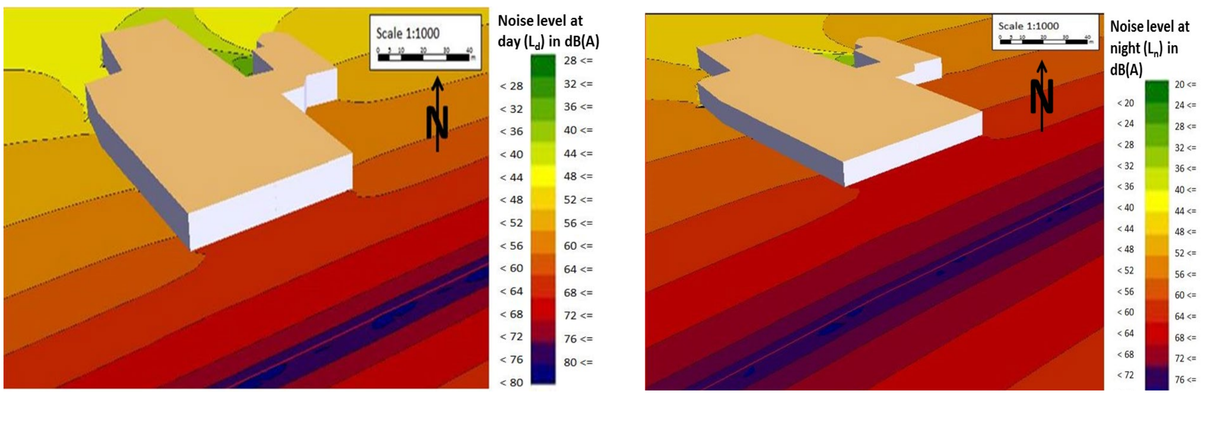
Fig.4(a) shows that the front façade of the office building was most exposed to the traffic noise. Ground floor to higher floors exposed to increasing range of noise level above 60 dB (A) at day time. During night the modelled noise level also increased above 56 dB (A) in the front façade. In the right side of the building façade the modelled noise level was > 50 dB (A) from ground floor level to upper floors (Fig.4 (b)).

In the grid noise map with grid spacing of 10 m, it shows that at day time modelled noise level (Fig.5(a)) exceeded 72 dB (A) near curb side and in the immediate vicinity of the front



(a) **(b)**

Fig. 4. (a) Day time and (b) night time Façade Noise Map (FNM) of public office building (receiver center of each floor)



