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Traffic Noise Pollution Assessment in Major Road Junctions of Imphal City, Manipur (India)

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ABSTRACT

Noise pollution assessment was carried out in selected traffic junctions of Imphal city of Manipur, India, using noise parameters and indices such as L_{10}, L_{50}, L_{90}, L_{eq} for the different periods of the day, i.e., morning, noon, and evening hours. The study of equivalent noise level (L_{eq}), noise parameters, and various noise indices have enabled the evaluation of the overall traffic noise environment of the city. The noise indices such as traffic noise index (TNI), noise climate (NC), traffic noise pollution level (L_{NP}), noise exposure index (NEI) along with day time (L_D), night time (L_N) average, and day-night (L_{dn}) noise levels were assessed for the selected traffic junctions. Moreover, spatial noise mapping was carried out using the geostatistical interpolation technique to evaluate the changes of traffic noise scenarios during the different time zones of the day. The L_{eq} values in a few traffic junctions exceeded the required noise standards. The study shows equivalent noise levels ranging between 52.2-69.9 dB(A) during the morning (7-10 am), 52.4 -69.3 dB(A) during noon (12 noon-2 pm), and 54.6-71.1 dB(A) during the evening (4-7 pm) hours, respectively.

INTRODUCTION

A sound is a form of mechanical energy generated from a vibrating body and transmitted through a medium in a series of cyclic compressions and rarefactions (Chanlett et al. 1973). Generally, the high-intensity sound causes noise pollution, which is considered to be an emerging urban environmental problem. High-intensity sound levels produced by increasing traffic volume result in chaotic and disturbed urban environments leading to various health issues (Al-Omari & Sharabi 2006). However, due to indirect and passive impacts, noise pollution studies received less priority than the other forms of urban environmental pollution. Selected studies across the world have revealed the effects of noise pollution on human health and urban biodiversity resulting from exposure to high noise levels (Sharma et al. 2014, Tyagi et al. 2014, Marathe 2012, Chauhan et al. 2010, Ogunsote 2010, Vera & Vila Goday 1992). Continual exposure to high-intensity noise can cause direct, indirect, and cumulative health impacts depending upon the noise sources, intensity, power, exposure time, and duration (Getzner & Zak 2012). Pervasive traffic noise pollution can cause various health impacts such as physical, physiological, psychological, heart problem, nervous system disorder, deafness, mental breakdown in individuals (Aluko & Nna 2015, Welch et al. 2013, Adedeji & Folurunso 2010, Banerjee et al. 2009, Singh & Davar 2004, Li et al. 2002). It can also cause indirect impacts on the economy, as high noise levels can deteriorate the working environment, efficiency, and performances of workers leading to a reduction in workforce and productivity (Pignier 2015, Al Refaee et al. 2013). Higher noise levels can impact wildlife and urban biodiversity by disturbing their habitats, ecological niches, disrupting breeding grounds, matting, and reproductive patterns in animals (Ortega 2012, Parris & Schneider 2009, Popper & Hastings 2009). As the impacts of noise pollution are indirect and passive, people are the least concerned about the impacts of noise pollution (Alam 2011). So for sustainable urban planning and management, regular monitoring and assessment of the noise environment are essential to curb the escalating noise pollution emerging from rapid urbanization and various developmental activities. In this regard various noise pollution abatement measures can be adopted such as design and fabrication of silencing devices, proper traffic management, banning on electronic horns, creating noise zones/noise barriers, development of open and green spaces, planting of green zones and trees to curb the escalating noise levels (Garg et al. 2017, Onder & Akay 2015, Onder & Kocbeker 2012, Mihaiescu & Mihaiescu 2009).

STUDY AREA

Imphal is capital city of the state of Manipur in India. It is one of the significantly growing cities in the north-eastern Indian region due to its strategic location and excellent prospects for various developmental initiatives for the south-east Asian region. Geographically the city extends between 24.48°-24.82° N latitude and 93.56°-93.95° E longitudes and covers 29.57 sq. km. (Fig. 1), with a population size of 9,74,105 (Census 2011). There are three major national highways, NH-53, NH-150, and NH-39, connecting Imphal to other Indian states and the international border town, Moreh, near Myanmar (Table 1). Imphal city is the fastest-growing urban center in the state due to developed basic civic facilities and services that have resulted in a sharp increase in the urban population in recent years. Moreover, the increasing population and number of vehicles have changed the overall traffic scenario of the city in the last few decades.

MATERIALS AND METHODS

Collections of Noise Levels

Noise levels were recorded during the morning, noon, and evening hours for selected traffic junctions of Imphal city using the sound level meter (SLM, Model: Lutron, SL-4001) in A-weighted decibels scale [dB (A)]. This scale represents and resembles human hearing range between 50-100 dB. The measurements were made at 1.5 m above the ground parallelly facing the source The coordinates of 30 spatially distributed traffic junctions used for noise mapping and delineation of vulnerable noise zone were collected using GPS (Garmin, etrex 20), respectively.

