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EVALUATION OF NOISE EXPOSURE LEVELS OF PEDESTRIANS IN SUBURBAN CHENNAI, INDIA

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Highlights:

- to assess traffic noise exposure levels of citizens walking on the sidewalks at important road crossings in commercial land zone regions of Chennai's suburbs;
- to collect the noise data from signalized and unsignalized intersections with a class I sound level meter for peak and non-peak hours from 6 AM to 10 PM and calculate different noise indices like A-weighted equivalent continuous noise level, Traffic Noise Index, Noise Pollution Level and Noise Climate and to compare the above results with Central Pollution Control Board (CPCB) and WHO standards;
- to conduct REA in the study area from two groups of people through questionnaire survey for the determination of health conditions of exposed people. The "home-interview" method was adopted for the people of age varies from 15 to more than 60 years category;
- it is observed that irrespective of the gender, the majority of the people are unhappy with the noise annoyance level in the study area. This study revealed that road users suffered with headache, irritation, lack of concentration and sleep disturbance due to noise pollution.

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Abstract. The study assessed traffic noise exposure levels of citizens walking on the sidewalks at important road crossings in commercial land zone regions of Chennai's suburbs. The noise data from signalized and unsignalized intersections are collected with a class I sound level meter for peak and non-peak hours from 6 AM to 10 PM. Different noise indices like A-weighted equivalent continuous noise level (L_{eq}), Traffic Noise Index (TNI), Noise Pollution Level (L_{np}) and Noise Climate (NC) are calculated and compared with Central Pollution Control Board (CPCB, 2017) and WHO standards. The inhabitants' noise exposure levels are at an average value of 80–107.1 dB(A) which is alarmingly higher than the threshold levels of 70 dB(A) by WHO. A Risk Exposure Assessment (REA) questionnaire survey conducted on the area revealed that unsafe health situations persist for the public in the study regions.

Keywords: correlation, noise indices, risk exposure assessment, sound level meter, WHO standards.

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1. Introduction

Minor noise from any source can be irritating, but extreme noise can affect a person's hearing skills. It is well-established that exposure to ambient noise poses a risk to human health (Licitra et al., 2022). Once it affects routine tasks like functioning, sleeping, and having conversations, noise becomes unwanted (Keerthana et al., 2013). In recent years, Noise Pollution (NP) has gained widespread recognition as a major concern that lowers the standard of living in urban places around the world. Over time, pollution has increased to a disturbing degree as a result of swift industrialization, urbanization, and various communication and transportation networks (Ozer et al., 2009; Gilani & Mir, 2021). According to the World Health Organization, noise is considered the third major type of hazardous type of pollution (WHO, 2005). Humans are negatively affected by noise pollution, which can lead to complaints of annoyance (Tong & Kang, 2021), loss of focus, sleep disorders with awakenings (Muzet, 2007), hearing loss, and cardiovascular problems. Other than damaging the hearing capability of people, it impacts mental state (Sahu et al., 2023), and activity issues and may cause injury to the heart, lungs, and urinary organs (Guha, 2022; Agarwal et al., 2009; Banerjee, 2012; Cyril & Bino, 2013). An increased risk of incident type 2 diabetes and dementia is also linked to long-term co-exposure to air pollution and road traffic noise (Hu et al., 2023; Yu et al., 2023). Sound is described in terms of the loudness and frequency of the wave. Loudness, also known as sound pressure level, can be represented in decibels (dB) units. On a logarithmic scale, a decibel expresses the relationship between the measured sound pressure level and a standard sound reference level (Ohiduzzaman et al., 2016). A portable device called a sound level meter is typically used to monitor noise levels and provides a single decibel measurement of the pressure that varies over time (Wang et al., 2004). A microphone, a processing segment, and a display unit make up the Sound Level Meter. The sound signal is transformed by the microphone into an equivalent electrical signal (CPCB, 2017).

Traffic noise is thought to be the loudest sort of noise created among all others. A significant source of noise emissions comes from motor vehicles (Banerjee et al., 2008; Nirjar et al., 2003).

Traffic noise prediction models represent diverse influencing factors to forecast traffic noise combined with the road network (Soni et al., 2022). Prediction of traffic noise in advance and preventive measures to reduce the impact can be employed with the help of noise models (Iglesias-Merchan et al., 2021; da Paz & Zannin, 2010; Cirianni & Leonardi, 2015). Noise models incorporated in software packages are more efficient, reliable and less time-consuming than field measurements (Petrovici et al., 2016).