(a) **(b)**

Fig. 5. (a) Day and (b) night time grid noise map (GNM) near roadside

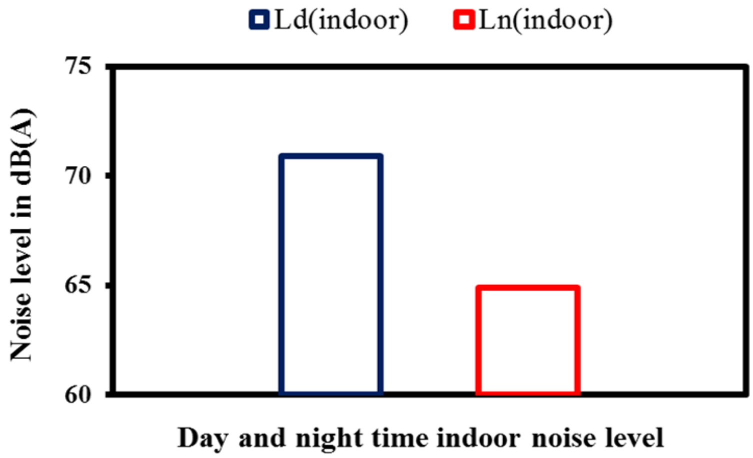


Fig. 6. Modelled noise level for indoor microenvironment

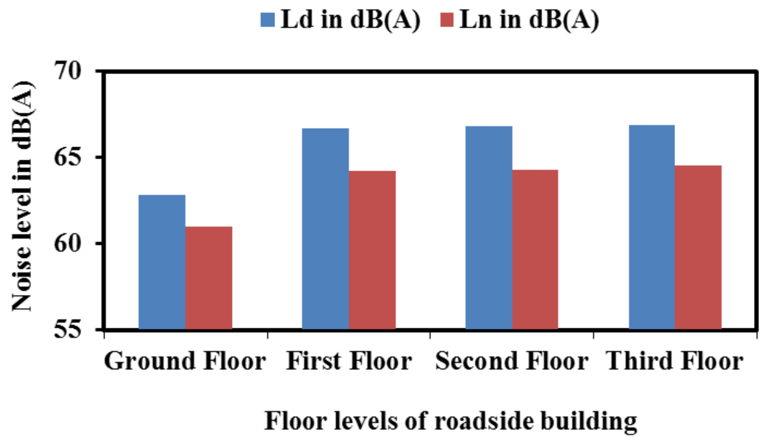


Fig. 7. Modelled noise level at different height of roadside building (assuming point receiver at center of each floor)

façade of the office building the same was between 68 - 72 dB(A) at daytime. While at night the modelled noise level near road side (Fig.5(b)) was found in the range of > 68 to ≤ 72 dB (A). On the other hand, in front of front façade of office building, the noise level is in the range of > 64 to 68 dB (A). Alam et al. (2021) also modelled the traffic noise for residential area with SoundPLAN software and observed the similar violation of noise level in South Delhi city of India. On the other hand, for indoor noise modelling approach, building façade consisting of brick wall and 30% of glass area for door and window, traffic induced noise was modelled in consideration of building materials, room geometry and of 2 dB (A) flanking transmission.

Fig.6 shows that inside the office building day time modelled noise level was 70.9 dB (A) whereas at night it was of 64.9 dB (A).

During working hour outdoor traffic density was higher than evening and night time that's why modelled indoor noise level was high. However at night, bike and car movement were the predominant traffic sources in the study area. All these study output nearly similar with the study of Jeong et al. (2010) and Ece et al. (2018).

In the case of single receiver at different floors of building, modelled traffic noise was found to be increased with the increase in building floors (Fig.7).

From the first floor onwards the modelled noise level was exceeded the 55 dB(A) annoyance level of USEPA throughout the entire day.

Model validation

The measured and modelled noise level has been validated with fractional bias (FB), factor of two (FAC2), factor of five (FAC5), normalised mean square error (NMSE) and co-efficient of determination (R^2) (Eq.(3)-Eq.(6)).

$$FB = \frac{2.\overline{(C_o - C_p)}}{\overline{C_o} + \overline{C_p}} \quad (3)$$

$$0.5 < FAC2 = \frac{C_p}{C_o} < 2 \quad (4)$$

$$0.5 < FAC5 = \frac{C_p}{C_o} < 5 \quad (5)$$

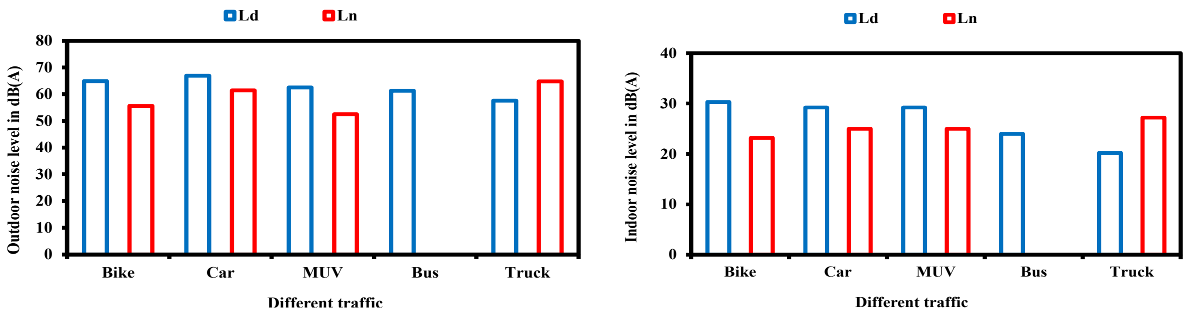
$$NMSE = \frac{\overline{(C_p - C_o)^2}}{\overline{C_o}.\overline{C_p}} \quad (6)$$

where, 'C_o' and 'C_p' are the measured and predicted noise level respectively.

