

Silent Streets and Urban Soundscapes: Examining Noise Levels in Imphal, Manipur amid COVID-19

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The study investigates the impact of the COVID-19 pandemic on urban soundscape dynamics in Imphal, Manipur, focusing on noise levels during restricted mobility and reduced economic activity. This study uses sound measurements and qualitative observations to explore the changes in ambient noise within the city, analyzing the implications of decreased vehicular traffic, commercial operations, and social activities on the acoustic environment. Through a comparative analysis of pre-pandemic and pandemic-induced noise levels, this research aims to delineate the alterations in the acoustic landscape, shedding light on the city's auditory transformation during the pandemic-induced lockdowns. Moreover, it examines the relationship between altered soundscapes and the community's well-being, considering potential implications for urban planning and public health policies. The findings contribute to a deeper understanding of the intricate relationship between societal changes, environmental acoustics, and the lived experience of urban environments amidst extraordinary circumstances like the COVID-19 pandemic.

Keywords: Decibel, L10, L90, LEQ, Pandemic, Sound meter

Introduction

Noise pollution presents a significant health risk alongside air and water pollution, as extensively examined in various research studies.¹⁻³ Generally attributed to high-intensity sound, noise pollution is increasingly recognized as a growing urban environmental issue. Elevated sound levels, primarily from rising vehicular traffic, create disorder and disturbance within urban settings, leading to various health concerns.⁴ Hence, continual monitoring, assessment, and analysis of ambient noise levels in urban areas are vital to formulate and implement effective measures for preventing and controlling noise pollution, ultimately reducing associated health risks. Multiple global studies highlight the adverse effects of noise pollution on human health and urban biodiversity from exposure to high noise levels.⁵⁻⁷ Widespread traffic-related noise pollution can lead to various health impacts encompassing physical, physiological, and psychological issues, including heart problems, nervous system disorders, deafness, and mental health breakdowns in individuals.⁸⁻¹⁰ Furthermore, heightened

noise levels can disrupt wildlife habitats and urban biodiversity, interfering with breeding grounds, mating, and animal reproductive patterns.^{11,12} Despite these indirect and passive effects, there is a general lack of concern among people regarding the impacts of noise pollution.^{13,14}

Since the onset of 2020, the global community has been grappling with the widespread impact of the COVID-19 pandemic. The World Health Organization officially labelled it a 'global pandemic' on March 11, 2020. In response, numerous nations, including India, implemented stringent measures such as nationwide lockdowns to curb the alarming transmission rates of the disease. India enforced a 14-hour voluntary public curfew known as the national 'Janata curfew' on March 22, 2020, followed by an extensive nationwide lockdown initially slated for three weeks from March 24 to April 14, 2020. This lockdown was extended multiple times until May 31, 2020, to contain the virus. The Indian government, through the Ministry of Home Affairs (MHA), enforced strict rules restricting social gatherings, schools, colleges, offices, and transportation systems, allowing only essential services to operate. The 'Janata Curfew' on March 22

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urged people to remain indoors, with exceptions for essential service providers like healthcare, security, and media workers. These measures were crucial in preventing the rapid spread of the pandemic. A study on noise pollution on a minor road revealed increased noise levels, honking, and traffic. A noise prediction model using multiple regression analysis was developed, confirming its accuracy and emphasizing the need for mitigation measures.¹⁵

Besides, different parameters related to biodiversity (AEI, ACI, and SPLrms) are calculated for different frequency bands.¹⁶ Furthermore, India's Central Pollution Control Board (CPCB) established the National Ambient Noise Monitoring Network (NANMN) in 2011, aiming to set up continuous real-time noise monitoring systems.¹⁷

Several studies have documented the effects of noise pollution during the COVID-19 lockdowns, highlighting significant reductions in urban noise levels due to decreased human and vehicular activities. Research from various global cities, including New York, London, and Delhi, has shown that noise levels dropped considerably during lockdowns, providing a unique opportunity to assess baseline urban soundscapes. However, studies on mid-sized Indian

cities, such as Imphal, remain scarce. The lack of research on smaller urban centers limits our understanding of how noise pollution varies across different city scales and socio-economic contexts.

The study investigates the unique impact of the pandemic on the acoustic environment of Imphal City. We aim to quantify the changes in noise levels during lockdowns and restrictions, creating a baseline for pre-pandemic soundscapes absent in existing research on Indian cities. Our findings will contribute to understanding noise pollution in Imphal and provide valuable insights into the relationship between urban activity and soundscapes in a mid-sized Indian city, a topic under-explored compared to larger metropolises.