Noise assessment can be done by different methodologies, namely modeling using statistical methods and by using simulation techniques (Salim & Saravanan, 2020). The design of the risk management process is aided by traffic noise prediction models, and noise mapping identifies the noise hotspot (Bostanci, 2018; Yilmaz & Özer, 2005; Mishra et al., 2021; Licitra et al., 2022). GIS noise mapping is a widely accepted tool for plotting (Prabhavathy & Anuradha, 2009; Gheibi et al., 2022; Esmeray & Eren, 2021; Naji et al., 2020). Dynamic noise mapping (Asdrubali & D'Alessandro, 2018), wireless acoustic sensor network-based approach (Alías & Alsina-Pagès, 2019), Internet of things (Liu et al., 2020) and digital signal processor-based acoustic sensors (López et al., 2020) and adjusted controlled pass by method (Moreno et al., 2023) are some modern inventions in the field of noise pollution.

The fuzzy expert system from MATLAB software was used to calculate the impact of road traffic noise on human job efficiency (Pal & Bhattacharya, 2012; Zaheeruddin & Jain, 2004). Artificial Neural Network (ANN) and Genetic Algorithm (GA) techniques were applied effectively for the noise assessment model estimation and validation in different areas (Manish et al., 2013; Rahmani et al., 2011). Machine learning algorithms were also implemented in the noise prediction models for the analysis of geographical specialities and the honking effects of vehicles (Alkheder & Almutairi, 2021; Singh et al., 2021). Statistical analysis of NP is a widely adopted technique. The correlation coefficients (r^2 value) between the predicted and observed values were calculated in the statistical analysis section (Chandran et al., 2005; Ibili et al., 2022). Individual calculations of the goodness of fit between the observed and calculated values can be made using the paired test, F test, and analysis of variance test (Mousavi & Sohrabi, 2018; Vijay et al., 2015; Moroe & Mabaso, 2022). Simulation techniques were used in some other cases for noise modelling (Ali & Albayati, 2022; Majid et al., 2015).

The measurement of noise parameters is essential for the assessment of NP. The noise parameters like ten percentile time exceeding noise level (L_{10}), fifty percentile time exceeding noise level (L_{50}), ninety percentile time exceeding noise level (L_{90}), equivalent continuous noise level (L_{eq}), Traffic Noise Index (TNI), and noise pollution level (L_{np}) are helpful to quantify the transportation noises enforced on the atmosphere.

A wide range of noise assessment research was carried out in Chennai city (Subramani & Sounder, 2016; Karthik & Partheeban, 2015). But there are very limited studies were executed for the outskirts of Chennai and there were no permanent noise monitoring stations in these areas. Intersection traffic noise is more related to the honking parameters of the vehicles (Khajehvand et al., 2021). The majority of economically developed cities create intersection-specific traffic noise models (Yadav et al., 2023). Indian small cities lack specified models where categorized vehicle composition plays a major role. This study aims to analyze the influence of NP on the health conditions of the inhabitants and conduct a health survey of noise exposure risk on the residents of the research region.

The major goals of this study are (1) to monitor traffic noise from different signalized and unsignalized intersections during peak and off-peak time for the assessment of noise indices and compare the obtained noise parameter levels with the standard values by CPCB and WHO for the evaluation of the health conditions of the residents (2) to evaluate the correlation of L_{eq} with different vehicle composition and noise indices for the valuation of annoyance levels and changes in the community and background noise level (3) to conduct a qualitative REA survey for the validation of the results from statistical analysis

2. Materials and methods

2.1. Study area

Chennai is one of the rapidly developing urban cities in Tamil Nadu. The city has around five million registered vehicles and the compound annual growth rate of the registered vehicles stood at 10.1 percent. Chennai has topped the vehicle density in India with 2093 vehicles per Km road length. As per the latest report from CPCB, Chennai is considered to be the noisiest city in India (Chaitanya, 2020). The major signalised intersections chosen for the study are Navallur and Sholinganallur junctions. The unsignalized intersections taken are Perumbakkam-Medavakkam main road and Vandalur-Kelambakkam road (Figure 1). The selected roads are bituminous and in good surface condition with a plain topography. The traffic flow is a mixed and heterogeneous pattern.