The FB for outdoor roadside area at day and at night were 0.0072 and 0.073 respectively, and for office indoor the same for day and night were -0.036 and 0.03 respectively. This finding was in line with the study by Fallah-Shorshani et al.(2022), they observed the FB lies between – 0.80 to 1.92 for CadnaA, GAM, HLTNM, XGB and Harmonoise noise propagation models. The observed coefficient of determination (R^2) was > 0.8 for both outdoor and indoor noise study, which indicate that, modelled noise level was well fitted with the measured noise level. The results show that FAC2, FAC5 and NMSE are within the acceptable model performance range of 0.5 to 2, 0.5 to 5 and close to zero, respectively for day and night time (Raokhande and Gokhale, 2008).

Contribution of different traffic activities on environmental noise pollution

Fig.8 shows that at day time car was observed as the noisiest traffic at that study area followed by bike, MUV, bus and truck which contributes 66.9 dB(A), 64.9 dB(A), 62.5 dB(A), 61.3 dB(A) and 57.6 dB(A) and at night truck was the noisiest traffic followed by car, bike and MUV which contributes 64.8 dB(A), 55.6 dB(A) and 52.5 dB(A), respectively.



(a) (b)

Fig. 8. Different traffic contributions on outdoor (a) and indoor (b) noise level

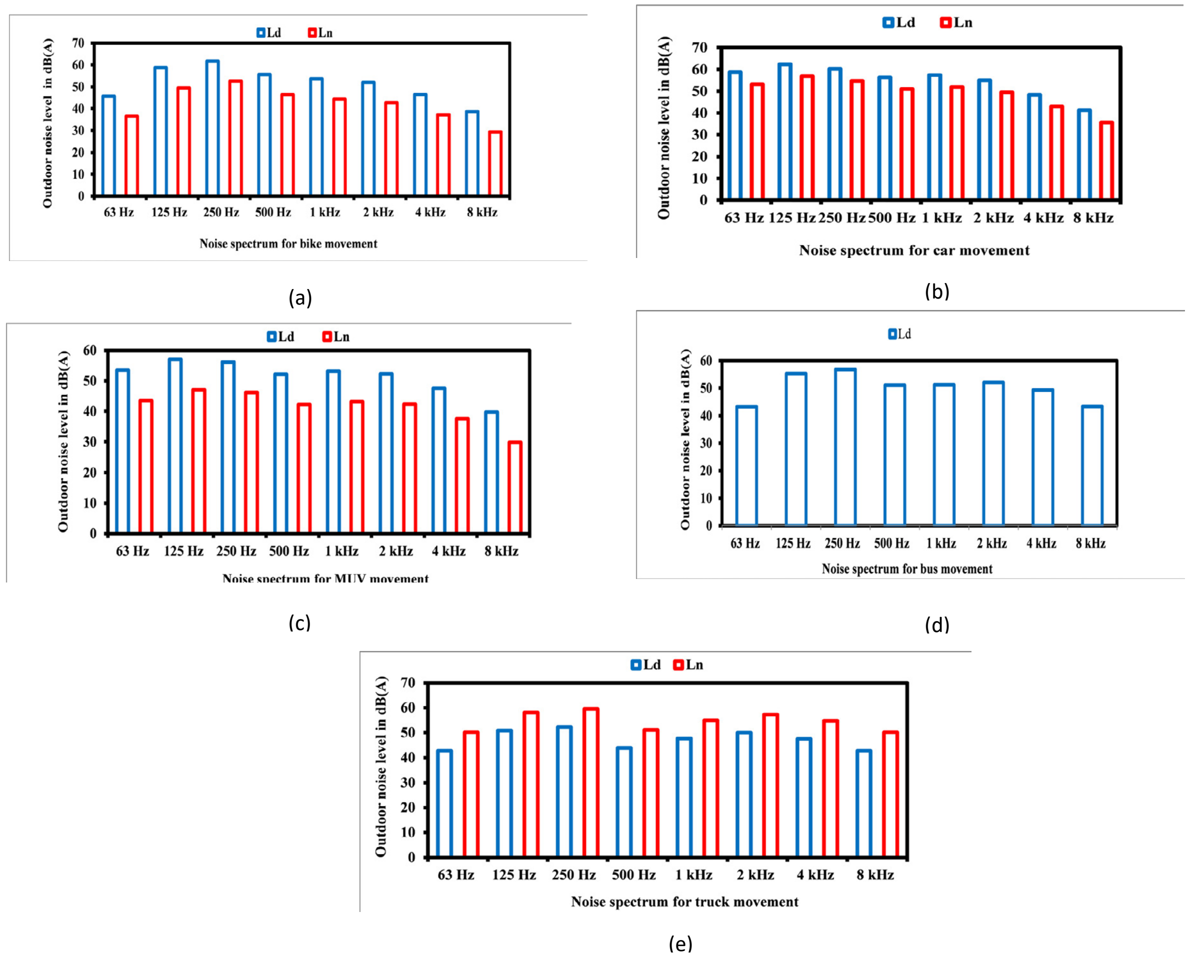


Fig. 9. Outdoor noise spectrum for (a) bike, (b) car, (c) MUV, (d) bus and (e) truck