Materials and Methods

Study Area

Imphal, the capital city of Manipur, India, is a rapidly evolving urban hub in the northeastern region. Its strategic location and potential for diverse developmental projects across Southeast Asia drive its growth. Covering an area of 29.57 sq. km, the city lies between 24.48°–24.82° N latitude and 93.56°–93.95° E longitude, at an average elevation of 790 meters above sea level (Fig. 1). Situated centrally in the Imphal

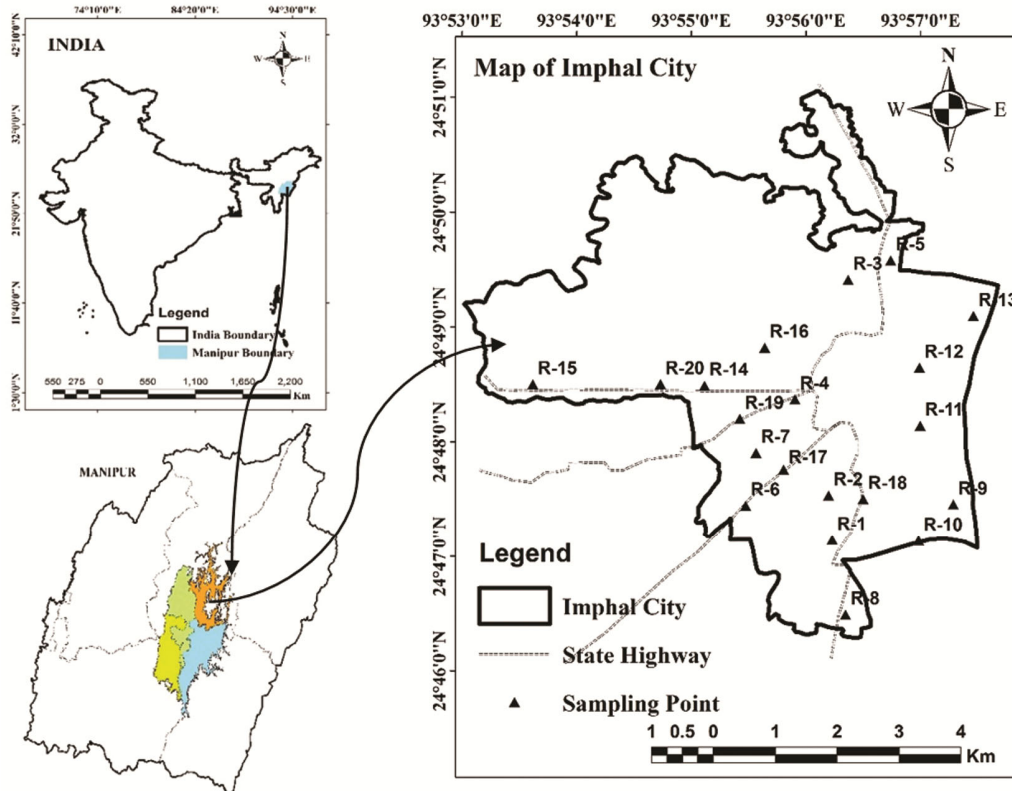


Fig. 1 — Map showing the study area of Imphal city and sampling locations

Valley, the city is surrounded by low-lying hills and blends urban and peri-urban landscapes. Imphal is home to a population of 9,74,105, with a population density of 8,039 persons per sq. km.¹⁸ Imphal City has experienced notable urban expansion, supported by a steadily improving civic infrastructure, which has attracted a substantial increase in its urban population. However, this rapid growth and a sharp rise in vehicular traffic have significantly altered the city’s traffic dynamics over recent decades. These shifts present challenges in addressing urban congestion and managing noise pollution, emphasizing the urgent need for sustainable urban planning and robust regulatory measures. From a sound and noise perspective, Imphal City faces a variety of noise sources driven by its expanding population, ongoing urbanization, and escalating vehicular activity.

The central areas, such as the busy market zone of Khwairamband Bazaar and major traffic junctions like BT Road, Uripok Road (UK Road), Nupi Lal Road, Wahengbam Leikai and Nagamapal, experience elevated noise levels due to intense commercial activities and heavy traffic congestion. Also, Imphal City is an important hub connected by three major National Highways—NH-53, NH-150, and NH-39—linking it to other Indian states and the international border town of Moreh near Myanmar. These zones act as hotspots for anthropogenic noise, often exceeding permissible limits, particularly during peak hours. In contrast, residential areas exhibit relatively moderate noise levels, although vehicular movements and local activities also impact them.

Collections of Noise Levels

The noise level measurements were systematically recorded at five-minute intervals during different periods of the day, specifically in the morning (07:00 AM to 10:00 AM), noon (12:00 PM to 02:00 PM), and evening (04:00 PM to 06:00 PM) during April 2020. This study was conducted within a residential area of Imphal City, focusing on the unique acoustic environment prevailing during the COVID-19 pandemic, characterized by reduced human activity and altered urban dynamics due to lockdowns and movement restrictions.

The Android mobile app used for measuring sound levels was the *Sound Meter*, calibrated in A-weighted decibels (dB(A)), corresponding to the human hearing range of 50 to 100 dB. During measurements, the sound-sensitive side of the mobile device was oriented toward the noise source at a uniform height

of 1.5 meters above ground level. The precise locations of sampling points were recorded using a GPS device (Garmin, eTrex 30).

A total of 20 locations were selected for noise level analysis, with sampling points strategically distributed across residential areas along state and national highways and other densely populated residential zones experiencing heavy traffic during regular times to capture variations in noise levels throughout the study area effectively. The sampling locations are as follows: R-1 Pishum, R-2 Keishamthong, R-3 DM College Eastern Gate, R-4 Wahengbam Leikai, R-5 Chingmeirong, R-6 Kwakeithel, R-7 Keishampat Thiyam Leikai, R-8 Waikhom Leikai, R-9 Wangkhei, R-10 Mangemakhong, R-11 Andro Parking, R-12 Hatta, R-13 Khurai, R-14 Uripok, R-15 Iroisemba, R-16 RIMS Road, R-17 Keishampat Junction, R-18 Moirangkhom, R-19 Sagolband, and R-20 Naoremthong.

