A retrospective view of ambient noise standards in India: Status and proposed revisions

N. Garg[a),b)], A. Kumar[c)], P.K. Saini[d)] and S. Maji[b)]

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The objective of this paper is to investigate the status and validity of ambient noise standards in India and propose revisions for noise abatement and control based on the available knowledge on noise policies and regulations followed around the world. The annual average L_{day} (06–22 h) and L_{night} (22–06 h) values observed under the pilot project on the establishment of National Ambient Noise Monitoring Network (NANMN) across seven major cities in India are analyzed for ascertaining the magnitude of annual average ambient noise levels, planning for noise abatement action plans and formulation of revised ambient noise standards in India. It is envisaged that the proposed revisions shall be instrumental in execution of noise abatement action plans for controlling noise pollution in India.

Primary subject classification: 52.1; Secondary subject classification: 82

1 INTRODUCTION

Noise pollution has become a serious concern globally. Every nation is concerned about the health effects of noise emitted from the expanding number of vehicles moving on the roads. It is thus imperative to adopt noise monitoring strategies to monitor the accentuated noise levels and planning for suitable noise abatement measures for reduction. The European Environmental Noise Directive 2002/49/EC[1] relating to the assessment and management of environmental noise establishes that the member states should create noise maps and action plans for the parts of their territory. The noise maps should present noise levels expressed in harmonized indicators: day–evening–night level, L_{den}, and night equivalent level, L_{night}. The long term noise monitoring studies are thus required not only for ascertaining the magnitude of ambient levels, but also for devising suitable control plans. There have been many such studies reported in different parts of the world[2–9]. Road traffic noise has been observed to be the major source of noise pollution in most of these studies carried out in the different parts of the world[10–12]. Also, the annoyance towards railway and aircraft related noise is reported to be different across the globe. For instance, annoyance caused by railway noise is more severe in Japan than in Europe attributed to the distance from noise sources to the houses[13]. There have been no such comprehensive long-term noise monitoring studies previously reported in India[14–17]. The development of a validated road traffic noise model for Indian conditions[18,19] similar to that used in developed nations is essential in conducting Environmental Impact Assessment (EIA) studies. The Central Pollution Control Board (CPCB), New Delhi, has taken many initiatives and carried out numerous studies in monitoring the ambient sound levels at noise hot-spots in metropolitan cities like Delhi city with an aim of implementation of suitable measures for noise mitigation. CPCB, India initiated the process of developing National Ambient Noise Monitoring Network (NANMN), a follow-up of Section 5.2.8 (IV) of National Environmental Policy (NEP)-2006, through which it was decided to include ambient noise as a regular parameter for monitoring in specified urban areas[20,21]. The real time noise monitoring network, NANMN project was established in year 2011 with an objective of collecting the real-time continuous noise monitoring data. Phase I of the NANMN began in 2011 and covers 35 locations in seven metropolitan cities and by phase II and phase III, 160 locations spread over 25 cities in 18 states will be established[22]. The network has resulted in creation of the base line data and facilitates its analysis for policy makers and implementation agencies to take appropriate actions for noise control at regional and national level. Thus, a retrospective view of the ambient noise

a) CSIR—National Physical Laboratory, New Delhi – 110 012, INDIA; email: ngarg@nplindia.org.

b) Department of Mechanical and Production Engineering, Delhi Technological University – 110 042, INDIA.

c) CSIR—National Physical Laboratory, New Delhi – 110 012, INDIA.

d) National Institute of Technology, Kurukshetra – 136 119, INDIA.

standards of India is also required so as to ascertain whether the current standards are appropriate enough to fight with ever increasing noise pollution in India, or some amendments or revisions are required for making them more suitable and effective in the recent times.

The objective of the present work is to investigate the status and validity of ambient noise standards in the Indian situation and propose revisions for noise abatement and control based on the available knowledge on noise policies and regulations around the world. The study is however an independent study done by authors based on the available knowledge on noise policies and regulations followed around the world and experience gained in conducting EIA studies with respect to noise[23–26]. It has nothing to do with any legal or government body sponsoring the work or accepting the conclusions of the present work. As such in India, it is the prerogative of many government agencies including CPCB, State pollution control boards, Ministry of Environment and Forests (MoEF) in consultation with National Committee on Noise Pollution Control to formulate and revise the ambient noise standards, ordinances and legislations.

2 METHODOLOGY

2.1 Establishment of NANMN Pilot Project in India

The phase I of NANMN covers 35 locations in seven metro cities as shown in Fig. 1[27]. Out of these 35 locations in seven major cities of India, 14 locations lie in commercial zones, 5 in Industrial, 7 in residential and 9 in silence zones. Earlier CPCB and State pollution control board had been carrying out short-term sporadic or isolated noise monitoring in urban areas.

Fig. 1—Long-term noise monitoring locations selected for NANMN project across seven major cities of India[27].

However, such a pilot study is the first of its type carried out in the wider Indian situation. The noise monitoring unit is a standalone remote terminal having a calibrated sound-level meter and consisting of a high quality microphone connected to an advanced acoustic signal-processing unit connected to an advanced high resolution data logger. The noise data are acquired locally, archived and communicated to a central station through an integrated GPRS modem[22]. Table 1 lists the area characteristics of the 35 locations all over India wherein long-term noise monitoring was conducted. The noise data analyzed in the present work is CPCB reported noise levels at 35 locations all over India for the year 2011[28]. The noise data can also be viewed for each of the 35 sites under consideration on CPCB website: http://cpcbnoise.com[29]. The noise data are acquired and analyzed continuously since data collection began in 2011 for the 35 locations listed in Table 1. The day equivalent level, L_{day}, and night equivalent level, L_{night}, is calculated from the 24 hours noise data for each day of the year. The day-time means from 6.00 a.m. to 10.00 p.m., while the night time means

Table 1—Summary of 35 noise monitoring locations all over India selected by Central Pollution Control Board, India for NANMN pilot project.