On the other hand, inside the office, contribution from bike at day time was highest followed by car, MUV, bus and truck which contributes (Fig.8). There was no bus observed at night. Fig.9 shows that car contributed low frequencies noise while, bike was observed as the leading contributor of 250 Hz noise frequencies. Heavy vehicles including bus and truck contributed higher frequencies (>1 kHz) of noise at the roadside area.

Relationships between different vehicular noise levels

Independent sample t-test between vehicular noise levels show that the noise emitted from bike and car are relatively similar. In the case MUV and truck there was relatively different noise level has been observed (Table 4 and Table 5).

Impacts of road traffic noise on sleep disturbances

The percentage highly sleep disturbance (%HSD) of exposed population due to different road traffic movement was calculated by using (Miedema and Borst, 2007) equation. The result shows 15%, 12%, 8% and 6% exposed outdoor population could experience the %HSD due to truck, car, bike and MUV movement in that study area. Similarly, 4%, more than and around 3% indoor populations could also experience the %HSD due to bike, car, MUV and truck movement, respectively.

Table 4. Independent sample t-test statistics for bike and car noise

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig.	Mean Difference	Std. Error Difference	95% CI LL	95% CI UL
Equal variances assumed	0.98	0.32	-2.14	46	0.03	-4.77	2.22	-9.25	-0.28
Equal variances not assumed			-2.14	44.79	0.03	-4.77	2.22	-9.25	-0.28

Table 5. Independent sample t-test statistics for MUV and truck noise

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig.	Mean Difference	Std. Error Difference	95% CI LL	95% CI UL
Equal variances assumed	4.27	0.04	-1.94	46	0.06	-3.31	1.70	-6.74	0.12
Equal variances not assumed			-1.94	40.33	0.06	-3.31	1.70	-6.76	0.13

Table 6. Spearman-rho correlation between traffic noise and $PM_{2.5}$ and meteorological variable

		T_{out}	T_{of}	$\%RH_{out}$	$\%RH_{of}$	ATMP
Street	L_{peak}	-.224	-.229	.181	.076	.256
	L_{max}	-.289	-.291	.177	.078	.339*
	L_{min}	-.116	-.231	-.056	-.180	.315*
	L_{eq}	-.355*	-.315*	-.022	-.146	.377**
	L_{10}	-.393**	-.290	.076	-.029	.336*
	L_{50}	-.371*	-.290	-.055	-.163	.327*
	L_{90}	-.324*	-.405**	-.011	-.158	.509**
	L_{95}	-.332*	-.390**	.003	-.141	.499**
	$NC_{(L90)}$	-.027	-.357*	.027	-.041	.249
	$NC_{(L95)}$	-.023	-.320*	.010	-.039	.199
Office	L_{peak}	-.167	.326*	-.054	.133	-.350*
	L_{max}	-.015	.231	-.195	-.041	-.307*
	L_{min}	-.170	.351*	-.024	.183	-.441**
	L_{eq}	-.096	.314*	-.207	-.020	-.386**
	L_{10}	-.028	.276	-.183	-.042	-.333*
	L_{50}	-.132	.355*	-.221	.012	-.421**
	L_{90}	-.124	.393**	.004	.251	-.473**
	L_{95}	-.104	.411**	.017	.284	-.458**
	$NC_{(L90)}$	.115	-.076	-.106	-.216	.106
	$NC_{(L95)}$	.036	-.090	-.073	-.216	.070

*Correlation is significant at the 0.05 level; **Correlation is significant at the 0.01 level where, 'T_{out}' and 'T_{of}' are the outdoor ambient and office indoor temperature, respectively; '$\%RH_{out}$' and '$\%RH_{of}$' are the street side ambient and office indoor relative humidity, respectively; '*SR*' is the solar radiation, '*ATMP*' is the atmospheric pressure and '*WS*' is the wind speed.