2.2. Data collection and methodology

The data such as noise levels, categorized traffic count, and road characteristics were collected from the research region (from June 2021 to Dec 2021). A pilot traffic vol-

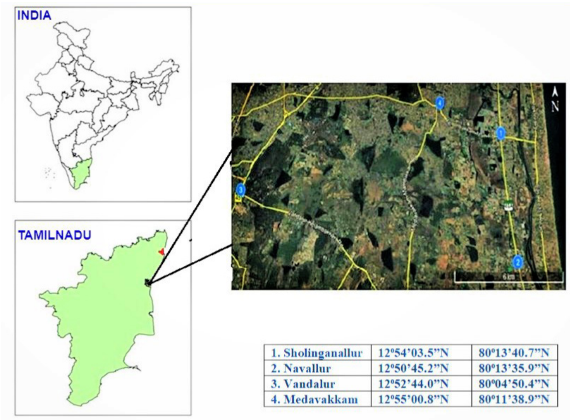

Figure 1. Location map of research area (source: Google Earth, 2022)

ume survey was conducted for a week to decide the peak and off-peak hours from all these road stretches. The peak hours were identified as 9 AM to 10 AM, 5 PM to 6 PM, and 9 PM to 10 PM. Correspondingly the spotted off-peak hours were 6 AM to 7 AM, and 1 PM to 2 PM. During this period, all the roadways' traffic volumes were analysed. Although there are other methods for measuring traffic volume, the video camera method is utilized in this instance since it is more accurate and trustworthy. A video camera was used to capture the amount of traffic, and the computer system's recorded footage from cameras was used to tally the number of vehicles. A video graphic camera was fixed at elevated locations within the nearby building to record the arrival and departure of vehicles in a particular area. The camera was set up to capture the road with the greatest possible coverage in both directions. The vehicles were categorised as 2 wheelers, three-wheelers,

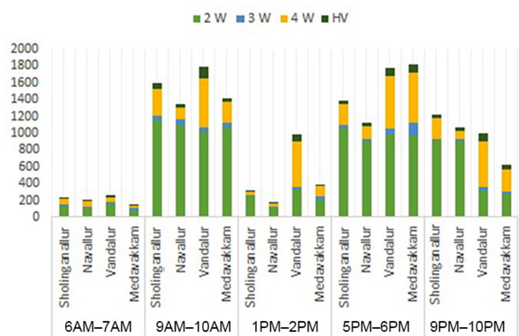

Figure 2. Traffic volume during different time intervals at selected sites

four-wheelers (including Light Commercial Vehicles (LCV), minibuses) and heavy vehicles (including buses, trucks and trailers) Figure 2 illustrates the average categorised traffic volume count at different junctions during the monitoring time.

Daily from Monday through Sunday, the noise levels were measured at intervals of two minutes per hour during peak and off-peak hours (ISO 1996-1). A class I sound level meter was used for noise monitoring. It was positioned 10 meters from the centre of the road and 1.5 meters above the ground (Ascari et al., 2022; Vijay et al., 2015). The readings were taken in a fast response mode and the minimum and maximum values were noted continuously. Table 1 displays the highest and lowest noise levels measured at signalised and unsignalized junctions during the monitoring period. According to Table 1, the average maximum noise level is more than 100 dB(A) at Vandalur intersection during morning and evening peak hours. Likewise, at the Medavakkam intersection, the noise level exceeds 100 dB(A) throughout the evening peak hours.

Several noise index values, including NC, L_{eq}, and L_{np}, are calculated using the noise data gathered from the research region. The noise values observed from the study area are compared with CPCB and WHO standards. Using the R studio 4.2.2 package, the correlation between different noise parameters is examined and the graphs plotted establish the outcomes.

3. Results and discussion

3.1. Noise Indices Calculation

To determine the NP levels, NP indices were computed using the Gaussian percentile. The sampled data were used to generate various noise percentile values, such as L_{10}, L_{50}, and L_{90}. Using these parameters, NC, L_{eq}, and L_{np} were evaluated for the chosen research area (Tripathi et al., 2006). These values are compared with the permissible values of the CPCB and WHO norms.