Assessment of Equivalent Noise Level (L_{eq})

Energy equivalent continuous sound level (L_{eq}) can be defined as the steady sound pressure level over a given period with the same amount of total energy as the actual fluctuating noise over that period. L_{eq} is the rms sound level for measuring duration for an averaging time (Canter 1996)

$$L_{eq} = 10 \log \left(\frac{1}{t} \int_0^T \frac{P^2(t)}{P_0} dt dt \right) = L_{eq} = 10 \log \frac{1}{T} \sum_{i=1}^{N} T_i ((10)^{L_i/10}) \quad \ldots(1)$$

where T= total time of operation; T_i= total time duration of the ith phase, $L_i = L_{eq}$ value of i^{th} phase and N= No. of phases; P(t) = sound pressure, P0 = reference sound pressure of 20 μPa. The L_{eq} is the energy equivalent sound level in dB (A) for any time under consideration. The daytime average sound pollution level (L_D), night-time average sound pollution level (L_N), and Day-night average (L_{dn}) is calculated as per the given equations.

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

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

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

Assessment of L_{10}, L_{50}, L_{90}

L_{10} is defined as the sound pressure level (SPL) that does not

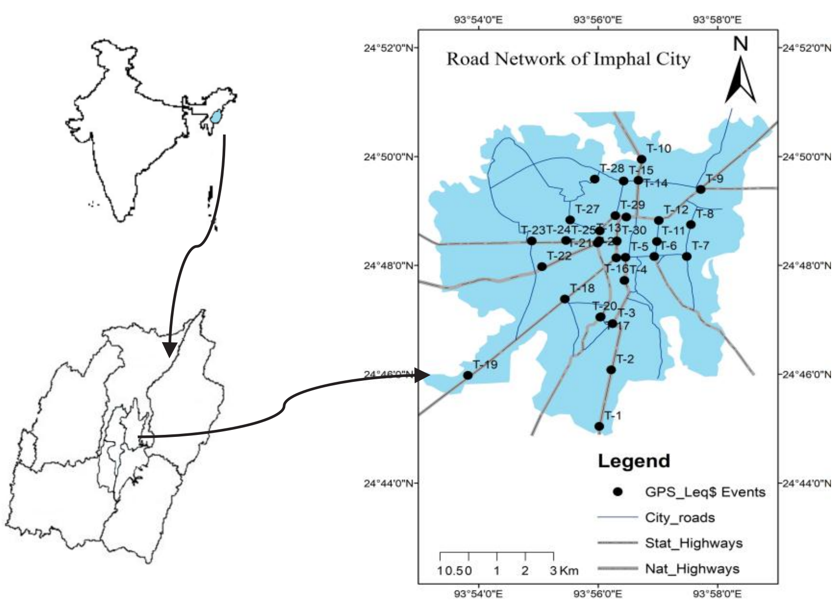

Fig.1: The study area and noise assessment locations.

Table 1: Table showing selected traffic-junctions of Imphal city.

Sl. No.	Name of Locations	Coordinates		Elevation [m]
		Lat [N]	Lon [E]	
T-1	Manipur University Gate	24.7507	93.9336	779
T-2	Kakwa Traffic point	24.7681	93.9370	780
T-3	Singjamei Traffic point	24.7822	93.9373	785
T-4	Keishamthong-Hijam Irabot Point	24.7954	93.9407	783
T-5	Kangla- Babupara Road	24.8025	93.9410	784
T-6	Konung- Mamang Road	24.8028	93.9490	784
T-7	Soibam leikai-Junction Road	24.8028	93.9581	785
T-8	JN Institute of Medical Science (JNIMS) Gate	24.8125	93.9592	783
T-9	Khurai Thoudam Leikai, Ayangpalli	24.8233	93.9620	782
T-10	Chingmeirong-Sangakpham	24.8325	93.9454	787
T-11	Checkon Traffic point	24.8074	93.9497	783
T-12	Hatta-Checkon Road	24.8138	93.9503	784
T-13	Kangla-BOC Road	24.8148	93.9412	784
T-14	Chingmeirong-Dewhlaland	24.8261	93.9445	786
T-15	Assembly House Gate	24.8259	93.9405	787
T-16	Kangla-GP Womens College Road	24.8023	93.9384	782
T-17	Keishampat Traffic point	24.7842	93.9339	783
T-18	Kwakeithel Traffic point	24.7898	93.9241	782
T-19	Imphal International Airport	24.7664	93.8970	780
T-20	Mayailambi-Ningom Leirak Road	24.7843	93.9341	783
T-21	Waheng leikai-Humped bridge Road	24.8069	93.9332	782
T-22	Sagolband-Khamnam Leikai Road	24.7996	93.9177	785
T-23	Naoremthong Bridge-Uripok Road	24.8075	93.9148	783
T-24	Uripok-Bachaspati Leikai Road	24.8077	93.9243	783
T-25	Flyover-samumakhong Road	24.8076	93.9336	784
T-26	Nagamapal Traffic point	24.8106	93.9338	783
T-27	Rims-Uripok-Nagamapal Road	24.8140	93.9255	783
T-28	Lamphel-Sanakeithel-Thangmeiband	24.8264	93.9324	781
T-29	Khoyathong Traffic point Road	24.8153	93.9381	782
T-30	Kangla Gate-Biotech Park Road	24.8075	93.9385	784

exceed 10% of the total time under consideration. It is also called impulse noise or instantaneous noise. L_{10} is a valid descriptor of road traffic noise as it takes account of any annoying peaks of noise or upper limit of fluctuating noise such as that from road traffic. L_{50} is the statistical average that considers 50% of the time under consideration and L_{90} is the 90% of the time under consideration. L_{90} is also called the ambient background noise level in the absence of any vehicular motor traffic.

