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Study of Road Traffic Noise Sound Pressure Levels in Varanasi City, India

Kanakabandi Shalini[1], Brind Kumar[2]

Department of Civil Engineering
Indian Institute of Technology (BHU), Varanasi, Varanasi-221005, U.P, India.

Abstract:

Traffic noise is considered as one of the important sources of noise pollution that adversely affects human health in residential urban areas. It is strongly time dependent and to account for this feature, measurements of noise parameters are essential. The noise parameters such as L_{10}, L_{50}, L_{90}, Leq, TNI, and NPL are used to describe and quantify the sporadic and random manner that transportation noises impinge on the acoustic environment. A study was carried out to assess the existing status of noise levels and its impacts on the environment with a possibility of a further expansion of the Varanasi city.

Keywords: Traffic noise, noise parameters, L_{eq}, TNI, and NPL

INTRODUCTION

Noise pollution consistently ranks high on the list of citizens concerns [1]. The sources responsible for noise pollution are traffic noise, industrial noise, construction activities, and community noise. Traffic noise is one of the significant sources of the noise compared to the other sources. Traffic noise, itself, is categorised into four major groups: road traffic noise, airport noise, railway noise, and seaport noise [2]. The several adverse effects of noise pollution are due to road traffic operation on individuals which include annoyance, loss of concentration, and reduction of work efficiency, apart from other physiological and psychological damages and also road traffic noise intensity undergoes geometric progression in pace with economic, and technological growth [3, 4].

The combination of rapid urbanisation and motorisation has been a critical cause of numerous transport problems in developing cities [5]. Urban sprawl and limited mobility of vehicles in cities have resulted in congestion and delays, environmental (air pollution and noise pollution) pollution and safety concerns. In a rapidly urbanising country like India, the transportation sector is growing fast, and the number of vehicles on Indian roads is increasing at a rate of more than 7 percent per annum [6]. In developing countries, most of the urban population growth is at low-income spectrum. This leads to the reduction in purchasing power of the formal urban sector. Old vehicles, poor maintenance and poor fuel mixes are the results.

Statutory body like the Ministry of Environment and Forests has framed noise standards which are documented in the Noise Pollution (Regulation and Control) Rules 2000 under the Environment Protection Act 1986 mandating certain safe value of noise levels for various urban landuse like residential, commercial, and industrial and silence zone as shown in Table 1[7]. The permissible limits for TNI and NPL are 74 and 88 dBA, respectively [8,9].

Table 1: Ambient air quality standards in respect of noise

Area Code	Category of area	Limits in dBA L_{eq}	
		Day time (6.00 – 22.00 hrs)	Night time (22.00 – 6.00 hrs)
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	Silence zone	50	40

The urban traffic on roads in India is heterogeneous in character. It consists of not only fast moving motor traffic but also of fundamental modes such as tongas, rickshaws, bullock carts etc. There is also a considerable volume of cycle traffic and pedestrian traffic in urban streets due to high density of population. These wide varieties of traffic units with great disparity of size and speed create a number of problems and areas of conflict. Because of low travel speed of certain types of vehicles, the capacity of road is adversely affected and severe congestion occurs. When traffic speed drops downs considerably, it causes delay, frequent stoppage, acceleration and deceleration patterns, movement in low gears, increase in operational costs, increase in wear and tear of vehicles, and environmental degradation in the form of air pollution and noise pollution [10].

Varanasi is one of the oldest cities in continuous habitation in the world, with a history dating back to more than 3000 years. Considered holy by Hindus, Buddhists, and Jains and is home to more than 1.3 million people who crowd its narrow streets. Rapid urbanisation, industrialisation, expansion of road network and infrastructure caused severe noise pollution problem [11].

Varanasi city has not been developed through proper town planning for instance here residential, commercial, industrial areas and silence zones are not separate. This has aggravated the problem of traffic noise in sensitive areas. So, Because of above issues, a complete study of road traffic noise in Varanasi city is required.

NOISE PARAMETERS

Percentile Noise Levels

Road traffic noises are strongly time dependent. Their distribution function is determined by analyzing noise level data with some form of statistical analysis using the following parameters [12]:

L_{10} : ten percentile time exceeding noise level, is the one which exceeds 10% of the total observation time. It indicates peak levels of intruding noise.