Noise climate, which is determined by Equation (1) is the span over which the sound levels vary within a time.

$$NC = \left(L_{10} - L_{90}\right), \tag{1}$$

where, L_{10} = the levels which exceeded 10% of the calculated time in dB(A); L_{90} = the noise levels which exceeded all 90% of the measuring time in dB(A). Equivalent continuous noise level over a given period is measured using Equation (2)

Table 1. Comparison of maximum and minimum noise levels from the study area

Location	6 AM–7 AM		9 AM–10 AM		1 PM–2 PM		5 PM–6 PM		9 PM–10 PM	
	L_{max}	L_{min}	L_{max}	L_{min}	L_{max}	L_{min}	L_{max}	L_{min}	L_{max}	L_{min}
Sholinganallur	82.41	76.34	91.17	77.74	87.99	78.9	94.35	78.82	87.1	78.3
Navallur	81.66	75.33	94.93	82.48	88.15	78.89	82.41	76.34	84.2	74.1
Vandalur	80.41	72.3	105.2	76.3	98.5	79.7	107.1	83.7	80.1	77.1
Medavakkam	78.9	70.5	105	76.06	99	77.6	101.3	77.9	87.5	76.4

$$L_{eq} = L_{50} + NC^2 / 60, \quad (2)$$

where, L_{50} = the levels which exceeded for the duration of 50% of the measuring time in dB(A).

Equation (3) is used to measure the traffic noise index, which is used to calculate the degree of variance (degree of aggravation) in a traffic flow. NP level (L_{np}) which describes community noise is determined by Equation (4).

$$TNI = 4\left(L_{10} - L_{90}\right) + L_{90} - 30 \text{ dB}; \quad (3)$$

$$L_{np} = L_{eq} + \left(L_{10} - L_{90}\right). \quad (4)$$

The traffic noise indices at research regions were evaluated and Figures 3 and 4 show the pattern of variation of the derived noise indices for the signalised and unsignalized crossings.

During peak hours, the key noise metrics such as L_{eq}, L_{10}, L_{50}, L_{90}, and L_{np} from both signalized intersections reached over 100 dB(A) (Figure 3). This might be caused by the heavy traffic and the region's residents' propensity for excessive honking. Both of the unsignalized intersections' noise index levels during morning and evening rush hours were close to 100 dB(A) (Figure 4). Heavy vehicles generate strong noise than lighter vehicles due to high axle load (Shukla et al., 2009). The greater noise parameter values were caused by the higher percentage of heavy vehicles as compared to the other categories. The other increased noise parameters were also caused by uncontrolled travel patterns from unsignalized junctions.

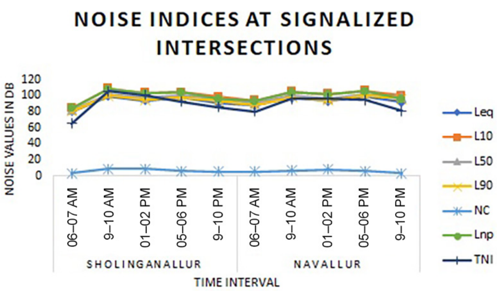

Figure 3. Different noise indices at signalized intersection during the monitoring period

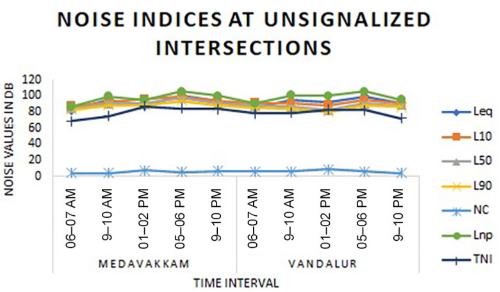

Figure 4. Different noise indices at unsignalized intersections during the monitoring period

3.2. Comparision with CPCB and WHO standards

The CPCB is a legal organisation under the Ministry of Environment, Forest and Climate Change (MoEFCC). It was established in 1974 under the Water (Prevention and Control of Pollution) Act, 1974. The allowable standard noise level in India has been determined by CPCB for various locations. The permitted maximum in industrial areas is 75 dB(A). It is 65 dB(A) in commercial sectors and 55 dB(A) in residential areas. A separate land use zone known as the "silent zone" encompasses the regions that are located within 100 meters of schools, colleges, hospitals, and courthouses. In this location, daytime noise levels are limited to 50 dB(A) (Table 2). The daytime refers to 6.00 AM to 10.00 PM and the night time is from 10.00 PM to 6.00 AM.

Table 2. Standard noise levels by the Central Pollution Control Board (source: Ministry of Environment and Forests, 2000)

Zone	L_{eq} in dB	
	Day	Night
Industrial	75	70
Commercial	65	55
Residential	55	45
Silence	50	40

The land use zones in all the study regions are commercial type, whose specified daytime noise level as mentioned was 65 dB(A). According to the comparative chart of average noise levels with CPCB standards (Figure 5) L_{max}, L_{min} and L_{eq} values are higher than the permissible standard levels in all the selected areas.