Assessment of TNI, NC, LNP and NEI

Traffic noise index (TNI) indicates the degree of variation in traffic noise levels and give the measure of annoyance behavior of human. It indicates the overall fluctuations of noise over time and disorderliness of traffic noise levels. Traffic noise index (TNI) or traffic noise pressure levels are estimated by the following equation (Banerjee et al. 2009) given below.

$$TNI = 4 \times (L_{10}-L_{90}) + (L_{90} - 30) \text{ dB (A)} \quad \ldots(5)$$

Noise climate (NC) indicates traffic noise annoyance. More the value of noise climate (NC), more is the difference between the peak noise and the background noise level in the absence of any motor vehicular traffic. Noise Climate is the range over which sound levels fluctuate in an interval of time and is estimated by the relation given below (Prachiti et al. 2014)

$$NC = (L_{10} - L_{90}) \text{ dB (A)} \quad \ldots(6)$$

Noise pollution level (L_{NP}) is also used to express the varying levels of noise that can cause physiological and psychological disturbances. It is expressed as shown below.

$$L_{NP} = L_{50} + (L_{10}-L_{90}) + (L_{10}-L_{90})^2/60 \quad \ldots(7)$$

The noise exposure index (NEI) is the measurement to assess noise-induced hearing loss and is determined by the given equation (Oyedepo et al. 2019)

$$NEI = \left[{}^{t1}/_{T1} + {}^{t1}/_{T1} + {}^{t1}/_{T1} + \cdots \ldots \ldots \ldots \ldots \ldots + {}^{tn}/_{Tn}\right] \quad \ldots(8)$$

where, t_1, t_2, $t_3 \ldots t_n$ are the actual limit of exposure and T_1, T_2, $T_3 \ldots T_n$ represents the permissible limits of exposure at the corresponding noise levels, respectively. The higher value of NEI (>1) is considered as exposure to excessive noise according to American National Standards (ANS) (NIOSH 1998).

Statistical Analysis and Cluster Analysis

The statistical correlation analysis was carried out to assess the co-variability between traffic noise descriptors and noise indices. The correlation (r) value in the range of $0.7 \leq r \leq \pm 1.0$, indicates strong co-variability/correlation between the parameters. Similarly, the correlation is considered to be moderate and weak if correlation lies between the value ±0.5 to ±0.7 and 0 to ±0.5, respectively. To identify the traffic junctions with similar noise characteristics, a hierarchical cluster analysis (CA) and dendrogram were plotted for the grouping of the traffic junctions.

Spatial Mapping

Spatial noise mapping is a statistical interpolation method used to better visualize and delineate vulnerable noise zones for the study area. Noise zone maps were prepared using ArcGIS software, using a geostatistical interpolation "kriging" technique which is an effective interpolation method to predict the unknown values using the coordinated spatial noise data (Alam 2011).

RESULTS AND DISCUSSION

Traffic Noise Descriptors and Noise Indices

Traffic noise descriptors such as annoying peak noise level (L_{10}), statistical average or 50th percentile (L_{50}), background noise level (L_{90}), and energy equivalent continuous noise levels (L_{eq}) and noise indices are presented in Table 2. It was observed that traffic noise levels exceed during evening hours than morning and noon hours due to high traffic congestions. The energy equivalent noise (L_{eq}) and background noise (L_{90}) levels exceed the noise standards of 65 dB(A) (CPCB 2000) in some of the traffic junctions of the city (Fig. 2).

Maximum noise level was recorded at traffic junction T-5 (83.2 dB(A)) followed by T-30 (82.8 dB(A)), T-9 (82.6 dB(A)), T-5 (80.9 dB(A)), T-7 (80.8 dB(A)), T-26 (80.6 dB(A)), T-4 (80.5 dB(A)) respectively, during evening hours. A similar trend was observed for L_{10}, L_{50}, and L_{90}. The annoying peaks of noise (L_{10}) were found higher than the noise standards of 65 dB(A) for the traffic flow scenario (Table 3).

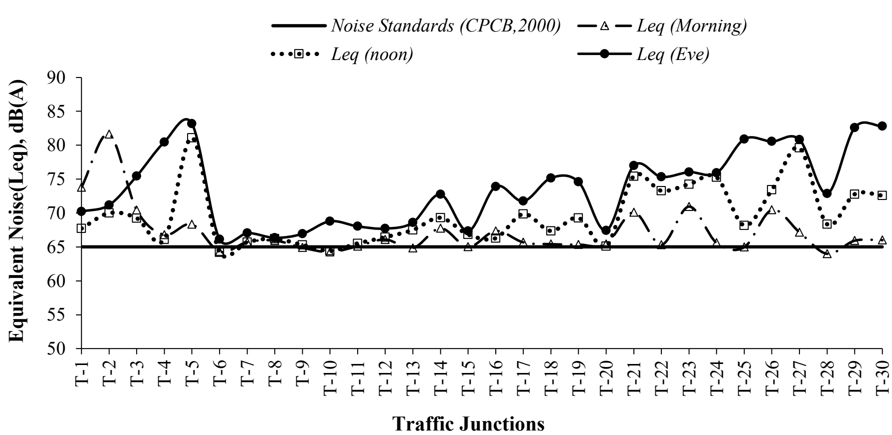

Fig. 2: Comparison of equise level (L_{eq}) with noise standards (CPCB 2000) for the traffic junctions during the morning, noon and evening hours.