L_{50} : fifty percentile time exceeding noise level, is the one which exceeds 50% of the total observation time. It indicates average noise level.

L_{90} : ninety percentile time exceeding noise level, is the one which exceeds 90% of the total observation time. It indicates background noise level.

In order to replicate the response of human ear to annoyance caused by road traffic noise, the A-weighted sound level meter readings were obtained. Therefore, all sound levels (L) referred in this work are in terms of A-weighted decibel or simply dBA.

Equivalent sound pressure level (L_{eq})

Equivalent sound pressure level (L_{eq}) is formulated to describe time varying nature of transportation noise into equal steady state noise level, which for a defined period of time contains the same acoustic energy as the time varying noise [12]. The L_{eq} is energy summation integration.

$$L_{eq} = 10\log\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2}\frac{P^2(t)}{P_o^{\,2}}dt \qquad \text{dBA} \qquad (1)$$

In terms of intensity,

$$L_{eq} = 10\log\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2}\frac{I(t)}{I_o}dt \qquad \text{dBA} \qquad (2)$$

$$L_{eq} = 10\log\frac{\sum_{i=1}^{n} f_i 10^{SPLi/10}}{\sum_{i=1}^{n} f_i} \qquad \text{dBA} \qquad (3)$$

where, f_i is the frequency or number of occurrence.

Robinson (1969), of the British National Physical Laboratory, worked out that for a Gaussian distribution of noise levels the alternative expression for L_{eq} given as [13]:

$$Leq = L_{50} + \left[\frac{(L_{10} - L_{90})^2}{56}\right] \qquad \text{dBA} \qquad (4)$$

Traffic Noise Index (TNI)

It is a traffic noise rating index obtained from a combination of noise levels, which gives a better correlation with dissatisfaction. It is obtained on the consideration that, L_{10} as an average peak level intrudes into L_{90} as an average background noise level when A-weighted noise levels are measured outdoors [8]. It is mathematically stated as,

$$TNI = \left[4\times(L_{10} - L_{90}) + L_{90}\right] - 30 \quad \text{dB(A)} \qquad (5)$$

The term *(L_{10} – L_{90})* is called “noise climate” and the final arbitrary constant is included to yield more convenient numbers. *TNI* is derived on the assumption that, extensive noise level fluctuations over time are the dominant factor in traffic noise annoyance. *TNI* attempts to make an allowance for the noise variability, since fluctuating noise is commonly assumed to be more annoying.

Noise Pollution Level (NPL)

According to Robinson (1969) of the British National Physical Laboratory, L_{eq} in itself is an insufficient descriptor of annoyance caused by fluctuating noise, and, road traffic noise is a significantly fluctuating noise. The index *NPL*, was developed to estimate the dissatisfaction caused by road traffic noise comprising of two terms. The first is a measure of the equivalent continuous noise level (L_{eq}) and the second represents the increase of annoyance caused by fluctuations in that level [14]. For a Gaussian distribution of noise levels, *NPL* can be expressed as given below:

$$NPL = L_{eq} + (L_{10} - L_{90}) \quad \text{dB(A)} \qquad (6)$$

STUDY AREA AND METHODOLOGY

Study area

Varanasi is a city on the banks of the Ganges in the Uttar Pradesh state of North India. It is one of the oldest cities in continuous habitation in the world, with a history dating back to more than 3000 years. Varanasi town lies between the 25°15’N to 25°22’ N latitudes and 82°57’E to 83°01’E longitudes [15]. Its ancient buildings and old roads have stood since ages but are unable to support the exponentially growing traffic since last few decades. Being a place of tourist attraction coupled with pre-developed colonies and civil amenities, it is constrained by considerable challenges in keeping pace with present and future requirements of this ancient city. Traffic congestion is a common scene in the entire city. The details of the selected intersections and their respective legs considered for data collection are shown in Table 2.