Impacts of meteorological parameters on noise indices

Spearman-rho correlation analysis (Table-6) between meteorological parameters and noise indices shows that outdoor ambient temperature was negatively correlated with ambient equivalent noise (L_{eq}) (ρ=-0.355; p=0.015), which could be the reason for lesser public activities during warmer days. Temperature inside the office was slightly correlated with indoor L_{eq} (ρ=0.314; p=0.034), this happens possibly due to intense public activities inside the office room.

Yang et al. (2018) also observed similar increase of indoor noise with temperature. Whereas atmospheric pressure was slightly correlated with ambient L_{eq} (ρ=0.377; p=0.010) and negatively correlated with indoor L_{eq} (ρ=-0.386; p=0.008). Solar radiation (SR) was positively correlated with ambient L_{eq} (ρ=0.356; p=0.015) and negatively correlated with indoor L_{eq} (ρ=-0.45; p=0.002).

DISCUSSION

Urban road traffic noise pollution has been studied near busiest G.S. road of Guwahati city in outdoor roadside and inside a public office building. The acoustic environment of both outdoor and indoor microenvironments has been sincerely degraded due to road traffic movement and other anthropogenic activities. The observed day and night time noise level has been exceeded >53 dB(A) of WHO level at both microenvironments (WHO, 2018). The SoundPLAN noise modelling indicates that in the outdoor roadside area the modelled noise level was higher than 60 dB(A) and at night it was exceeded 56 dB(A). Similar result was observed by Ece et al. (2018). In Indian city, Sonaviya and Tandel (2020) observed 4-11 dB(A) under prediction of traffic noise level by RLS-90 model in SoundPLAN essential 4.0 software. For indoor office building allowing 2 dB (A) of flanking transmission, day time modelled noise was 70.9 dB(A) and at night it was 64.9 dB(A). At day and night time grid noise map (GNM) near outdoor roadside showed that the modelled noise exceeded the CPCB prescribed limit mostly due to vehicular activities, horn honking, public redressal system and other anthropogenic activities. Noise level was increased with the elevation of building floors. In this study the car movement was found as the major noise contributor in that study area. Balaji et al.(2022) observed that at night time car was the leading sources of noise pollution in Hyderabad city of India. At night time very few truck movements contributed noise pollution in that study area. Bike movement generally dominated the 250 Hz noise frequency. The higher noise frequencies (>1 kHz) were influenced by bus and truck movement at that study area. The road traffic activities could also pose highly sleep disturbances (> 3%) of exposed population for both microenvironments. Similar findings also reported by Mishra et al. (2021) in Kanpur city. This observation could be helpful for developing the different traffic noise mitigation scenarios by identifying the noisiest traffic in that study area. In connection with this observation, the characterisation of vehicular noise in terms of horn honking, engine noise and road wheel interaction could better indicate the road traffic noise pollution near busiest roadside area.

CONCLUSION

The yearlong environmental noise study in developing Guwahati city was conducted to investigate the acoustic quality near the busiest urban roadside area at outdoor and indoor microenvironments. The observation of this research highlighted the clear violation of the WHO noise limit for both microenvironments, which could pose several delineating human health ailments. The noise modelling study concludes that noise levels near roadside buildings increased with the building floors. Car movement predominantly contributed to noise pollution, followed by bikes in that study area. Mid-frequency noise (250Hz) mostly emanated from bike movement, and higher noise frequencies (>1 kHz) mainly originated from truck and bus movements. More than 3% of the population in that study area could face high sleep disturbances due to road traffic movement. Therefore, limiting the car movement, decreasing horn honking, implementation of Noise Low Emission Zone (Noise LEZ), along with the installation of noise barrier, replacing building façade material by noise absorbing material could improve the acoustic quality in that study area, which could indirectly be helpful for the healthy survival of human being in urban areas. The outcome of this study could help in designing the Noise LEZ in developing cities.

AUTHOR STATEMENT

Argha Kamal Guha: conceptualization, methodology, field work, data analysis, and writing; Sharad Gokhale: conceptualization, results validation, review and editing.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

Alam, P., Ahmad, K., Khan, A.H., Khan, N.A., & Dehghani, M.H.,(2021). '2D and 3D mapping of traffic induced noise near major roads passing through densely populated residential area of South Delhi, India.' *Plos one*, *16*(3), p.e0248939.