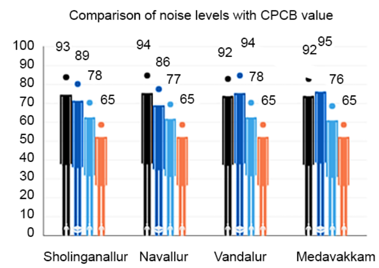

Figure 5. Comparative chart of observed values with the standard value by CPCB

TNI is an evaluation index for traffic noise created by combining noise levels, which has a stronger link with displeasure. It is derived from the assumption that high noise level fluctuations over time are the leading factor in traffic noise annoyance (Shalini & Kumar, 2018). L_{np} be established to assess the annoyance brought on by road traffic noise. It is defined as the sum of L_{eq}, and the rise in annoyance caused by fluctuations in that level (Robinson, 1971). The permissible limits for TNI and L_{np} are 74 and 88 dB(A) respectively (Langdon & Scholes, 1968; Robinson,

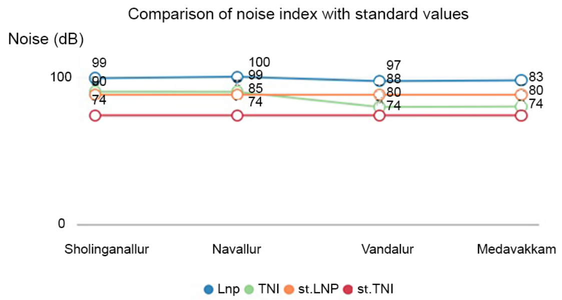

Figure 6. Comparative chart of noise index values with the standard value

1971). The deviation of the computed values of TNI and L_{np} from the reference levels (Figure 6) shows that all noise parameters exceed the limit, regardless of the intersection features.

WHO has established noise limit guidelines for each specific environment. Table 3 shows the standard limit values of noise levels for different environments. The co-existence of numerous elements, including age, gender, physical and psychological state of people, perception towards NP, level of exposure to NP, etc., makes it difficult to evaluate the health effects of NP (Kumari et al., 2023).

Table 3. Standard noise levels by WHO (source: WHO, 2005; CPCB, 2017)

Specific environment	Standard limit as per WHO guidelines (LAeq [dB])
Outdoor living area	50–55
Industrial, commercial, shopping and traffic areas, indoors and outdoors	70
Ceremonies, festivals and entertainment events	100
Public addresses, indoors and outdoors	85
Outdoors in parkland and conservation areas	Existing quiet outdoor areas should be preserved and the ratio of intruding noise to the natural background sound should be kept low

The perceived noise levels and associated health issues (Table 4) substantiate that normal traffic flow in the range of 80–90 dB(A) causes highly annoying health conditions and after 50 minutes of continuous noise from vehicles leads to hearing damage.

In all the selected study locations $L_{eq(A)}$ noise levels were found to be between 80 and 100 dB(A), which indicates that the residents' health is compromised. The validity of this will be evaluated with the help of statistical correlation analysis and health surveys.

3.3. Statistical analysis using R Programming

The amount of NP is determined by a variety of other factors in addition to the total number of vehicles (Mitchell, 2009; Wani & Jaiswal, 2010). In this study, compared to other times in the Vandalur crossroads, the average composition of heavy vehicles was higher during the evening peak hour (Figure 2). Similar to signalised crossings, unsignalized intersections have erratic traffic patterns and loud honking from passing cars. This is verifiable by correlation analysis.

Correlation analysis makes the relationship between two or more variables possible. Strong co-variability and correlation between the parameters are indicated by a correlation (r) value in the range of 0.7 to 1.0. If the correlation is between 0.5 and 0.7 and 0 to 0.5, respectively, it is considered moderate and weak (Nungate & Alam, 2022). The Pearson correlation coefficient is the most popular metric for evaluating linear correlations between two normally distributed variables. The connection between the equivalent continuous noise level, the number of vehicles per day, and the various vehicle categories are calculated in this section of the study. In the same manner, the co-variability between the noise parameters is calculated for the study region using the software "R". The pictorial depiction of the co-variability of noise level and vehicle combination (Figure 7) demonstrates the relationship between the L_{eq} and the categorized traffic volume.