Name of location	City	Area characteristics	Geographical coordinates
Dilshad Garden	Delhi	Silence	77° 19′ E, 28° 40′ N
CPCB HQ		Commercial	77° 17′ E, 28° 39′ N
DTU, Bawana		Silence	77° 5′ E, 28° 44′ N
ITO		Commercial	77° 14 E, 28° 37′ N
NSIT Dwarka		Silence	77° 2′ E, 28° 36′ N
Gomti Nagar	Lucknow	Residential	80° 59′ E, 26° 51′ N
Hazrat Ganj		Commercial	80° 53′ E, 26° 51′ N
Indira Nagar		Residential	80° 59′ E, 26° 52′ N
PGI Hospital		Silence	80° 55′ E, 26° 45′ N
Talkatora Industrial Area		Industrial	80° 53′ E, 26° 50′ N
Kasba Gole Park	Kolkata	Industrial	88° 23′ E, 22° 30′ N
New Market		Commercial	88° 21′ E, 22° 33′ N
Patauli		Residential	88° 22′ E, 22° 28′ N
SSKM Hospital		Silence	88° 20′ E, 22° 32′ N
WBPCB HQ		Commercial	88° 24′ E, 22° 34′ N
AS HP	Mumbai	Silence	72° 51′ E, 19° 1′ N
Bandra		Commercial	72° 49′ E, 19° 3′ N
MPCB HQ		Commercial	72° 52′ E, 19° 6′*N*
Thane MCQ		Commercial	72° 51′ E, 19° 0′ N
Vashi Hospital		Silence	73° 0′ E, 19° 4′ N
Abids	Hyderabad	Commercial	78° 28′ E, 17° 23′ N
Jeedimetla		Industrial	78° 28′ E, 17° 30′ N
Jubilee Hills		Residential	78° 24′ E, 17° 25′ N
Punjagutt		Commercial	78° 27′ E, 17° 25′ N
Zoo Park		Silence	78° 28′ E, 17° 22′ N
BTM	Bengaluru	Residential	77° 35′ E, 12° 54′ N
Marathahalli		Commercial	77° 34′ E, 12° 54′ N
Nisarga Bhawan		Residential	77° 35′ E, 12° 59′ N
Parisar Bhawan		Commercial	77° 34′ E, 12° 58′ N
Peenya		Industrial	77° 30′ E, 13° 1′ N
Eye Hospital	Chennai	Silence	80° 17′ E, 13° 6′ N
Guindy		Industrial	80° 12′ E, 13° 0′ N
Peerambur		Commercial	80° 14′ E, 13° 6′ N
T. Nagar		Commercial	80° 13′ E, 13° 2′ N
Triplicane		Residential	80° 16′ E, 13° 3′ N

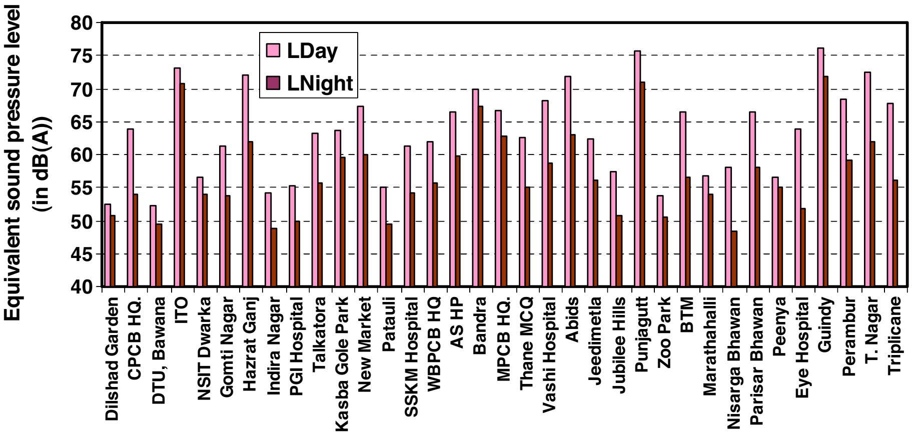

Fig. 2—L_{day} and L_{night} levels at 35 locations spread across 7 major cities all over India.