Table 2. Details of selected study locations and respective legs for data collection

S.No	Intersection	Location No	Leg (Towards)
1	BHU Gate	1	Naria
		2	Ravidas Gate
		3	Trauma Centre
2	Ravidas Gate	4	Assi
		5	BHU
		6	Durgakund
		7	Lanka Thana
3	Lanka-Sankatmochan	8	Durgakund
		9	Ravidas Gate
		10	Sankat Mochan Temple
4	Durgakund Temple	11	Bhelupur
		12	Ravidas Gate
5	Bhelupur	13	Assi
		14	Durgakund
		15	Kamachcha
		16	Ramapura
6	Rathyatra	17	Kamachcha
		18	Mahmoorganj
		19	Sigra
7	Sigra	20	Englishia Line
		21	Rathyatra
		22	Teliyabag
8	Englishia Line	23	a) Andharapul
		24	Lahartara
		25	Sigra

Noise Measurement:

A Bruel & Kjaer integrating-averaging Class 1 instrument 2240 was used for noise measurement. For the recording of noise level at any leg of an intersection, the sound level meter was positioned on the ground at the height of 1.20 m from the floor level and 1.0 m away from the façade line such that its microphone was facing traffic jam perpendicularly. All measurements were made with weighting network ‘A’ and time response characteristics ‘Fast’. Noise level measurements were done at a distance of more than 25 m away from the intersection so that the data is unaffected by intersection noise.

Traffic noise measurements were carried out in 2016, during the days of the week (Monday to Saturday). The traffic jam timing’s typically in the morning and evening during peak hours were identified through reconnaissance. The sound level data was collected for 10 minutes’ duration at intervals of 10 seconds, thereby providing 60 readings.

RESULTS AND DISCUSSIONS

The experimental details of estimation of noise descriptors like L_{10}, L_{50}, and L_{90} has been discussed here. A graph was plotted taking the noise levels on the x-axis and cumulative percentage of time noise level exceeds average noise level (%) values on the y-axis. The plot shown in Figure 1 is used for the estimation of noise levels like L_{10}, L_{50}, L_{90}. e.g. to find the value of L_{10}, a horizontal line is drawn from y-axis at a value of 10% to meet the curve, and the corresponding value of noise exceeding dBA is read from the x-axis, this is the value of L_{10}. Similarly L_{50}, L_{90} etc. are determined.

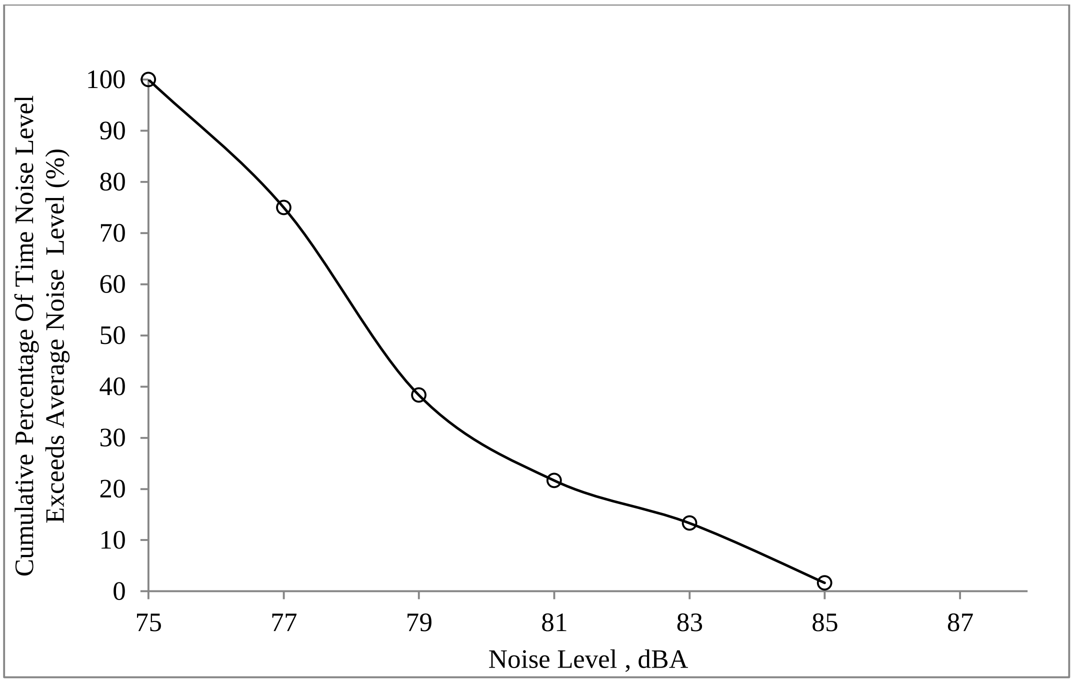

Figure 1: Noise level vs. Cumulative percentage of time noise level exceeds average noise level