A strong correlation of $r = 0.83$ manifested a strong relationship between the L_{eq} and the total number of vehicles presented in a day. Also, every type of vehicle shows

Table 4. Noise levels and associated health hazards (source: National Institute on Deafness and Other Communication Disorders, 2022)

Common source of noise	Average Sound Level (dBA)	Responses on exposure
Normal conversation, air conditioner	50–60	Comfortable sound
Dog barking, washing machine	60–70	Annoyance (non-hazardous noise)
Urban traffic (normal traffic flow)	80–90	Highly annoying
Motorcycle, truck traffic	95	Possible damage to hearing after 50 minutes of constant exposure
Headphones, train horns	100	Hearing loss is possible after 15 min
Rock concert, snowmobile riding	105–110	Hearing loss is possible in less than 5 min
Shouting or barking in the ear	110	Hearing loss is possible in less than 2 min
Standing close to sirens, firecrackers	120–130	Immediate pain threshold
Jackhammer, Jet taking off, dynamite blasts	140–150	Pain and ear injury

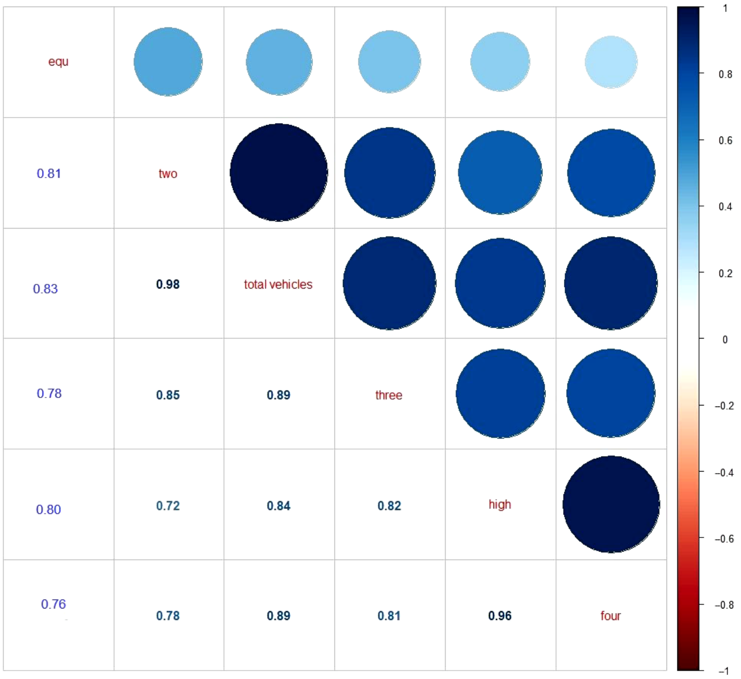

Figure 7. Correlation of L_{eq} and different categories of vehicles

a strong link with the noise index. Two-wheelers and three-wheelers display a very good positive correlation of r = 0.81 and r = 0.78 with L_{eq} in the particular road segments. Moreover, heavy vehicles and four-wheelers also express a strong relationship with r = 0.80 and r = 0.76 respectively. It suggests that in addition to the overall number of vehicles, the type of vehicles on the road at a given moment also affects the level of NP. Analysis and plotting are done to show the relationship between L_{eq} and all the other noise descriptors. Figure 8 displays the co-variability between the various noise parameters in the chosen road segments.

The noise descriptors and noise indices are strongly correlated, as seen by the correlation coefficient of $r \geq 0.7$. The noise indices L_{eq}, L_{10}, L_{50} and L_{90} have a strong correlation with TNI and L_{np} values. It indicates that the noise level has a drastic effect on a high degree of fluctuation in noise levels and annoyance from a particular road stretch. A strong correlation between these noise indices and TNI or L_{np} values suggests that variations in the average, high percentiles, median, and lower percentiles of noise levels are consistent with the overall noise pollution assessment. It indicates that the chosen indices effectively capture the different aspects of noise in the environment, providing a comprehensive understanding of NP levels over time.

Neighbourhood noises had to less impact on the noise parameters in the chosen stretches, as evidenced by the weak correlation (r < 0.5) between NC and L_{eq}. This