from 10.00 p.m. to 6.00 a.m. The value of L_{day} and L_{night} is calculated as:

$$L_{\text{day},n} = 10 \log\left[\frac{1}{n}\sum_{i=1}^{n} 10^{0.1\left(L_{\text{day},i}\right)}\right] \quad (1)$$

$$L_{\text{night},n} = 10 \log\left[\frac{1}{n}\sum_{i=1}^{n} 10^{0.1\left(L_{\text{night},i}\right)}\right], \quad (2)$$

where n is the number of days or nights included in the long-term (e.g. $n = 28$, 30 or 31 for a month) and $L_{\text{day},i}$ and $L_{\text{night},i}$ are the ith corresponding A-weighted equivalent level for the considered period. The annual equivalent average level is calculated in present study as:

$$L_{\text{day},LT} = 10 \log\left[\frac{1}{LT}\sum_{i=1}^{LT} 10^{0.1\left(L_{\text{day}}\right)_i}\right] \quad (3)$$

$$L_{\text{night},LT} = 10 \log\left[\frac{1}{LT}\sum_{i=1}^{LT} 10^{0.1\left(L_{\text{night}}\right)_i}\right], \quad (4)$$

where LT is number of months in a year for which noise monitoring is conducted. Figure 2 shows the annual average L_{day} and L_{night} levels for the 35 locations. The maximum value of L_{day} of 76 dBA is observed for Guindy industrial site, while the minimum value of 52 dBA for Delhi Technological University (DTU), Bawana site. The maximum value of L_{night} of 72 dBA is observed for the Guindy industrial site and minimum value of 48 dBA for Nisarga Bhawan site. The present study also considers day–night average sound level, L_{dn}, for the assessment of overall average sound levels calculated as:

$$L_{dn} = 10 \log\left[\frac{1}{24}\left(16 \times 10^{\left(\frac{L_{\text{day}}}{10}\right)} + 8 \times 10^{\left(\frac{L_{\text{night}}+10}{10}\right)}\right)\right]. \quad (5)$$

Equation (5) uses the standard 10 dB night time adjustment to account for the increased sensitivity of noise at night, the expectation that the night time noise will be lower than during the day and for disturbance sleep protection.

2.2 Analysis of Long-Term Noise Monitoring Data

Figure 3 shows the annual average L_{dn} value for the 35 sites under consideration. It can be observed that

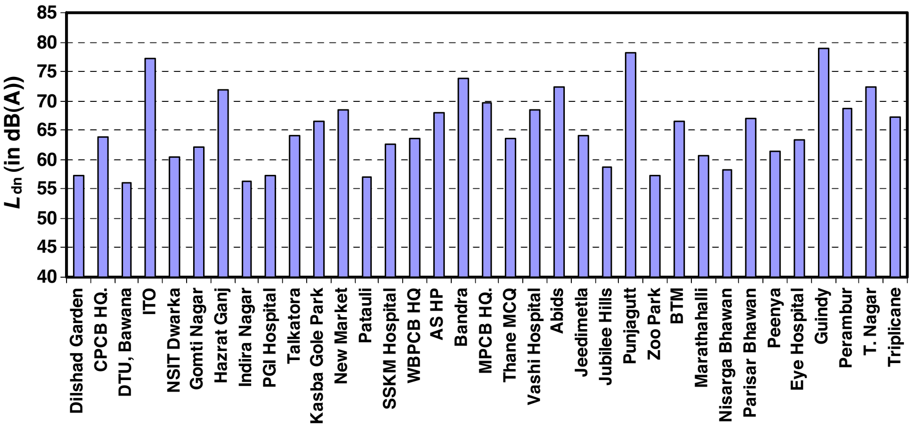

Fig. 3—Day–night average sound levels, L_{dn} at 35 locations spread across 7 major cities all over India.

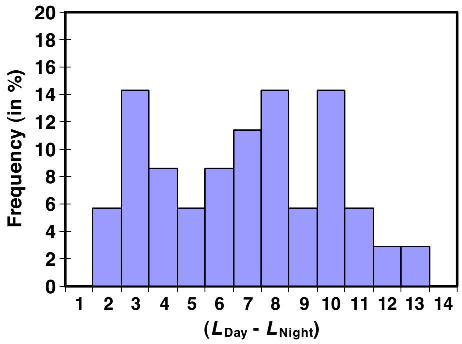

Fig. 4—Frequency histogram (in %) for difference ($L_{day} - L_{night}$) values in dB for 35 sites in year 2011.

the maximum value of L_{dn} of 79 dBA is observed for Guindy industrial site, while the minimum value of 56 dBA for Delhi Technological University, Bawana site as it is in the silence zone. Figure 4 shows the histogram of the difference of ($L_{day} - L_{night}$) for 2011, across the seven major cities in India. This difference is considered with an objective of ascertaining the severity of night levels in comparison to the day levels. The average difference of 6.4 dB and minimum value of 12.7 dB and 1.5 dB are observed for the 2011 data. The analysis of difference shows that 11.4% of the observations show a difference of ≥10 dBA, 60% are between 5 and 10 dB and 28.6% of the observations are less than 5 dB. The observation that 60% of data for ($L_{day} - L_{night}$) is between 5 and 10 dB implies that the night time level is higher than the day time level when taking into account the standard 10 dB night time adjustment. This is also the case when difference is less than ≤5 dB, the L_{dn} value in that case is higher than the individual L_{day} and L_{night} value, which may not represent the actual situation as being considered as the representative average value. Consequently, the noise monitoring data are also analyzed in terms of equivalent continuous sound pressure level for 24 hours, $L_{Aeq,24h}$ (equivalent to L_{dn} noise metrics with no 10 dB night adjustment).

Figure 5 shows the annual average $L_{Aeq,24h}$ for the 35 sites under consideration. It can be observed that the maximum value of 75 dBA is observed for Guindy industrial site, while the minimum value of 52 dBA for DTU, Bawana site.