Assessment of Equivalent Noise Level (Leq)

The Energy equivalent continuous sound level (Leq) refers to a consistent sound pressure level maintained throughout a specific duration, holding an identical total energy quantity as the varying noise within that timeframe. Leq represents the Root Mean Square (RMS) sound level for a measurement period averaged over a specified interval.¹⁹

$$L_{eq} = 10 \log \frac{1}{T} \sum_i^N T_i (10)^{L_i/10} \dots (1)$$

where, T= total time of operation from the beginning of the initial phase (I = 1) until the beginning of the final phase(i=N); Ti= the time duration of the ith phase, Li = Leq value of ith phase and N = No. of phases

The Leq represents the dB (A) sound level corresponding to the energy equivalent for any given duration. The calculations for daytime average noise pollution (LD), nighttime average noise pollution (LN), and the day-night average (Ldn) are determined using specified equations.

$$L_D = 10 \log_{10} \times \frac{1}{2} \left[\text{Antilog} \left(\frac{L_{eq}(M)}{10} \right) + \text{Antilog} \frac{L_{eq}(A)}{10} \right] \dots (2)$$

$$L_N = 10 \log_{10} \times \frac{1}{2} \left[\text{Antilog} \left(\frac{L_{eq}(A)}{10} \right) + \text{Antilog} \frac{L_{eq}(E)}{10} \right] \dots (3)$$

$$L_{dn} = 10 \log_{10} \times \frac{1}{24} [15. (10)^{(L_D/10)} + 15. (10)^{(L_N+10/10)}] \dots (4)$$

Statistical Analysis and Spatial Mapping

Statistical correlation analysis evaluated the interrelation between traffic noise descriptors and noise indices. A strong correlation, indicated by an 'r' value within the 0.7 to ± 1.0 range, demonstrates significant co-variability among these parameters. Conversely, correlations between ± 0.5 to ± 0.7 and 0 to ± 0.5 signify moderate and weak associations, respectively. Spatial noise mapping, achieved through a statistical interpolation technique, vividly displays and defines vulnerable noise zones within the study area. Utilizing ArcGIS software, noise zone maps were generated using the geostatistical interpolation method known as "IDW (Inverse Distance Weighted)."

Results and Discussion

Descriptive Statistical Analysis

The descriptive statistics are presented in Table 1 of the noise indices measured during three-time intervals: morning (M), noon (N), and evening (E). The analysis includes the minimum, maximum, average, and Standard Deviation (SD) of four noise metrics: L10, L50, L90, and LEQ. L10 represents the sound level exceeded for 10% of the measurement period, capturing frequent high noise events. L50, the median noise level, is exceeded 50% of the time, indicating typical conditions. L90 reflects the sound level exceeded for 90% of the period, representing background or ambient noise by excluding short-term spikes. LEQ provides the equivalent continuous noise level, summarizing the average sound energy over a specified period, expressed in decibels (dB). Together, these metrics offer a comprehensive view of noise variations at different times of the day, encompassing peak levels, typical conditions, and ambient noise across the study area.

During the COVID-19 pandemic, noise levels varied across different times of the day due to changes in human activity patterns. For all noise indexes, the highest values were consistently observed at noon. For L10, the morning noise ranged from 18.46 to

24.46 with an average of 21.71 ± 1.97 , while noon values ranged from 18.46 to 38.46, averaging 28.86 ± 5.24 , and evening values ranged from 16.46 to 23.46 with an average of 20.81 ± 1.90 . Similarly, L50 showed morning values ranging from 32.51 to 34.76 (average 33.63 ± 0.66), noon values from 27.50 to 47.67 (average 36.58 ± 5.28), and evening values from 28.55 to 33.55 (average 31.73 ± 1.31). For L90, the noise levels ranged from 35.98 to 38.54 in the morning (average 37.19 ± 0.72), 31.44 to 52.03 at noon (average 41.24 ± 5.23), and 34.34 to 37.59 in the evening (average 35.97 ± 0.75). The Leq values followed a similar trend: morning values ranged from 36.96 to 39.15 (average 38.08 ± 0.65), noon values from 32.77 to 52.66 (average 42.65 ± 4.90), and evening values from 35.36 to 37.97 (average 36.93 ± 0.77).

Lower noise levels observed in the morning and evening can be attributed to a significant reduction in vehicular traffic and restricted human activities, particularly during lockdown periods. During these hours, fewer people commute, and businesses remain closed or operate at minimal capacity, leading to a quieter environment. The movement of heavy vehicles, a major contributor to noise pollution, is also limited during early mornings and late evenings, further reducing overall noise levels.