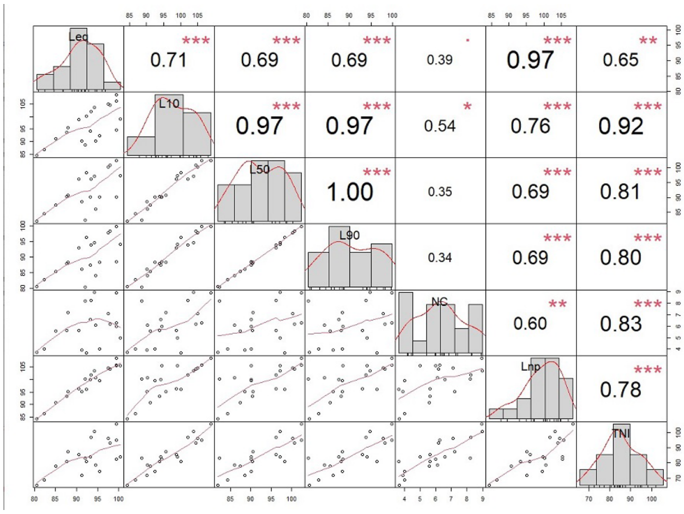

Figure 8. Co-variability of various noise parameters

indicates that the L_{eq} value obtained does not contain any disturbance from background noise. The vehicle traffic from the chosen roadways contributes to L_{eq}'s overall value. A low or negative correlation might indicate that the chosen indices are not effective in representing the actual levels of noise pollution. This could be due to various factors, such as the indices not being sensitive enough to certain types of noise, or the presence of confounding variables that influence the indices independently of noise pollution.

3.4. Questionnaire survey on the health of road users

Since L_{np} considers fluctuations in the sound signal, it is a more accurate measure of environmental pollution and it disrupts human systems on a physiological and psychological level (Swain & Goswami, 2014). Long-time noise exposure leads to a reduction in working performance (Vukić et al., 2021), learning impairment (Erickson & Newman, 2017), elevated stress levels (Rossi et al., 2018), increased hypertension (Dratva et al., 2012; Van Kempen & Babisch, 2012; Bluhm et al., 2007; Petri et al., 2021; Lee et al., 2019) and increased annoyance level (Licitra et al., 2016; Fredianelli et al., 2019; Miedema & Oudshoorn, 2001) in people residing in that area.

L_{eq} and L_{np} have a high positive association which can be substantially comparable with a questionnaire health survey. A questionnaire was prepared for long-term exposures (residents in the vicinity of the area, vendors, shopkeepers etc.) along the roads. The long-term noise exposures are surveyed using a self-administered questionnaire. People were split into two groups category:

- Group 1: Residents from the locality of the study stretches.
- Group 2: Shop possessors and vendors who spent a lot of time around loud traffic.

After a thorough literature review, the questionnaire is created with three captions (Rahman et al., 2022; Chowdhury et.al., 2010). A questionnaire with multiple-choice questions is developed for long-term exposures such as residents and roadside shop vendors to elicit accurate responses from the groups. Face-to-face interviewing is employed to obtain better results (Roopa & Rani, 2012; Jain, 2021). A random sampling procedure is used for the determination of sample size (Krejcie & Morgan, 1970).

The questionnaire has three sections that ask about the respondent's perception of noise, mitigation strategies, and understanding of pollution-related health risks. The "home interview" method is adopted for the residents living in the vicinity of the study area. The questionnaires are distributed among the vendors and helpers of different varieties of shops such as supermarkets, hotels, apparel, hardware and electronic shops in and around the study area. Respondent's ages, genders, education levels, driving records, and modes of transportation are all detailed in Section A's demographic data. Part B covers the frequency and time interval of respondent's travel through the study area, the purpose and mode of travel and the distance of the house or shop from the road etc. It also discusses respondents' level of annoyance and perception of people about noise and the level of noise perceived. The third section dealt with public awareness of pollution control strategies and the damaging consequences of NP on people's health. People's awareness of the detrimental effects of NP is rated as either yes, no, or don't know. Participants are asked to write down any health difficulties they had, including headaches, hearing troubles, sleep disturbances, and loss of concentration.

Out of the total 394 respondents, 75% were found to be men and 25% were female. 60% of the respondents were exposed to loud noise for more than 6 hours per day whereas 15% of the people stated continuously working or staying in the same place for more than 2 years. According to the frequency of loud noise (>80 dB) exposure by the general public (Figure 9), on the selected road stretches, 40% of respondents experienced occasional disturbances from loud noise, 30% reported experiencing NP frequently, and 2% people never faced NP. Of the interviewees, 40% had just completed their primary school, 31% had completed their secondary education, 25% were uneducated, and the remaining 4% were determined to be very knowledgeable about the ill-effects of noise pollution.