The analysis of ambient noise levels at 35 sites across seven major cities of India reveals that the maximum value of L_{day} and L_{night} is observed for the industrial sites. It can also be observed from Table 2 that the ($L_{day} - L_{night}$) is smallest for the industrial site. The L_{day} levels varied from 60 to 70 dBA for 18 sites (51.4%), while the L_{night} levels varied from 50 to 60 dBA for 22 sites (62.9%). Table 3 shows the frequency distribution of L_{day} and L_{night} and day–night average sound levels, L_{dn}, in dBA for seven major cities (35 sites) in the year 2011. The day–night average sound levels, L_{dn}, varied from 55 to 65 dBA for 19 sites (54.3%).

3 STATUS OF CURRENT AMBIENT NOISE STANDARDS

The principal rules concerning ambient noise standards in India were published in the Gazette of India vide number S.O. 123 (E) dated 14 February, 2000 and subsequently amended vide S.O. 1046 (E) dated 22 November, 2000, S.O. 1088 (E) dated 11 October, 2002; S.O. 1569 (E) dated 19 September, 2006 and S. O. 50 (E) dated 11 January, 2010[21]. Accordingly the State pollution control boards and pollution control committees in consultation with CPCB, India shall collect, compile and publish technical and statistical data relating to the noise pollution and the measures derived for its effective, prevention, control and abatement[20,28]. Table 4 enlists the ambient noise standard currently followed in India. The silence zone is an area comprising not less than 100 m around hospitals, educational institutions, courts, religious places or any other area which

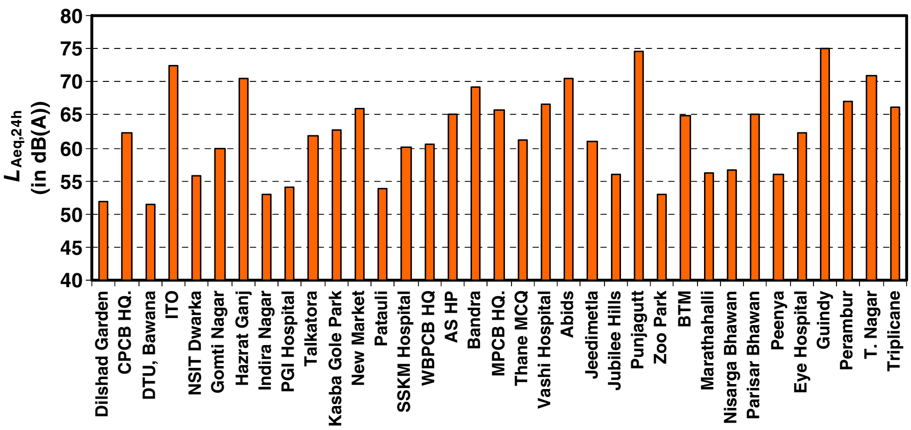

Fig. 5—$L_{Aeq,24h}$ at 35 locations spread across 7 major cities all over India.

Table 2—Variation of L_{day} and L_{night} values and difference ($L_{day} - L_{night}$) values in dBA for different areas/zone in year 2011.

Area code	Category of area/zone	L_{day}		L_{night}		($L_{day} - L_{night}$)		L_{dn}		$L_{Aeq,24h}$	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
A	Industrial	56.5	76.1	55.0	71.8	1.5	7.2	61.3	78.9	61.0	75.1
B	Commercial	56.9	75.7	53.9	71.0	2.2	10.5	63.5	78.8	56.1	74.6
C	Residential	54.2	67.8	48.4	56.5	5.4	11.6	56.3	67.3	53.0	66.2
D	Silence zone	52.3	68.2	49.4	59.7	1.6	12.1	56.1	68.4	51.5	66.7

Table 3—Frequency distribution of L_{day} and L_{night} and day–night average sound levels, L_{dn} in dBA for seven major cities (35 sites) in year 2011.

Variation of parameters, L_{day}, L_{night}, L_{dn} and $L_{Aeq,24h}$	L_{day}		L_{night}		L_{dn}		$L_{Aeq,24h}$	
	No. of sites	Percentage of noise monitoring locations	No. of sites	Percentage of noise monitoring locations	No. of sites	Percentage of noise monitoring locations	No. of sites	Percentage of noise monitoring locations
$45 \leq L_{eq} \leq 50$ dBA	0	0	5	14.3	0	0	0	0
$50 \leq L_{eq} \leq 55$ dBA	4	11.4	10	28.6	0	0	6	17.1
$55 \leq L_{eq} \leq 60$ dBA	7	20.0	12	34.3	8	22.9	6	17.1
$60 \leq L_{eq} \leq 65$ dBA	9	25.7	4	11.4	11	31.4	9	25.7
$65 \leq L_{eq} \leq 70$ dBA	9	25.7	1	2.9	9	25.7	8	22.9
$70 \leq L_{eq} \leq 75$ dBA	4	11.4	3	8.6	4	11.4	5	14.3
$75 \leq L_{eq} \leq 80$ dBA	2	5.7	0	0	3	8.6	1	2.9