In contrast, noise levels peak at noon due to increased human and commercial activities. Essential services such as market visits, grocery shopping, and transportation of goods occur predominantly during this period, leading to a surge in ordinary and vehicular movement. Additionally, localized noise sources, such as construction activities, contribute significantly to the midday noise peak. With overall ambient noise levels reduced due to lockdown restrictions, these localized sources become more prominent, making their impact on noise pollution more noticeable. This trend aligns with studies on urban noise patterns, which indicate that mid-day peaks are typical due to concentrated economic activities and increased public movement in city centers.

Table 1 — Descriptive statistical of noise index in different time period

Noise Index	Morning				Noon				Evening			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
L10	18.46	24.46	21.71	1.97	18.46	38.46	28.86	5.24	16.46	23.46	20.81	1.90
L50	32.51	34.76	33.63	0.66	27.50	47.67	36.58	5.28	28.55	33.55	31.73	1.31
L90	35.98	38.54	37.19	0.72	31.44	52.03	41.24	5.23	34.34	37.59	35.97	0.75
LEQ	36.96	39.15	38.08	0.65	32.77	52.66	42.65	4.90	35.36	37.97	36.93	0.77

Traffic Noise Descriptors and Noise Indices

The traffic noise descriptors are presented in Table 2, including L10 dB(A), L50 dB(A), L90 dB(A), and Leq dB(A), measured across three distinct periods—morning (M), noon (N), and evening (E)—at 20 different sampling locations within the study area. The table comprehensively compares noise levels at varying times of the day, reflecting the temporal variations in traffic-related noise. These descriptors highlight the acoustic environment and the impact of daily human activities on noise levels at the specified locations. The equivalent noise levels in the study area are significantly

lower, as illustrated in Fig. 2, than the prescribed noise standard of 55 dB(A) during the daytime.

This reduction is attributed to the COVID-19 pandemic, which caused a substantial decline in human activities and vehicular movement, particularly during the daytime. The noise levels were so low that they barely approached the standard limit of 55 dB. However, a notable exception was observed at noon, when noise levels were higher compared to the morning and evening. This midday peak can be attributed to essential activities, market operations, and limited transportation.

Table 2 — Traffic noise descriptors during morning (M), noon (N) and evening (E) hours

Sample Location	L ₁₀ dB (A)			L ₅₀ dB (A)			L ₉₀ dB (A)			L _{eq} dB (A)		
	M	N	E	M	N	E	M	N	E	M	N	E
R-1	23.5	29.5	23.5	32.5	37.0	32.2	36.7	42.0	36.3	37.5	43.2	37.9
R-2	22.5	36.5	22.5	34.7	47.7	33.4	37.4	49.1	36.6	38.3	50.3	37.2
R-3	20.5	30.5	20.5	33.4	37.8	32.3	36.4	41.6	36.3	37.8	42.9	36.9
R-4	22.5	32.5	22.5	33.6	38.1	32.5	37.1	42.2	36.0	38.5	42.3	37.7
R-5	22.5	32.5	22.5	33.4	36.3	33.4	36.3	45.1	36.3	38.0	46.6	38.0
R-6	23.5	23.5	23.5	33.2	33.3	33.5	36.6	39.0	36.7	37.1	40.7	37.3
R-7	22.5	38.5	22.5	34.0	46.8	29.6	36.9	52.0	34.3	37.7	52.7	35.7
R-8	24.5	32.5	18.5	32.6	40.1	31.5	36.6	41.9	35.1	37.9	43.7	35.6
R-9	18.5	24.5	20.5	34.2	31.0	28.6	36.8	34.9	35.4	37.6	37.1	36.5
R-10	18.5	32.5	18.5	33.6	43.8	31.5	36.9	49.5	36.2	37.7	50.0	37.1
R-11	22.5	36.5	20.5	33.0	40.7	31.6	37.2	48.4	35.0	37.7	49.3	35.4
R-12	22.5	28.5	18.5	33.6	34.4	31.8	36.7	37.1	35.0	37.3	38.6	36.2
R-13	18.5	27.5	20.5	32.9	31.4	33.1	36.0	37.6	35.5	37.0	41.4	37.4
R-14	18.5	18.5	16.5	34.0	27.5	32.3	37.9	31.4	36.3	38.9	32.8	37.2
R-15	23.5	24.5	22.5	34.8	34.0	33.0	37.8	38.8	37.6	38.8	40.0	37.9
R-16	24.5	22.5	18.5	34.6	31.3	31.5	38.5	38.7	36.7	38.9	39.4	37.5
R-17	23.5	23.5	20.5	34.5	33.3	29.8	38.4	39.0	35.4	39.1	40.7	36.5
R-18	21.5	26.5	21.5	33.8	36.0	31.3	37.8	39.8	35.9	38.2	40.8	36.2
R-19	20.5	32.5	22.5	33.1	40.1	30.3	38.2	41.9	36.3	38.9	43.7	37.2
R-20	20.5	24.5	20.5	33.0	31.0	31.3	37.8	35.0	36.6	38.8	37.1	37.2