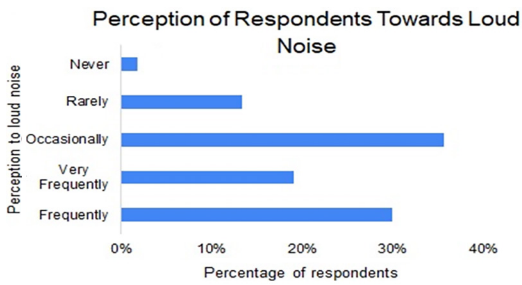

Figure 9. Respondent's perception to noise pollution

Table 5. Respondent's age group classification

Age group	Male	Female
15–21 years	27	13
21–35 years	85	77
36–60 years	80	59
>60 years	10	5

The respondent's age is divided into four categories using different age ranges (Abraham et al., 2022) for convenience (Table 5). The male and female respondents in the 21–35 years category responded efficiently and positively to the survey. The higher L_{np} values from the road study area indicate irrespective of gender both males and females are unhappy with high noise annoyance. The residents and shopkeepers of different age groups along the selected road stretches are observed with different types of health problems such as headache, ear pain, hearing problems, sleep disturbances, increased heartbeat, etc. (Table 6). The response results indicate that 40% of people from the young generation (15–21 years) experience headaches and ear pain during loud noise, and 20% face a lack of concentration problem. Ear pain and hearing problems (51%) are the main concerns in adults (21 to 35 years) whereas increased heartbeat (29%) due to peak noise plays a major health problem in middle aged people (36–60 years). Old aged people (>60 years) are suffered with ear pain and hearing problems and lack of concentration due to the continued exposure to NP.

Table 6. Respondent's health conditions due to noise pollution

Health hazards	Percentage of respondents			
	15–21 years	21–35 years	36–60 years	>60 years
Headache	40%	19%	16%	20%
Ear pain and hearing problems	40%	51%	16%	40%
Lack of concentration	0%	5%	15%	40%
Sleep disturbances	0%	23%	24%	0%
Increased heartbeat	20%	2%	29%	0%

The REA study indicates that road users on the selected road stretch experienced several health issues due to loud noise. These elements unquestionably contribute to the low quality of life of residents in the locality.

4. Conclusions

In the present study, both signalised and unsignalized junctions are monitored for noise during peak and off-peak hours. The findings demonstrate that at Vandalur, during evening peak hours (5–6 PM), the maximum noise level is observed to be 107.1 dB(A). The minimum noise value obtained is 70.5 dB(A) from Medavakkam intersection during the morning 6–7 AM. The comparative evaluation of maximum, minimum and equivalent noise levels from the selected stretches, with CPCB regulations, indicates that NP levels are rising quickly even in Chennai's suburbs. The estimation of traffic noise index and NP levels from the research area display alarmingly high results when compared with the standard limits.

The results of the statistical correlation study performed in R Studio show a significant positive association (r = 0.83), between traffic NP and the total number of vehicles per day. Similarly, types of vehicles on the road also exhibit a positive correlation with equivalent continuous noise levels in the road segments. The observed noise data and statistical analysis revealed that the percentage of type of vehicles has a prominent impact on the NP level.

The investigation of the correlation between various noise indices, including L_{eq}, L_{10}, L_{50}, L_{90}, TNI and L_{np}, carried out, shows a fairly strong relationship, except NC. A weak correlation of r = 0.39 validates the insignificant influence of neighbourhood noise on the study area's traffic noise levels. The higher correlation values of TNI and L_{np} with L_{eq} reflect the community noise level increment which has a significant impact on human physical and mental health condition. This is verified with a public perception REA survey. The response results indicate that 35% of people experience headaches during loud noise, and 2% feel ear pain and hearing problems. Lack of concentration (5%), sleep disturbances (27%) and increased heartbeat (10%) are the other health issues faced by the respondents.

The health survey of the pedestrians on the road stretches substantiated the fact that the high level of noise harmed the health of people. However, a more comprehensive perception survey is required covering long-term exposures and short-term exposures for better analysis. Noise prediction modelling will be further developed by considering the results from the questionnaire survey, road and traffic characteristics, environmental parameters etc. for the proper planning and development of the suburbs of Chennai. Statistical correlation analysis of the questionnaire survey will be performed to evolve a health-integrated noise prediction model for the study stretches. Future development will aim to evolve noise propagation maps by integrating the results from REA. The propagation maps will play a key role in the identification of noise hot spot areas, alternate route alignment, proper development of the city etc.

The rapid growth in population, commercial activity, and industrialisation are other factors that are expected to produce a major increase in the frequency of noise complaints shortly. Furthermore, now is the ideal time for the local government to adopt preventative measures to preserve lives in light of suburban Chennai's current and future development tendencies.

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