is declared as such by the competent authority. Mixed categories of areas may be declared as one of the four categories stated in Table 4 by the competent authority. With reference to the noise monitoring data observed in NANMN pilot project, it is observed that 8 locations involving 4 commercial and 4 industrial meet the ambient noise standards. Surprisingly, no location lying in the residential or silence zone meets the ambient noise norms. These observations thus suggest the need for reformulation of the ambient standards. The noise monitoring data observed in NANMN projects also reveals that for some locations like Indira Nagar, Lucknow; Patauli, Kolkata and West Bengal Pollution Control board (WBPCB) Head quarters, Kolkata; the L_{day} levels are within the norms, but the L_{night} levels are higher than the ambient standards. It can be observed from Table 3 that L_{night} levels are ≥55 dBA for 20 sites (57.1%). Thus, in light of expanding vehicular population at a Compounded Annual Growth Rate (CAGR) of 9.9% between 2001 and 2011[30], it is imperative to revise the ambient noise standards to a more reasonable values that can be easily enforced so as to meet the current situation. Consequently, it will be more rational approach to use a single-noise metrics as followed in some countries[31]. A single-noise metrics can be easily correlated with the community response rather than two individual metrics for the day and night respectively. Also, there is a lack of comprehensive noise annoyance survey in Indian conditions as widely conducted in Europe and other developed nations. Thus, a cumulative noise exposure metrics such as day–night average sound level used in these countries may also be considered for Indian situation so as to develop a harmonized approach.

Table 4—Ambient air quality standards in respect of noise in India.

Area code	Category of area/zone	Limits in dBA L_{eq}[a]	
		Day time	Night time
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	Silence zone	50	40

[a] L_{eq} denotes the time weighted average of the sound level in decibels in A-weighting.

4 PROPOSED REVISIONS IN THE AMBIENT STANDARDS

The International Institute of Noise Control Engineering (I-INCE) has categorized the community noise legislations and guidelines in many developed countries[31–33]. The majority of countries use time-averaged A-weighted sound levels. However, differences were found in many aspects of the national approaches for example, category of each legislative document (regulation or guidelines), noise descriptor, assessment time, interval and so forth[31,32]. Due to the differences in legal systems, it is hard to predict what the actual effect of a certain limit value will be. It could be a relatively high value but rigidly enforced or a very low value with no legal binding whatsoever[34]. Day–night average sound level, L_{dn}, has been endorsed by many scientific bodies[35–38] for the valuation of community noise impact as 10 dB penalty to night time is applied to account for increased human sensitivity to noise at night. In light of many published studies, day–night average sound level is considered the most adequate noise descriptor for use in the environmental impact analysis to assess the overall impact of noise from general transportation. The World Health Organization (WHO) recommends a 16 hour day time average sound level, $L_{Aeq,16h}$, not more than 55 dB and 8 hour night time average sound level, $L_{Aeq,8h}$, of not more than 45 dB to prevent annoyance in the residential areas[39]. The day time and night time average sound levels are equivalent to 55 dB L_{dn}. The Federal Transit Administration (FTA) states 65 dB L_{dn} to determine the lower boundary of region of severe impact[40]. The Schultz curve[41] indicates that approximately 13% of the population is highly annoyed at a noise level of 65 dBA L_{dn}. It also indicates that the percent of people describing themselves as being highly annoyed accelerates for the L_{dn} value between 55 and 70 dBA. The European position paper[42] (2002) recommends % highly annoyed as 16% due to road traffic, 9% due to rail traffic and 26% due to aircraft noise for 65 dB L_{den}. L_{dn} ≤65 dBA is normally acceptable, while that between 65 and 75 dBA is normally unacceptable and that ≥75 dBA is unacceptable[43]. It may be noted that the ambient air quality standards in respect of noise are recommended in India in terms of L_{day} and L_{night}, while the single noise-metrics: day–night average sound level, L_{dn}, calculated using Eqn. (5) is used to know the sound exposure on people/residents due to aircrafts and for land use planning around airports[44]. Some of the limitations associated with L_{dn} metrics can be overcome by use of normalized L_{dn} metrics. Normalized L_{dn} is the basic L_{dn} value with a number of adjustments added to account for the specific character and factors of sound[45]. Consequently, adjustments enlisted in ISO 1996-1:2003[46] can account for tonality, intermittent noisy events etc. Recent studies by Fidell et al.[47] and Schomer et al.[48] establish a simple model that can account for the aggregate influences of non-L_{dn} related factors on annoyance prevalence rates in different communities in terms of a single parameter expressed in L_{dn} units — a "community tolerance level."

In Indian conditions as the majority of difference between the L_{day} and L_{night} value lies between 5 and 10 dB, thus 10 dB night adjustment to L_{dn} metrics seems unsuitable. Thus, the equivalent continuous sound pressure level for 24 hours, $L_{Aeq,24h}$, would rather be more suitable as it is a common way of expressing L_{dn} without 10 dB night adjustment. Table 5 shows the SWOT (strengths, weaknesses, opportunities and threats) analysis of $L_{Aeq,24h}$ metrics in consideration for the ambient noise standards after exhaustive review[49–52]. Table 6 shows the proposed ambient noise standards. It is proposed that for areas under silence zone, the limit is 55 dBA; while that for commercial area and mixed residential and commercial zones, the limit is recommended as 65 dB $L_{Aeq,24h}$. The $L_{Aeq,24h}$ for assessing the minimum acceptable degree of annoyance for residential zone should be 60 dBA. However, to compensate for the existing urban residential areas with high population density and areas under the silence zone where there are only few alternatives left for the application of noise abatement measures, an additional 5 dB relaxation to the existing residential area and existing areas under silence zone may be provided by the competent authority depending upon the site and situation. Table 7 shows the modified adjustments to ISO 1996-1:2003 to be added to the measured or predicted $L_{Aeq,24h}$ depending upon the type of sound source and the character of sound. The adjustments from ISO 1996-1:2003 are to be added to the measured or predicted $L_{Aeq,24h}$ sound levels depending upon the type of sound source, character of sound and time of day. However, these adjustments particularly related to railway and aircraft noise are not suitable in Indian scenario as there is no clear guidelines about the recommended adjustment range of +3 to +6 dB for the aircraft noise. Also, for the railway noise, an adjustment of −3 to −6 dB may not be appropriate in Indian conditions. In Indian scenario, metro trains are running on the elevated corridor in some of the major cities every day from 6.00 a.m. up to 11.00 p.m. and have become a major source of public transportation mode in recent years. Thus, for areas in immediate vicinity of metro trains (≤5 m), the adjustment of +3 dB is proposed, while for others, a range of 0 to 3 dB is recommended depending upon the situation[23,25,53]. An adjustment of +5 dB should be added to the measured or predicted $L_{Aeq,24h}$ levels similar to that proposed for day–night