Amini, F., Karbassi, A., & Amiri, M. J. (2024) 'Localized Environmental Pricing of Noise Pollution in Iran', *Pollution*, 10(2), pp. 779–789. doi: 10.22059/poll.2024.370774.2210.

Asensio, C., Pavón, I., Ramos, C., López, J.M., Pamiés, Y., Moreno, D., & de Arcas, G., (2021). 'Estimation of the noise emissions generated by a single vehicle while driving.' *Transportation Research Part D: Transport and Environment*, *95*, p.102865.

Balaji, S., Tiwari, P., Suresh, A., Sharma, D., Kumar, G.V., VJ, H., & Mondal, A., (2022). 'Noise Mapping and Variance of Road Traffic Noise: Identification of Most Noise Impacting Vehicular Type in an Urban Region.' *Indian Journal of Pure & Applied Physics (IJPAP)*, *60*(10), pp.823-832.

Banerjee, D., Das, P. P., & Fouzdar, A. (2014) 'Urban Residential Road Traf fi c Noise and Hypertension : a Cross-Sectional Study of Adult Population', 91(6), pp. 1144–1157. doi: 10.1007/s11524-014-9916-1.

Caciari, T., Rosati, M.V., Casale, T., Loreti, B., Sancini, A., Riservato, R., Nieto, H.A., Frati, P., Tomei, F., & Tomei, G.,(2013).' Noise-induced hearing loss in workers exposed to urban stressors.' *Science of the total environment*, *463*, pp.302-308.

Can, A., Leclercq, L., Lelong, J., & Botteldooren, D.,(2010). 'Traffic noise spectrum analysis: Dynamic modeling vs. experimental observations.' *Applied Acoustics*, *71*(8), pp.764-770.

Das, C.P., Goswami, S., Swain, B.K., & Das, M., (2022).' Association between traffic noise-induced psychophysiological, and socio-demographic factors of motorcycle riders.' *Applied Acoustics*, *196*, p.108898.

Dratva, J., Zemp, E., Dietrich, D.F., Bridevaux, P.O., Rochat, T., Schindler, C., & Gerbase, M.W., (2010). 'Impact of road traffic noise annoyance on health-related quality of life: Results from a population-based study.' *Quality of life research*, *19*, pp.37-46.

Fallah-Shorshani, M., Yin, X., McConnell, R., Fruin, S., & Franklin, M., (2022). 'Estimating traffic noise over a large urban area: An evaluation of methods.' *Environment International*, *170*, p.107583.

Gan, W.Q., McLean, K., Brauer, M., Chiarello, S.A., & Davies, H.W., (2012). 'Modeling population exposure to community noise and air pollution in a large metropolitan area.' *Environmental* *research*, *116*, pp.11-16.

Gelb, J., & Apparicio, P. (2021) 'Cyclists' exposure to atmospheric and noise pollution: a systematic literature review', *Transport Reviews*. Taylor & Francis, 41(6), pp. 742–765. doi: 10.1080/01441647.2021.1895361.

Gilani, T. A. (2021) 'RESEARCH ARTICLE A study on the assessment of traffic noise induced annoyance and awareness levels about the potential health effects among residents living around a noise-sensitive area'. Environmental Science and Pollution Research, pp. 63045–63064.

Guha, A. K., & Gokhale, S. (2023) 'Urban workers ' cardiovascular health due to exposure to traf fi c-originated PM 2 .5 and noise pollution in different microenvironments', *Science of the Total Environment*. Elsevier B.V., 859(October 2022), p. 160268. doi: 10.1016/j.scitotenv.2022.160268.

Ishiyama, T., & Hashimoto, T. (2000) 'Impact of sound quality on annoyance caused by road traffic noise: an influence of frequency spectra on annoyance', *JSAE review*, 21(2), pp. 225–230. doi: 10.1016/S0389-4304(99)00090-9.

Jiménez-Uribe, D.A., Daniels, D., González-Álvarez, Á., & Vélez-Pereira, A.M., (2020). 'Influence of vehicular traffic on environmental noise spectrum in the tourist route of Santa Marta City.' *Energy Reports*, *6*, pp.818-824.

King, E. A. (2022) 'Here, There, and Everywhere: How the SDGs Must Include Noise Pollution in Their Development Challenges', *Environment: Science and Policy for Sustainable Development*. Taylor & Francis, 64(3), pp. 17–32.