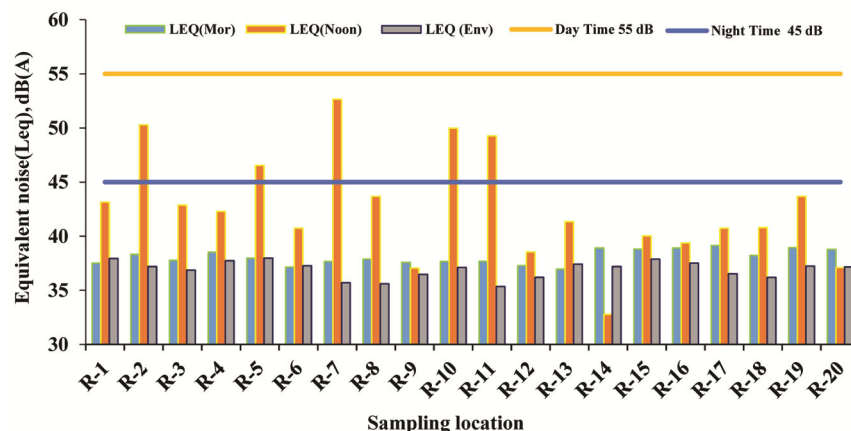


Fig. 2 — Comparison of equivalent level (Leq) with noise standards (CPCB 2000)²⁰ for the residential during the morning, noon and evening hours

Maximum noise level was recorded at residence area R-7 (52.7 dB (A)) followed by R-2 (50.3 dB (A)), R-10 (50 dB (A)), R-11(49.3 dB (A)), R-5 (46.6 dB (A)), R-8 (46.6 dB (A)) respectively, during noon hours. The maximum and annoying peaks of noise (*L10*) were recorded at residence area R-7 (38.5 dB (A)) followed by R-2 (36.5 dB (A)), R-11 (36.5 dB (A)), R-4(32.5 dB (A)), R-5 (32.5 dB (A)), respectively, during noon hours. Moreover, the maximum background noise was recorded at the residence area R-7 (52 dB (A)) followed by R-10 (49.5 dB (A)), R-2 (49.1 dB (A)), R-11(48.4 dB (A)), R-5 (45.1 dB (A)), respectively, during noon hours. For (*L50*), the maximum values were recorded at residence area R-2 (47.7 dB (A)) followed by R-7 (46.8 dB (A)), R-10 (43.8 dB (A)), R-11 (40.7 dB (A)), R-8 (40.1 dB (A)), respectively in (Table 2).

The average noise levels for different times of day, including daytime, nighttime, and the whole day, are presented in Table 3. During the daytime, the highest average noise level was recorded in R-7 (38.0 dB (A)), followed by R-2 (37.3 dB (A)), R-10 (36.3 dB (A)), R-11 (35.1 dB (A)), and R-19 (33.9 dB (A)). At night, the maximum average noise levels were observed in R-1 (30.4 dB (A)), followed by R-5 (30.3 dB (A)), R-6 (30.3 dB (A)), R-15 (30.1 dB (A)), and R-4 (30.0 dB (A)). Over the entire day, the highest

average noise level was found in R-7 (34.8 dB (A)), followed closely by R-2 (34.7 dB (A)), R-10 (34.1 dB (A)), R-11 (32.4 dB (A)), and R-5 (32.4 dB (A)).

The observed variations in noise levels throughout the day, nighttime, and the entire day can be linked to the local activity patterns and noise sources specific to each region. During the daytime, areas like R-7, R-2, and R-10 experienced higher noise levels due to busy roads, markets, and construction activities. Nighttime noise levels, particularly in R-1 and R-5, were influenced by residual traffic and industrial operations still active in those areas. For the whole day, regions such as R-7 and R-2 had higher average noise levels attributed to continuous human activities, including transportation and commercial operations, maintaining elevated noise levels throughout the day. The measurements were conducted during the COVID-19 pandemic, which likely affected typical noise patterns due to movement restrictions, transportation, and industrial activity changes.

Statistical Assessment

The co-variability between the parameters is assessed using the Karl Pearson correlation coefficient (*r*) ranging from -1 to +1 (i.e., $r = \pm 1$). The correlation value (*r*) is classified as strong correlation if $\pm 0.7 < r < \pm 1$, moderate correlation if $\pm 0.5 < r < \pm 0.7$, and weak correlation if $0 < r < \pm 0.5$. The correlation of noise descriptors during morning, noon and evening hours is given in Table 4. During the morning, there is a positive correlation between

Table 3 — Showing the average noise level during the day time, night time and one day

Sample Location	L _{Day} (LD) dB(A)	L _{Night} (LN) dB(A)	L _{Day-Night} (L _{DN}) dB(A)
R-1	33.0	30.4	32.1
R-2	37.3	29.4	34.7
R-3	33.3	29.4	32.0
R-4	32.9	30.0	32.0
R-5	33.4	30.3	32.4
R-6	31.4	30.3	31.1
R-7	38.0	28.3	34.8
R-8	33.7	28.4	31.9
R-9	29.5	28.4	29.1
R-10	36.3	29.8	34.1
R-11	35.1	28.4	32.9
R-12	30.9	27.9	29.9
R-13	30.5	29.8	30.3
R-14	28.6	28.9	28.7
R-15	32.1	30.1	31.4
R-16	31.4	29.7	30.8
R-17	32.2	28.8	31.0
R-18	32.4	28.6	31.1
R-19	33.9	29.4	32.4
R-20	30.0	29.7	29.9