Table 5—SWOT (strengths, weaknesses, opportunities and threats) analysis of $L_{Aeq,24h}$ descriptor in consideration for the proposed ambient noise standards.

Strengths	Weaknesses	Opportunities	Threats
• Measure is applicable for the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods of time. • Simple, practical and accurate • Useful for planning, monitoring and for enforcement purposes. $L_{\text{Aeq,24h}}$ as a single number measure is useful for predicting the effects of the long-term exposure of environmental noise.	• $L_{\text{Aeq,24h}}$ is based on a time-average of sound pressure over a 24-hour period. As such it does not change very much with the inclusion of a few loud events which, if they occurred at night, may increase the likelihood of awakenings, which could be a cause of increased annoyance. • $L_{\text{Aeq,24h}}$ does not take into account other sound characteristics such as tonality, rate of loudness onset that can influence annoyance and sleep disturbance levels. • Few loud events can have the same $L_{\text{Aeq,24h}}$ as many quieter events, thus impact of very different soundscapes are described as equal. • It is insensitive to the time when an event occurs e.g. noise early in night causes different sleep disturbance than noise in the morning. • As with other metrics based on A-weighting, $L_{\text{Aeq,24h}}$ underestimates the impact due to low frequency noise sources	• It can be used for road, rail and aircraft noise and thus ambient standards shall be applicable for various defined areas including areas prone to the aircraft noise. • A number of adjustments may be added to account for the specific character and factors of sound. Consequently, corrections enlisted in ISO 1996-1:2003 can account for tonality, intermittent noisy events etc. • The only strong argument of using night adjustment in day–night average sound levels, L_{dn} which is widely used single-noise metrics, is based on as 10 dB penalty to night time is applied to account for increased human sensitivity to noise at night. As established in NANMN project that 60% of data shows the ($L_{\text{day}} - L_{\text{night}}$) between 5 and 10 dB, the 10 dB night time correction may not be suitable. The noise metrics, $L_{\text{Aeq,24h}}$, is a common way of expressing L_{dn} without 10 dB adjustment. • Eventually, an exposure–effect relationship correlating $L_{\text{Aeq,24h}}$ with community annoyance is to be derived for Indian scenario.	$L_{\text{Aeq,24h}}$ metrics is unable to capture factors like rural or urban environment effects, previous experience with intruding noise, attitudinal factors etc.

Table 6—Proposed ambient noise standards.

Area code	Category of area/zone	$L_{Aeq,24h}$ (in dBA)
A	Industrial area	70
B	Commercial area, mixed zone	65
C	Residential area[a]	60
D	Silence zone[b]	55

[a] The modified adjustment factors to ISO 1996-1:2003 enlisted in Table 7 should be applied to the measured $L_{Aeq,24h}$ in analysis of environmental noise.
[b] An additional 5 dB relaxation to the existing urban residential area with high population density and existing areas under silence zone may be provided by the competent authority depending upon the situation when there are only few alternatives left for the application of noise abatement measures.

average sound levels caused by aircraft noise in vicinity of airports when relating the L_{dn} to the expected annoyance of residents[52]. However, for other areas, where the number of aircrafts flyover is significant, an adjustment factor (K) similar to that proposed by Switzerland Noise Abatement ordinance[31] issued in 1996 (revised in 2006) is proposed, whereby $K = 10\log\left(\frac{N}{15{,}000}\right)$ dB for $N \geq 15{,}000$; N being the annual number of movements (take offs and landings) over that area. The other adjustments like seasonal correction, correction for previous exposure and community attitudes, noise-induced rattle, time period adjustments, public relations and so forth as recommended by Schomer[45] are not considered for the Indian scenario. Schomer recommended that normalization will provide for better, more precise assessments and can remove much of the scatter to dose–response relationships[45].

Thus, it is envisaged that these adjustments added to $L_{Aeq,24h}$ will be not only be able to overcome the limitations of tonality and character of sound but also shall be applicable to road, rail and aircraft noise and thus ambient standards shall be applicable for various defined areas including areas prone to the aircraft noise. The proposed standards shall be thus a rational approach for deciding the noise limits for various areas categorized under silence, residential, commercial, industrial and mixed type zones. Interestingly, with reference to the proposed standards and noise monitoring data gathered under NANMN pilot project, 18 out of 35 (51.4%) locations meet the ambient norms proposed in Table 6 out of which only 4 lie in silence zone, 5 in residential area, 5 in commercial area and 4 in industrial zone, which seems to be rational. An additional 5 dB

Table 7—Modified adjustments to ISO 1996-1:2003 recommendations to be added to the measured or predicted $L_{Aeq,24h}$ depending upon the type of sound source and the character of sound.