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

Sl. No.	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
T-1	51.0	53.1	56.4	64.9	59.1	62.4	73.3	65.1	69.0	73.8	67.7	70.2
T-2	54.3	56.7	58.4	64.1	62.8	66.4	72.1	67.7	71.0	81.6	70.0	71.2
T-3	52.7	51.1	61.3	60.1	58.6	68.7	69.2	65.9	73.9	70.4	69.2	75.5
T-4	54.6	49.4	61.6	61.5	59.3	74.0	63.5	65.1	78.5	66.8	66.1	80.5
T-5	51.1	55.9	66.8	63.0	62.5	77.6	67.1	64.5	81.9	68.4	81.1	83.2
T-6	48.6	50.4	54.6	57.6	57.3	60.5	62.2	62.9	64.8	64.3	64.2	66.1
T-7	49.7	49.7	53.3	57.5	57.5	61.9	63.6	63.6	65.2	65.7	65.7	67.1
T-8	50.2	50.2	53.4	59.4	59.4	61.1	64.7	64.7	65.2	66.0	66.2	66.4
T-9	46.3	48.1	50.2	56.8	58.7	59.7	62.9	63.1	64.5	64.9	65.3	66.9
T-10	53.2	51.3	58.0	58.7	57.1	65.2	62.8	62.9	67.6	64.3	64.4	68.8
T-11	51.3	48.3	58.3	60.2	58.7	61.4	64.1	64.5	65.8	65.1	65.5	68.0
T-12	50.1	46.7	52.6	56.9	63.7	60.5	63.6	65.7	64.3	66.1	66.4	67.7
T-13	48.6	51.0	58.2	56.2	63.5	63.1	62.6	66.6	66.6	64.9	67.5	68.6
T-14	52.0	50.3	58.2	65.2	60.1	68.9	67.1	68.7	72.5	67.8	69.3	72.7
T-15	48.2	49.3	51.3	57.3	57.9	62.6	62.5	64.5	66.0	65.0	66.8	67.3
T-16	51.3	52.6	58.0	60.5	62.3	66.8	66.4	65.1	72.3	67.4	66.3	73.9
T-17	52.3	53.3	62.1	60.3	66.3	68.0	64.0	69.5	69.4	65.7	69.8	71.8
T-18	52.1	50.0	58.6	59.6	63.3	67.4	63.4	66.0	73.1	65.4	67.3	75.2
T-19	50.3	58.6	60.1	58.0	62.7	68.3	64.0	67.7	71.1	65.4	69.3	74.6
T-20	51.3	50.6	51.8	58.0	60.6	61.4	63.1	63.7	64.9	65.4	65.1	67.4
T-21	50.8	58.3	62.6	61.3	69.7	69.6	69.1	74.1	74.1	70.1	75.4	77.0
T-22	50.1	58.3	60.6	57.9	65.4	67.9	62.7	71.8	73.9	65.3	73.3	75.3
T-23	61.4	51.8	61.7	68.3	68.5	70.8	70.5	72.3	74.7	71.0	74.2	76.0
T-24	51.2	59.2	63.6	58.0	69.0	69.7	64.3	73.3	74.9	65.6	75.3	75.9
T-25	48.6	51.8	62.3	58.6	62.5	72.1	62.8	67.3	76.5	65.0	68.2	80.9
T-26	58.4	57.3	68.3	66.0	64.4	76.5	68.1	71.9	78.4	70.5	73.4	80.6
T-27	52.1	61.4	60.6	60.9	73.3	73.0	66.1	78.7	79.6	67.2	79.6	80.8
T-28	48.1	50.3	57.3	58.2	61.0	65.8	62.0	67.7	69.6	64.0	68.4	72.9
T-29	58.3	58.3	66.8	61.4	64.3	76.7	64.6	71.3	82.0	65.9	72.8	82.6
T-30	50.3	52.3	66.4	59.0	65.3	78.0	63.9	70.6	80.9	66.0	72.6	82.8

The higher value of TNI indicates more disturbances due to fluctuating noise concerning L_{10}. More annoyance *w.r.t.* TNI was observed in the evening hours as compared to morning and noon hours.

Similarly, L_{NP} is a better indicator that accounts for variations in the sound signal and serves as a measure for noise pollution descriptor for physiological and psychological disturbance for the human. The highest TNI of 106.4 dB(A) is recorded at T-27 during noon and evening hours, followed by T-4, T-5, T-29, and T-30 (Table 3). NC also indicates traffic noise annoyance occurred due to sound level fluctuations in an interval of time. More NC represents more differences between the L_{10} and L_{90}. It is found that fluctuations between annoying peaks noise were higher during the morning hours than noon and evening hours, indicating more noise contribution from road traffic during morning hours. This also suggests that the background noise levels during morning hours are less due to fewer heavy motor vehicles.