Table 4 — The correlation of noise descriptors during morning, noon and evening hours

Noise index	L10	L50	L90	LEQ
Morning				
L10	1			
L50	0.07	1		
L90	0.18	0.54	1	
LEQ	0.14	0.48	0.89	1
Noon				
L10	1			
L50	0.91	1		
L90	0.89	0.93	1	
LEQ	0.90	0.92	0.99	1
Evening				
L10	1			
L50	0.17	1		
L90	0.22	0.53	1	
LEQ	0.31	0.52	0.78	1

*Bold represents significant Correlation value at $p < 0.05$ (ANOVA)

all noise indices. This means that as one noise index increases, the other noise indices also tend to increase. The strongest correlation is between L90 and Leq ($r = 0.89$), suggesting that background noise levels (L90) significantly contribute to the equivalent continuous sound level (Leq). This finding aligns with previous studies highlighting that traffic-induced noise exhibits a strong dependence on background noise levels, particularly in urban environments.²¹ During the noon period, a stronger interrelationship among noise indices is observed, with the highest correlations noted between L50 and L10 ($r = 0.91$), L90 and L10 ($r = 0.89$), and L90 and L50 ($r = 0.93$).

The highest correlation occurs between Leq and L90 ($r = 0.99$), indicating that background noise

levels primarily influence the equivalent noise level at noon. This trend is consistent with research indicating that peak commercial and vehicular activities significantly affect midday noise exposure in urban areas.²² Similarly, the evening follows a similar trend, with Leq and L90 showing the strongest association ($r = 0.78$), indicating that, as background noise (L90) increases, the equivalent noise level (Leq) is significantly impacted, reflecting the cumulative influence of residual and peak noise events. Evening correlations are slightly weaker than noon, possibly due to variations in traffic patterns and human activities, leading to fluctuating noise levels.²³

The scatter plots in Fig. 3 illustrate the correlation between different noise parameters (L10, L50, L90,

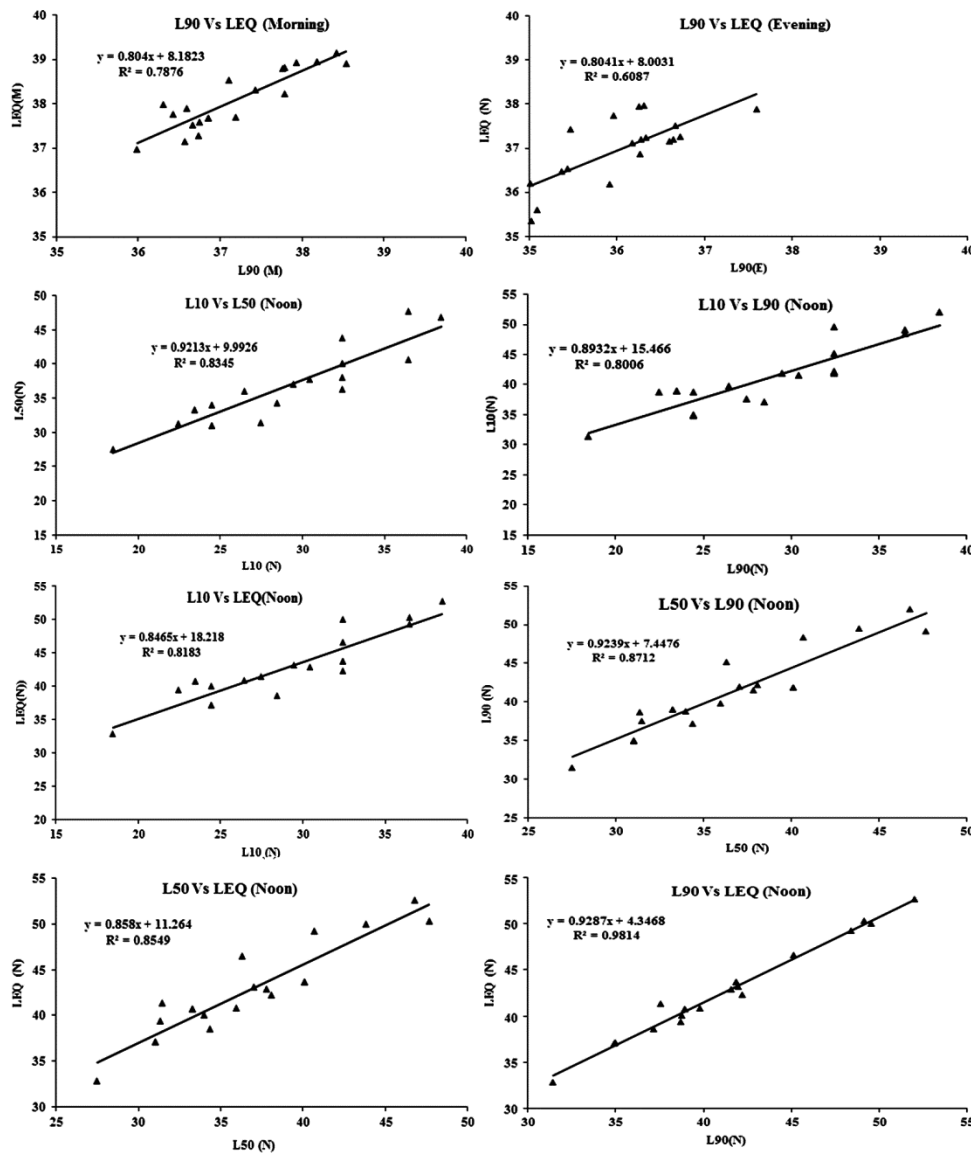


Fig. 3 — Scatter plot amongst different indices of noise parameter during Morning, Noon & Evening