Adjustment type	Specification	Adjustment to be added to $L_{Aeq,24h}$ in dBA
Sources of sound	Road traffic	0
	Aircraft	+3 to +6
	Railway	0 to 3
	Industry	0
Character of sound	Regular impulsive	+5
	Highly impulsive	+12
	High-energy impulsive	See Annex B of ISO 1996-1:2003
	Prominent tones	+3 to +6

Note 1: When a range of adjustments is given, the amount to be added to a measured or predicted $L_{Aeq,24h}$ levels shall be determined by appropriate local authorities.
Note 2: If more than one adjustment applies for a type of sound source as far the character of a given single sound source, only the largest adjustment shall be applied.
Note 3: Adjustments for the impulsive character of sound shall be applied only for impulsive sound sources that are audible at the received location. Adjustments for tonal character shall be applied only when the tonal sound is known to be audibly tonal at the receiver location.
Note 4: An adjustment of +5 dBA should be added to measured or predicted $L_{Aeq,24h}$ levels caused by the annoyance of aircraft noise for areas in the vicinity of airports. Adjustment for annual number of take offs and landings, N may be added as:
$K = 0$ for $N < 15{,}000$.
$K = 10\log\left(\frac{N}{15{,}000}\right)$ dB for $N \geq 15{,}000$.
Note 5: An adjustment of +3 dBA should be added to measured or predicted $L_{Aeq,24h}$ levels for areas in the immediate vicinity of Metro elevated corridor.

relaxation recommended for existing areas under silence zone and residential zone if considered reveals that 21 out of 35 (60%) locations meets the ambient norms. It may be noted that these criteria are proposed with an objective of enforcing a reasonable $L_{Aeq,24h}$ limit value enlisted in Table 6 rather than following a lower limit with no legal binding nor with an objective of qualifying the maximum number of sites monitored. Also, in light of many previous studies[45,54–56] focused on community attitude towards noise and offering a debate on 5 dB bonus or penalty to the good community relations, the present study does not considers the "public relations" adjustment[52] to be added to the measured or predicted $L_{Aeq,24h}$ to account for the effect of public relations or complaints.

5 CONCLUSIONS AND RECOMMENDATIONS

This paper provides an overview of the current status of ambient noise levels in India across 35 locations spread across 7 major cities. In accordance with the existing ambient noise standards, only 8 sites out of the 35 sites meet the ambient standards. Surprisingly no site in the residential and silence zone meets the ambient standards. Thus, it suggests the need for revision of ambient noise standards to cope with the current situation of road traffic noise and aircraft noise pollution in India especially for areas with mixed residential and commercial activities. A reasonable permissible limit rigidly enforced can be more rational approach