Liu, C.S., Young, L.H., Yu, T.Y., Bao, B.Y., & Chang, T.Y., (2016). 'Occupational noise frequencies and the incidence of hypertension in a retrospective cohort study.' *American journal of epidemiology*, *184*(2), pp.120-128.

Menge, C.W., Rossano, C.F., Anderson, G.S., & Bajdek, C.J., (1998). *FHWA traffic noise model, Version 1.0 technical manual* (No. DOT-VNTSC-FHWA-98-2). United States. Federal Highway Administration. Office of Environment and Planning.

Miedema, H. M. E., & Borst, H. C. (2007) 'Rating environmental noise on the basis of noise maps within the framework of the Environmental Noise Directive', *Internoise 2007-Noise and Sustainability, Istanbul, Turkey, August 28-31, 2007*, p. 4044.

Mishra, A., Das, S., Singh, D., & Maurya, A.K., (2021). 'Effect of COVID-19 lockdown on noise pollution levels in an Indian city: a case study of Kanpur.' *Environmental Science and Pollution Research*, *28*, pp.46007-46019.

Münzel Mette; Daiber, Andreas, T. S. (2021) 'Transportation noise pollution and cardiovascular disease.', *Nature reviews. Cardiology*. Nature Publishing Group, 18(9), pp. 619–636. doi: 10.1038/s41569-021-00532-5.

Münzel, T., Sørensen, M., & Daiber, A. (2021) 'Transportation noise pollution and cardiovascular disease', *Nature Reviews Cardiology*, 18(9), pp. 619–636. doi: 10.1038/s41569-021-00532-5.

Ranpise, R. B., & Tandel, B. N. (2022) 'Assessment and Appraisal of Morning Peak Time Urban Road Traffic Noise at Selected Locations of Major Arterial Roads of Surat City, India', *Asian Journal of Water, Environment and Pollution*. doi: 10.3233/ajw220012.

Shamsipour, M., Zaredar, N., Monazzam, M.R., Namvar, Z., & Mohammadpour, S., (2022). 'Burden of diseases attributed to traffic noise in the metropolis of Tehran in 2017.' *Environmental Pollution*, *301*, p.119042.

Silvaggio, R., Curcuruto, S., Mazzocchi, E., Borchi, F., Bartalucci, C., Governi, L., Carfagni, M., Bellomini, R., Luzzi, S., Colucci, G., & Cattani, G., (2020). 'Life Monza: Comparison between ante and post-operam noise and air quality monitoring activities in a Noise Low Emission Zone.' *Noise Mapping*, *7*(1), pp.171-191.

Smith, M. G., Cordoza, M., & Basner, M. (2022) 'Environmental Noise and Effects on Sleep : An Update to the WHO Systematic Review and Meta-Analysis', 130(July), pp. 1–23.

Sonaviya, D. R., & Tandel, B. N. (2020) ‘Integrated road traflc noise mapping in urban Indian context’, pp. 99–113.

Thakre, C., Laxmi, V., Vijay, R., Killedar, D.J., & Kumar, R., (2020). ‘Traffic noise prediction model of an Indian road: an increased scenario of vehicles and honking.’ *Environmental Science and Pollution Research*, *27*(30), pp.38311-38320..

Thompson, R., Smith, R.B., Karim, Y.B., Shen, C., Drummond, K., Teng, C., & Toledano, M.B., (2022).’ Noise pollution and human cognition: An updated systematic review and meta-analysis of recent evidence.’ *Environment international*, *158*, p.106905.

Tortorella, A., Menculini, G., Moretti, P., Attademo, L., Balducci, P.M., Bernardini, F., Cirimbilli, F., Chieppa, A.G., Ghiandai, N., & Erfurth, A., (2022). ‘New determinants of mental health: the role of noise pollution. A narrative review.’ *International Review of Psychiatry*, *34*(7-8), pp.783-796.

Verma, A., Harsha, V., & Subramanian, G. H. (2021) ‘Evolution of Urban Transportation Policies in India: A Review and Analysis’, *Transportation in Developing Economies*. Springer International Publishing, 7(2), pp. 1–15. doi: 10.1007/s40890-021-00136-1.

WHO (2018). Environmental noise guidelines for the European region,World Health Organization Regional Oflce for Europe, Copen-hagen.