NEI represents the noise exposure level *w.r.t.* the reference duration (t) to the permissible limit of noise exposure duration (T) at the corresponding noise level. The NEI values (Table 4 & Fig. 3) of morning hours show higher NEI followed by the noon and evening hours. Some of the traffic junctions (T-6, T-9, T-11, T-12, T-20) show higher NEI values (NEI>1) throughout the assessment period (morning, noon, evening), indicating a high level of noise exposure due to excessive traffic congestion and noise levels. The higher value also suggests the possibility of annoyance among the exposed population due to elevated noise levels throughout the exposed time. During morning hours 67.7%, noon hours 48.4%, and evening hours 26.1% of locations exhibit higher NEI (NEI>1) values which are considered undesirable. Similarly, day time (L_D), night time (L_N), and day-night (L_{dn}) average noise level exceeding 80 dB(A) is not acceptable as they may have undesirable impacts on human health. Moreover, the higher L_{dn} values also indicate that people in the vicinity of the traffic junctions are more vulnerable and exposed to noise pollution.

Statistical Assessment

The correlation between the noise descriptors and noise indices (Table 5), shows the co-variability between the parameters. Higher correlation (r) (> ±0.7) indicates a significant strong co-variability between the noise descriptors and noise indices (at $p < 0.05$). TNI, NC, and L_{NP} show a strong correlation with each other. Similarly, the noise descriptor, $L_{eq,}$ and L_{50} show a high to moderate correlation with the TNI and NC. The CA shows the traffic junctions with similar noise descriptors or equivalent noise levels during the morning (Fig. 4), noon (Fig. 5), and evening (Fig. 6) hours, respec-

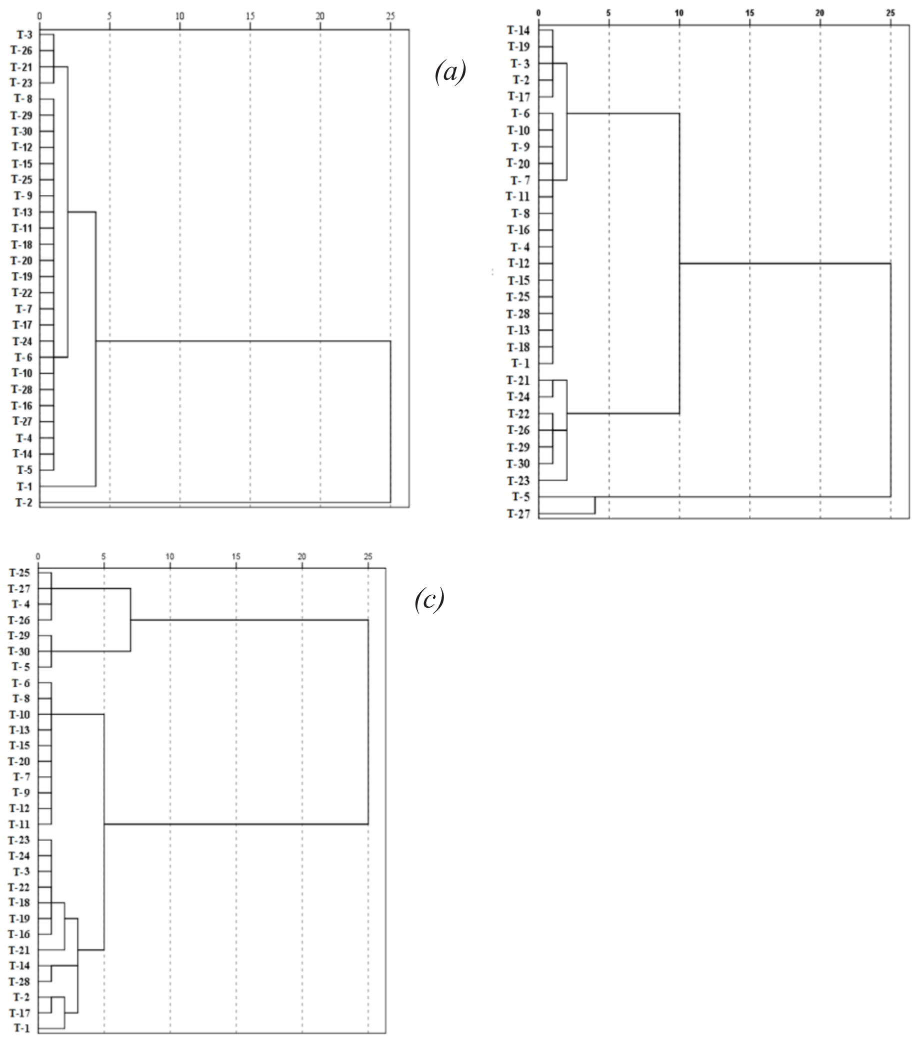

Fig. 3: Dendogram showing the cluster of traffic junctions with similar trend of noise levels during (a) morning (b) Noon and (c) evening hours

Table 3: Traffic Noise Index (TNI), Noise Pollution Level (L_{NP}) and Noise Climate (NC) for the selected traffic junctions.