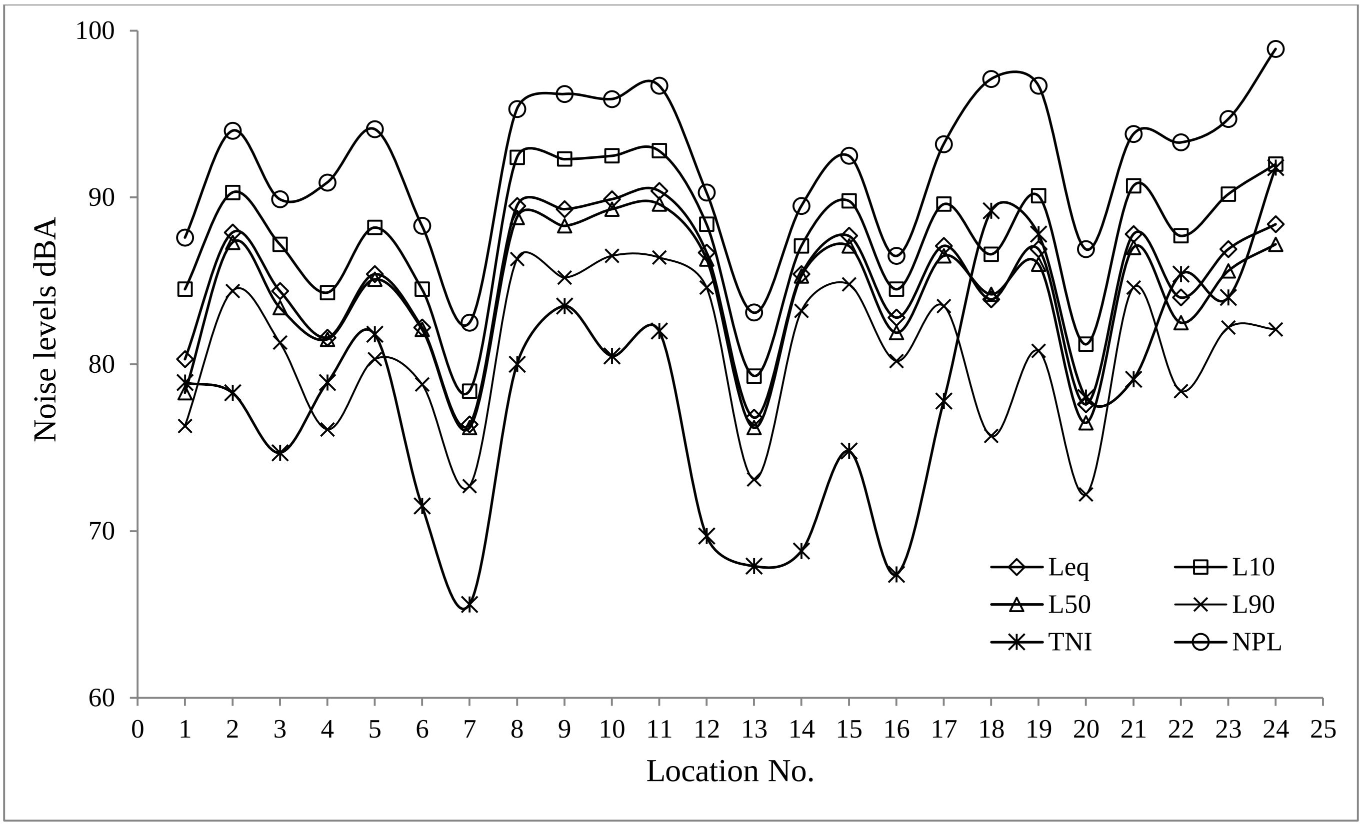

Figure 2: Noise parameters at different locations

The landuse flanking the intersections under the study was commercial, whose stipulated daytime noise level as mentioned in earlier was 65 dBA. It was observed that the field L_{eq} values exceeded this limit for all observer locations irrespective of the observer distance ranging from 2.40 to 14.99 m from the noise source. The L_{eq} observed during the study are shown in Figure 2. It was found that L_{eq} had varied between 92.0 to 70.2 dBA when data for all intersections were considered. This data is to be viewed from the strength of literature stating that, a 3 dBA decrease in noise intensity signifies halving of source strength, while a 3 dB increase in noise intensity denotes doubling of source strength [12]. Noise variations were observed to be exceeding 3 dBA for almost all legs of the intersections, signifying the doubling of source strength.