and Leq) during the morning, noon, and evening periods. The relationship between $L90$ and Leq in the morning ($R^2 = 0.7876$) and evening ($R^2 = 0.6087$) suggests that background noise significantly influences the equivalent continuous noise level (Leq), with a stronger correlation in the morning. The $L10$ vs. $L50$ ($R^2 = 0.8345$) and $L10$ vs. $L90$ ($R^2 = 0.8006$) plots indicate a strong association between peak noise levels and background noise, emphasizing that higher noise levels affects overall noise conditions. The $L10$ vs. Leq correlation ($R^2 = 0.8183$) further highlights that peak noise levels contribute substantially to the overall noise environment. Similarly, $L50$ vs. $L90$ ($R^2 = 0.8712$) and $L50$ vs. Leq ($R^2 = 0.8549$) demonstrate that the median noise levels play a crucial role in noise distribution. The strongest correlation is observed in $L90$ vs. Leq (Noon) with $R^2 = 0.9814$, signifying that background noise levels are highly predictive of Leq . Overall, the results confirm that all noise indices are interrelated, with $L90$ serving as a key determinant of Leq , while $L10$ and $L50$ also contribute significantly to noise variations.

Noise Mapping

Spatial noise mapping involves creating detailed maps that estimate the potential vulnerability to noise by utilizing available geographical data. These maps are generated by interpolating existing noise data based on their corresponding geographical coordinates. The primary objective of this process is to delineate distinct noise zones within a specified

area while displaying the fluctuations in noise levels across different locations during specific periods of the day—morning, noon, and evening. The resulting noise maps visually represent the varying noise intensities throughout different times of the day. For instance, observing the noise map during noon hours in Imphal city reveals a notably expanded area of heightened noise pollution compared to the morning and evening hours. This phenomenon is primarily attributed to the increased movement of ambulances and essential transport services during midday.

The spatial distribution map of noise level according to different indices was highlighted as geospatial maps for the potentially vulnerable zone of noise based on the noise index such as $L10$, $L90$, and Leq during Morning, Noon, and Evening time in Fig. 4. Darker areas represent higher noise.

Imphal City’s noise levels for $L10$ dB (A) are depicted in Figs 4 (a), (b) and (c) at morning, noon and evening, respectively. The darkest areas are reaching 24.45, 38.43 and 23.45 $L10$ dB (A) for the morning, noon and evening respectively. Similarly for noise level $L90$ dB (A) in morning, noon and evening, the values corresponding to darkest areas are 38.53 (Fig. 4d), 51.99 (Fig. 4e) and 37.99 (Fig. 4f). Finally, noise levels at Leq dB (A) corresponding to darker areas for morning (Fig. 4g), noon (Fig. 4h) and evening (Fig. 4i), respectively are 39.14, 52.63 and 37.97.

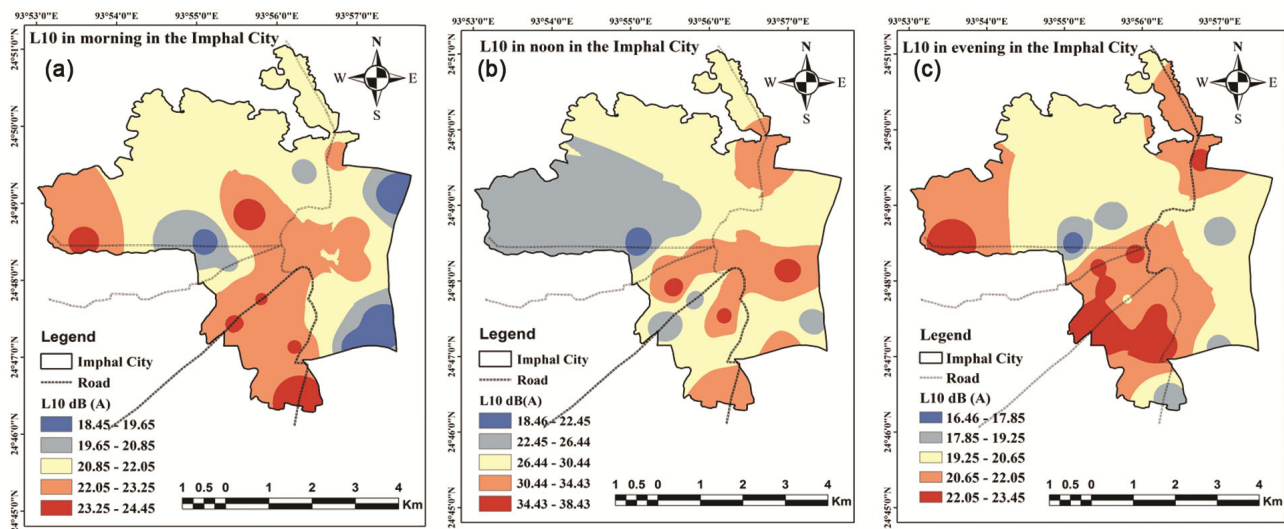


Fig. 4 — Geospatial maps showing the potential vulnerable zone of noise based on the noise index $L10$ during (a) Morning, (b) Noon and (c) Evening, noise index $L90$ (d) Morning, (e) Noon and (f) Evening, noise index Leq (g) Morning, (h) Noon and (i) Evening (Contd.)