Sl No.	TNI dB(A)			L_{NP} dB(A)			NCdB(A)		
	M	N	E	M	N	E	M	N	E
T-1	110.0	71.0	76.7	95.4	73.5	77.6	22.3	12.0	12.6
T-2	95.5	70.7	78.9	87.2	75.8	81.7	17.8	11.0	12.6
T-3	88.9	80.4	81.8	81.2	77.0	84.0	16.5	14.8	12.6
T-4	60.1	82.0	99.3	71.6	79.0	95.7	8.9	15.7	16.9
T-5	85.0	60.4	97.1	83.2	72.4	96.5	16.0	8.6	15.1
T-6	73.1	70.3	65.5	74.4	72.4	72.4	13.6	12.5	10.2
T-7	75.2	75.2	70.9	74.6	74.6	76.1	13.9	13.9	11.9
T-8	78.0	78.0	70.7	77.4	77.4	75.2	14.5	14.5	11.8
T-9	82.7	78.1	77.3	77.9	77.4	77.4	16.6	15.0	14.3
T-10	61.7	67.9	66.4	69.9	71.0	76.3	9.6	11.6	9.6
T-11	72.6	83.2	85.3	75.8	79.3	69.8	12.8	16.2	7.5
T-12	74.2	92.6	69.2	73.4	88.7	74.4	13.5	19.0	11.7
T-13	74.4	83.4	62.0	73.4	83.2	72.8	14.0	15.6	8.4
T-14	82.6	94.0	85.4	84.2	84.2	86.7	15.1	18.4	14.3
T-15	75.6	80.1	80.1	75.0	77.0	80.8	14.3	15.2	14.7
T-16	81.6	72.7	85.2	79.3	77.5	84.5	15.1	12.5	14.3
T-17	69.0	88.0	61.2	74.2	86.9	76.2	11.7	16.2	7.3
T-18	67.1	84.0	86.4	73.0	83.6	85.3	11.3	16.0	14.5
T-19	75.2	65.0	74.1	74.9	73.2	81.4	13.7	9.1	11.0
T-20	68.6	72.9	74.2	72.1	76.5	77.3	11.8	13.1	13.1
T-21	93.9	91.5	78.8	85.1	89.7	83.4	18.3	15.8	11.5
T-22	70.5	82.1	83.7	73.2	81.9	84.1	12.6	13.5	13.3
T-23	67.9	103.8	83.8	78.8	96.0	86.6	9.1	20.5	13.0
T-24	73.5	85.5	78.6	73.9	86.4	83.1	13.1	14.1	11.3
T-25	75.3	83.9	89.3	76.1	82.1	89.7	14.2	15.5	14.2
T-26	67.2	85.8	78.9	77.3	82.6	88.4	9.7	14.6	10.1
T-27	78.1	100.5	106.4	78.2	95.5	97.9	14.0	17.3	19.0
T-28	73.9	89.9	76.4	75.3	83.4	80.6	13.9	17.4	12.3
T-29	53.3	80.2	97.8	68.3	80.1	95.8	6.3	13.0	15.2
T-30	74.9	95.4	94.3	75.7	89.2	95.9	13.6	18.3	14.5

tively. The CA categorizes the traffic junctions with similar equivalent noise levels and locations with possible potential impacts due to higher values of noise indices (Table 6).

Noise Mapping

Spatial noise mapping shows the interpolated vulnerable noise maps prepared using the existing data concerning their geographical coordinates. The noise mapping delineates the noise zones and shows the variations of noise levels at various locations during the morning, noon, and evening hours. The noise map during the morning hours shows a greater extent of the noise environment of Imphal city because of more traffic congestions occurring during these hours due to plying of more vehicles for offices and schools. The higher extended noise zones during the morning hours spread towards the south-eastern region of the city in the state and national highways. Similarly, recorded high noise levels in the central commercial zone of the city due to more traffic congestion and gathering of people in the central zone of the city markets during the noon hours. In the evening hours, high noise levels

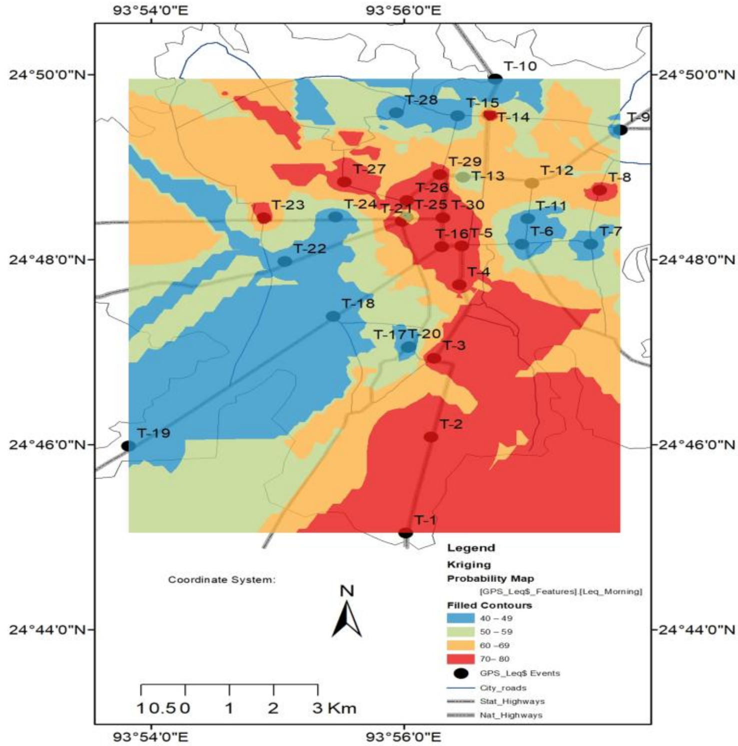

Fig. 4: Spatial variation mapping of noise levels in Traffic Junctions of Imphal city during morning (7-10 am) hours.