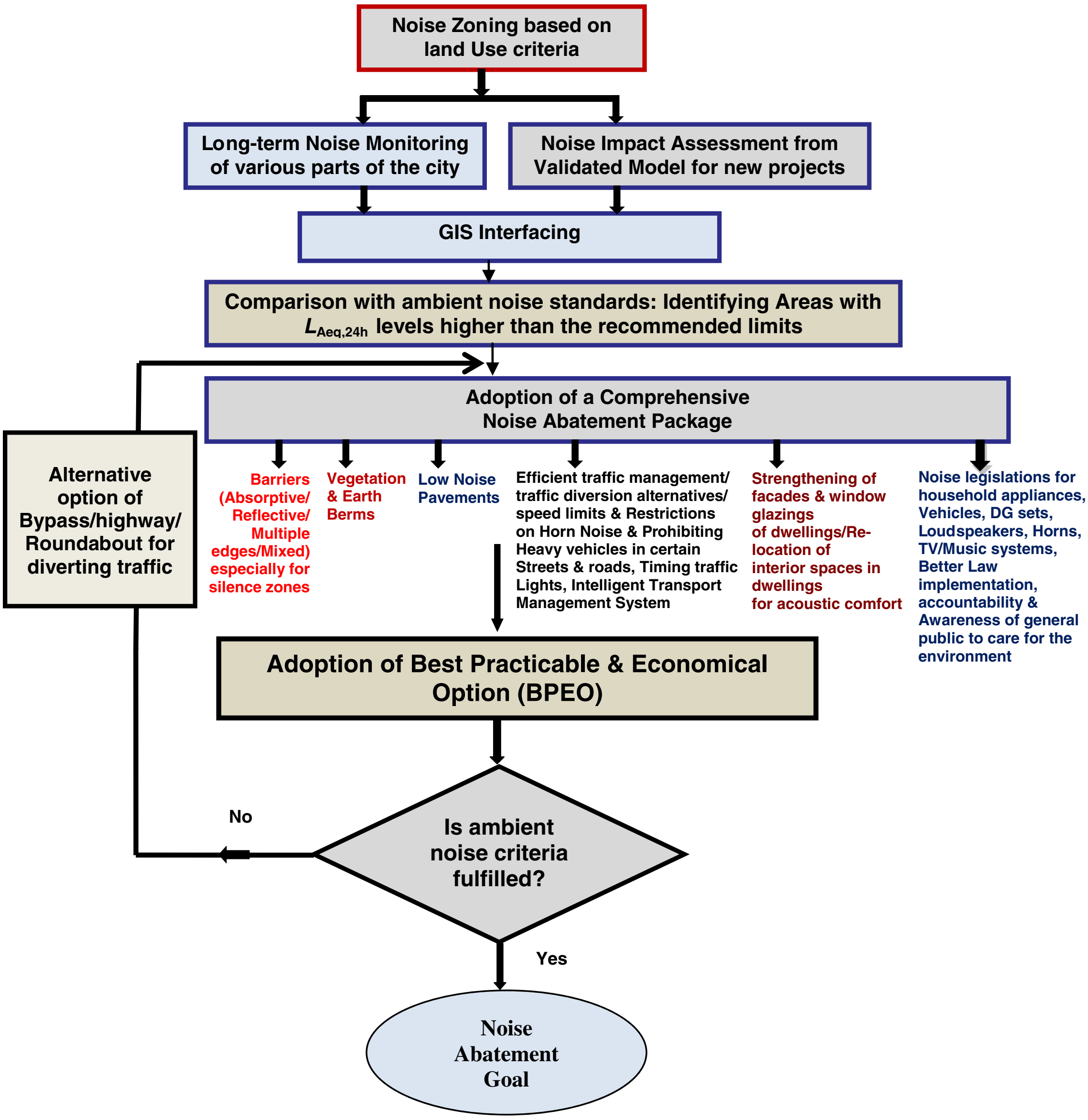

Fig. 6—Flow chart of the proposed comprehensive noise abatement program enforcing the proposed ambient standards with a Noise Abatement Goal for reducing the ambient noise levels in Indian cities.

for controlling the noise pollution in India. Equivalent continuous sound pressure level for 24 hours, $L_{Aeq,24h}$, is recommended to be the noise metrics and revised ambient noise standards are proposed for commercial, residential, industrial and silence zones. SWOT analysis of $L_{Aeq,24h}$ metrics is conducted for consideration as the cumulative noise exposure metrics for framing the ambient noise norms. The $L_{Aeq,24h}$ criterion for assessing the minimum acceptable degree of annoyance in newly developed noise sensitive areas (silence zone) is recommended to be 55 dBA and that for new residential projects of 60 dBA. The modified adjustment factors to ISO 1996-1:2003 recommendations pertaining to the type of sound source and character of sound are recommended for analyzing the environmental noise. It is envisaged that these adjustments added to $L_{Aeq,24h}$ metrics will be not only be able to overcome the limitations of tonality and character of sound, but also shall be applicable to for road, rail and aircraft noise and thus ambient standards shall be applicable for various defined areas including areas prone to the aircraft noise. Eventually, with further modifications or amendments in ISO 1996-1, these adjustments may be accordingly modified depending upon the situation for analyzing the environmental noise. With reference to the proposed standards, interestingly 21 out of 35 (60%) locations meet the norms. It is envisaged that the proposed revisions shall be instrumental in execution of noise abatement action plans for controlling the noise pollution in India.

The implementation of noise abatement measures essentially requires a strategic noise abatement planning with enforcement of proposed ambient standards and formulation of noise abatement goal with special budgetary allocations for accomplishing the noise abatement goal in next two decades. The Dutch noise abatement goal[57] of decreasing the number of houses exposed to a noise level >70 dBA by 100%, the number >65 dBA by 90% and the number >60 dBA by 50% to be realized till 2030 serves as an good illustration for Indian perspectives. Figure 6 shows the proposed strategy of such a plan. Noise zoning based on land use criteria and enforcement of ambient noise standards shall be instrumental for controlling the noise pollution. A validated road traffic noise model integrated with GIS interface is essential for noise predictions, forecast and management especially for new projects. Table 8 lists the efficacy of various noise abatement measures to be implemented for road traffic noise abatement[58]. It is recommended that noise maps based on $L_{Aeq,24h}$ descriptor should be developed for every big city in India to serve as a noise control measure thus allowing a comprehensive look at problem of multiple sources and receivers and for communicating the results of assessment of environmental noise to general public and for the government authorities to devise noise abatement measures[59–61]. Identification of hot spots having higher $L_{Aeq,24h}$ sound levels than the recommended limits and implementing the best practicable and economical option (BPEO) among the various alternatives to these hot spots is required for achieving the targets. An alternative option of bypass/highway or a roundabout is to be decided in cases where the noise control measures become inadequate to achieve the targets. Finally, the adherence to a noise goal by a stipulated time and periodic management review of progress brings synergy to whole program for accomplishing the targets[62]. It is envisaged that provision of erection of noise barriers should be there in future projects planned especially for the areas under silence zones. Other measures like strengthening the sound insulation of facades and windows, installation of green belts, low noise pavements and intelligent transportation system can be instrumental in controlling the noise pollution in India[63–69]. Social surveys[70–76] with an objective of quantifying the noise annoyance, on health and amenity issues related to noise pollution should also be conducted in parallel, which shall be helpful in conducting the Environmental Impact Assessment (EIA) studies in respect of noise.

Table 8—Noise abatement measures for road traffic noise and their efficacy[58].

Noise abatement action plans	Efficacy
Legislations for vehicles/tires	−2...−3 dB
Traffic calming, 30 km/h	−2...−3 dB
Steady driving	0...−3 dB
Lorry bans	−1...−3 dB
Reduction in number of vehicles:	
20%	−1 dB
50%	−3 dB
90%	−10 dB
Shift from private cars to public transport depending upon technical standard and occupancy of vehicles	+6...−9 dB
Redistribution of road space e.g. bus lanes	−1...−2 dB
Noise barriers	+3...−15 dB
Noise reduction goal	−13 dB

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