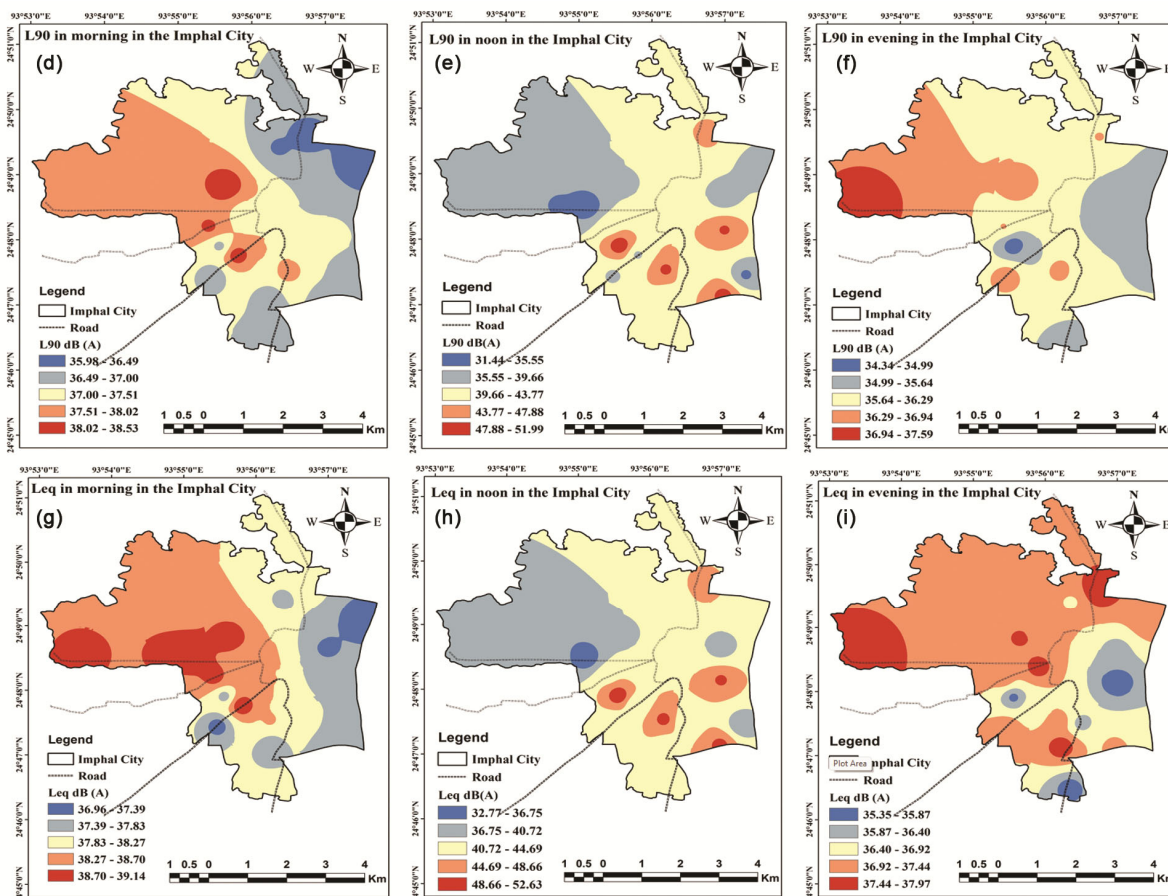


Fig. 4 — Geospatial maps showing the potential vulnerable zone of noise based on the noise index L10 during (a) Morning, (b) Noon and (c) Evening, noise index L90 (d) Morning, (e) Noon and (f) Evening , noise index Leq(g) Morning, (h) Noon and (i) Evening

Conclusions

This study highlights the significant impact of COVID-19 restrictions on urban noise levels in Imphal, showing a considerable reduction in traffic-related noise across all selected zones. The decline in noise pollution resulted from limited vehicular movement and reduced human activity during lockdowns, aligning with similar trends observed in cities like Delhi, New York, and London. The analysis indicates that noise levels generally remained below the Central Pollution Control Board (CPCB) limits, with peak noise occurring at noon due to essential activities. Spatial noise mapping identified areas prone to noise exposure, emphasizing the need for targeted mitigation strategies in dense urban locations. However, the study's primary limitation lies in its focus on pandemic conditions, which may not fully reflect regular traffic scenarios. Future research can examine post-pandemic noise trends, incorporating real-time monitoring to assess long-

term changes. These insights can aid policymakers in optimizing urban noise management and traffic regulations for a healthier environment.

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Conflict of interest

The authors declare no competing interests.

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