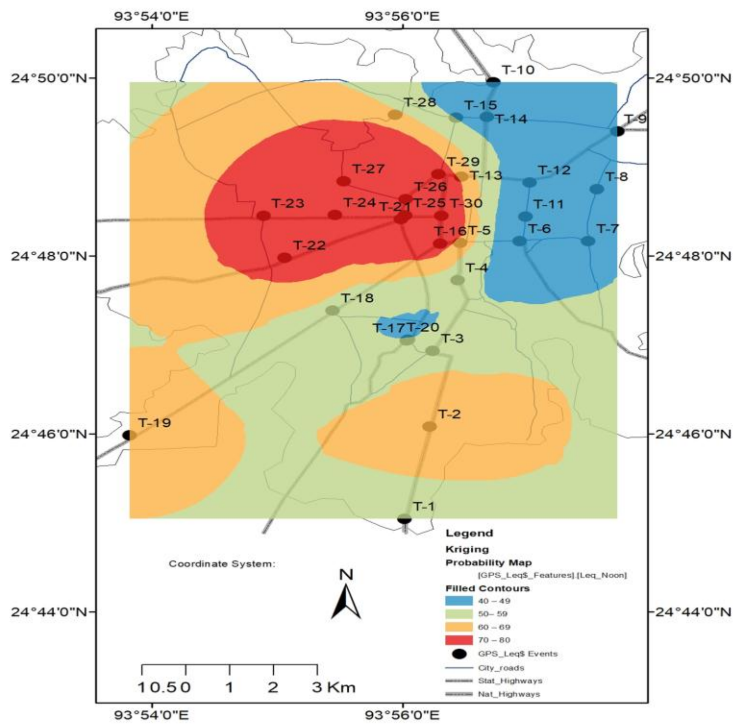

Fig. 5: Spatial variation mapping of noise levels in Traffic Junctions of Imphal city during noon (12-2 pm) hours.

Table 4: Noise Exposure Index (NEI) and Day time (L_D) and Night time (L_N) average.

Sl No.	NEI			$L_{day}(L_D)$ dB(A)	L_{night} (L_N) dB(A)	$L_{daynight}$ (L_{DN}) dB(A)
	M	N	E			
T-1	0.76	1.11	0.68	73.0	69.2	76.4
T-2	0.53	0.73	0.45	79.2	70.6	79.8
T-3	0.82	1.09	0.31	74.4	73.4	79.9
T-4	1.35	1.17	0.19	77.8	77.6	84.0
T-5	0.87	1.08	0.10	82.3	82.3	88.7
T-6	1.52	1.54	1.07	66.7	65.3	71.9
T-7	1.35	1.35	0.97	68.0	66.4	73.1
T-8	1.14	1.14	0.98	67.9	66.3	73.0
T-9	1.62	1.39	1.22	67.6	66.2	72.8
T-10	1.43	1.50	0.76	68.1	67.1	73.7
T-11	1.17	1.25	1.01	68.2	67.0	73.6
T-12	1.42	1.33	1.12	68.6	67.1	73.8
T-13	1.61	0.88	0.82	69.0	68.1	74.6
T-14	1.01	0.88	0.37	72.2	71.4	77.9
T-15	1.54	1.26	0.94	68.3	67.1	73.7
T-16	0.98	1.04	0.43	72.3	71.6	78.1
T-17	1.17	0.70	0.59	71.5	70.9	77.4
T-18	1.24	1.02	0.38	73.2	72.8	79.3
T-19	1.26	0.82	0.51	73.1	72.7	79.2
T-20	1.34	1.24	1.04	67.9	66.4	73.1
T-21	0.90	0.32	0.29	76.8	76.3	82.8
T-22	1.48	0.45	0.33	74.7	74.4	80.9
T-23	0.61	0.49	0.27	76.0	75.2	81.8
T-24	1.24	0.33	0.26	75.8	75.6	82.0
T-25	1.42	0.81	0.45	78.2	78.1	84.5
T-26	0.85	0.49	0.24	78.7	78.3	84.8
T-27	0.96	0.22	0.23	80.4	80.2	86.7
T-28	1.55	0.99	0.70	71.6	71.2	77.6
T-29	1.13	0.50	0.11	80.1	80.0	86.4
T-30	1.28	0.64	0.12	80.3	80.2	86.6

were witnessed in the core city zone and the north-western and south-eastern extent of the city, comprising significant state and national highways.

CONCLUSION

The traffic noise assessment for selected traffic junctions of the Imphal city was an attempt to appraise the traffic noise scenario considering noise descriptors, indices, and vulnerable noise zone mapping. Noise descriptors were found beyond the noise standards in many traffic junctions due to the increasing number of vehicles, high traffic congestions, poor road conditions, lack of diversion roads/flyovers, and poor traffic management system. Similarly, traffic noise indices such as L_{NP}, NC, NEI represent the higher traffic noise scenario, abrupt noise fluctuations, and noise exposure levels. Spatial noise mapping and cluster analysis indicate the vulnerable traffic junctions of the city based on their elevated noise levels. The study highlights the requirement of direct or indirect noise pollution control management and mitigation initiatives such as the development of pedestrian and cycling lanes, increasing more greenery along the roadside, restricting the use of pressure and multi-tone horns, checking the vehicle's condition, constructing road medians,

Table 5: The correlation of noise descriptors, indices during morning, noon and evening hours.