Although, all the obtained approximate range show value far exceeding the stipulation of 65 dBA, but some of them were hovering around the 90 dBA mark, emphasizing cognizance of literature suggesting that sustained exposure to traffic noise of 90 dBA or more may lead to irreversible physiological and psychological damages in humans beings including permanent loss of hearing [12].

The maximum value of L_{10} is 92.8 dBA which is recorded at Durgakund Temple intersection towards Bhelupur and, the minimum value 84.5 dBA, is recorded at BHU gate intersection towards Naria. The maximum value of L_{50} is 89.6 dBA recorded at Durgakund Temple towards Bhelupur and, the minimum value is recorded at Bhelupur towards Assi which is 76.2 dBA. The background noise which is expressed by L_{90} i.e. noise levels exceeded 90 percent of the total noise. The maximum value of L_{90} is 86.5 dBA recorded at Lanka-Sankatmochan towards Sankatmochan temple and, the minimum value is recorded at Sigra towards Englishia Line which is 72.2 dBA.

As mentioned in earlier, the permissible values of TNI and NPL were 74 and 88 dBA, respectively, their obtained values in the present work were put to comparison. TNI and NPL were observed to be exceeding their permissible values in many instances at most of the intersections. However, they were found to be maintaining their maximum values at similar legs of the intersections where the L_{eq} value was hovering around 90 dBA mark.

The L_{eq} obtained from equation (4) for each location has been compared with the observed L_{eq} values of each location and presented in Figure 3. The regression coefficient R^2 value appears to be 0.978 which shows good correlation between two values.

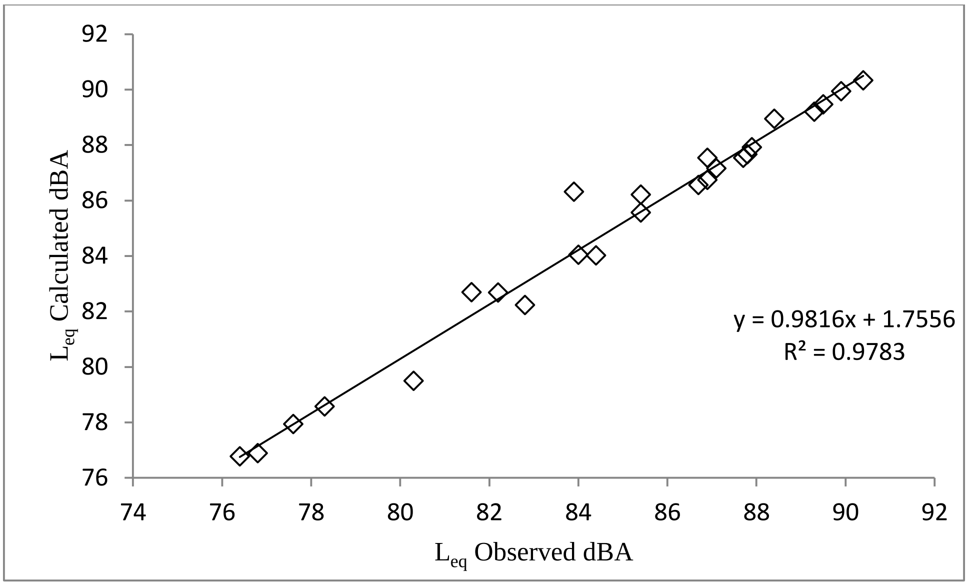

Figure 3: Correlation Plot between Observed and Calculated L_{eq} Values

CONCLUSION

Traffic jam noise in terms of L_{eq} exceeded the permissible limit of daytime noise for commercial area at all 25 legs covered under the study irrespective of the observer distance ranging from 2.40 to 14.99 m from the noise source. TNI and NPL were observed to be exceeding their permissible values of 74 and 88 dBA. So With the increase in the motorised vehicles in the city, the hazard of the noise pollution has increased and exceeded the level of tolerance.

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