	L_{10}	L_{50}	L_{90}	L_{eq}	TNI	NC	L_{NP}	NEI
L_{10}	1.00							
L_{50}	0.76*	1.00				Morning hours		
L_{90}	0.50	0.81*	1.00					
L_{eq}	0.43	0.68	0.90*	1.00				
TNI	-0.32	0.22	0.66	0.60	1.00			
NC	-0.54	0.00	0.46	0.42	0.97*	1.00		
L_{NP}	-0.01	0.57	0.84*	0.74*	0.92*	0.82*	1.00	
NEI	0.65	0.86*	0.93*	0.83*	0.45	0.23	0.68	1.00
L_{10}	1.00							
L_{50}	0.69	1.00				(b) Noon hours		
L_{90}	0.75*	0.91*	1.00					
L_{eq}	0.77*	0.77*	0.78*	1.00				
TNI	0.10	0.60	0.66	0.30	1.00			
NC	-0.35	0.31	0.35	0.01	0.93*	1.00		
L_{NP}	0.21	0.81*	0.78*	0.49	0.94*	0.81*	1.00	
NEI	0.80*	0.89*	0.95*	0.78*	0.53	0.21	0.68	1.00
L_{10}	1.00							
L_{50}	0.92*	1.00					(c) Evening hours	
L_{90}	0.89*	0.97*	1.00					
L_{eq}	0.88*	0.97*	0.99*	1.00				
TNI	0.48	0.74*	0.83*	0.80*	1.00			
NC	0.08	0.42	0.53	0.50	0.91*	1.00		
L_{NP}	0.69	0.90*	0.94*	0.92*	0.95*	0.76*	1.00	
NEI	0.88*	0.92*	0.95*	0.92*	0.73*	0.42	0.85*	1.00

*Indicates significant r at $p < 0.05$ (2-tailed)

Table 6: Clusters Analysis (CA) representing the Traffic Junctions with showing similar noise levels.

Group	Noise Range, dB(A)	Sampling Stations		
		Morning	Noon	Evening
Group A	Above 75	T-1, T-2	T-5, T-21, T-24, T-27	T-4, T-5, T-25, T-26, T-27, T-29, T-30
Group B	70-75	T-3, T-21, T-23, T-26	T-22, T-23, T-26, T-29, T-30	T-1, T-2, T-17, T-28, T-14, T-21, T-16, T-19, T-18, T-22, T-3, T-24, T-23
Group C	60-70	T-4, T-5, T-6, T-7, T-8, T-9, T-10, T-11, T-12, T-13, T-14, T-15, T-16, T-17, T-18, T-19, T-20, T-22, T-24, T-25, T-27, T-28, T-29, T-30	T-1, T-2, T-3, T-4, T-6, T-7, T-8, T-9, T-10, T-11, T-12, T-13, T-14, T-15, T-16, T-17, T-18, T-19, T-20, T-25, T-28,	T-6, T-7, T-8, T-9, T-10, T-11, T-12, T-13, T-15, T-20
Group D	50-60	Nil	Nil	Nil

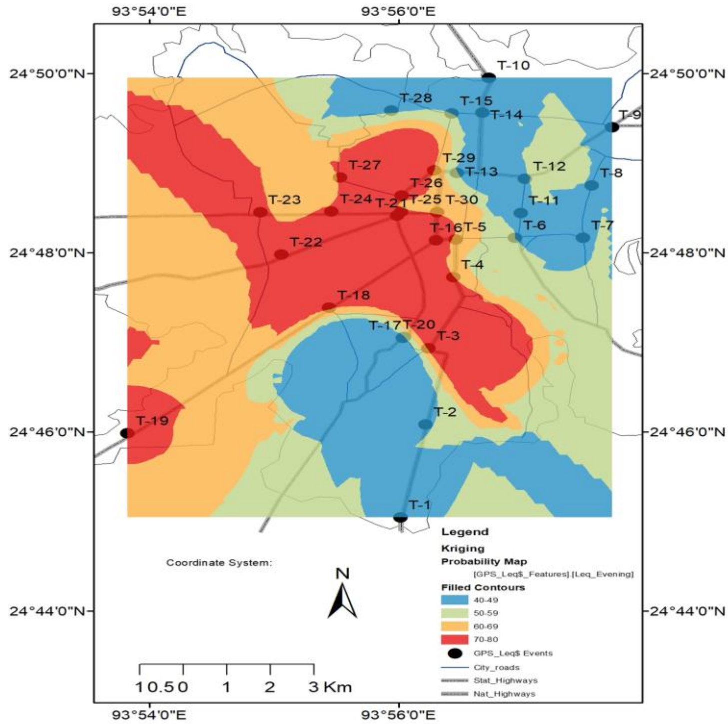

Fig. 6: Spatial variation mapping of noise levels in Traffic Junctions of Imphal city during evening (4-7 pm) hours.

etc. along with strict enforcement of noise pollution control regulations and traffic rules.

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