

# Environmental Noise in North Central Mumbai, India: Unravelling Human-Environmental Interactions

Vijaya Laxmi, Harshad Arote & Harish C Phuleria\*

Indian Institute of Technology Bombay, Maharashtra 400 076, India

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This study investigates traffic-related noise in residential zones within an educational institution in North Central Mumbai, India. It uses objective and subjective noise assessments to understand the relationship between objective noise levels, reported noise annoyance, and sensitivity. As there is limited research pertaining to the Indian context, this research study introduces a fresh perspective and seeks to contribute to a better comprehension of the impacts of noise pollution. Systematic noise monitoring was performed at designated sites (35), adhering to regulatory guidelines, and employing a tripod-mounted sound level meter. A well-structured questionnaire designed for community noise survey. The average noise levels in the residential community were 61.2 dB(A) during traffic non-rush hours. The study found that 33% of participants were highly annoyed by noise, with 18% being annoyed. Noise annoyance was influenced by objective noise levels, proximity to roads, and nearby parks or lakes. Among participants, 39% were highly noise-sensitive, with females and middle-aged residents being more sensitive. However, sensitivity had little impact on annoyance. The study suggests that noise management strategies should be incorporated into urban planning and educational institution policies, despite the presence of vegetation and noise barriers.

**Keywords:** Noise, Noise-annoyance, Noise-sensitivity, Objective-noise, Subjective-noise

## Introduction

The ongoing expansion of urbanization and the rapid pace of technological advancement have significantly contributed to societal progress. However, they have also intensified a critical environmental challenge like noise pollution. This pervasive phenomenon poses substantial risks to human health and well-being.<sup>1</sup> Noise is the term for unwanted sound, and it is an omnipresent factor in our day-to-day activities.<sup>2</sup> Noise characterization is very subjective to the person who is exposed to it. Since noise differs from other pollutants in terms of source and diffusion properties, it is referred to as an underestimated pollutant.<sup>3</sup> In urban environments, noise pollution emanates from a multitude of sources such as transportation, construction, community etc.<sup>4</sup> Traffic noise consists of various components, including propulsion noise from engines, transmissions, and exhaust systems, as well as interactions between the road and tires and aerodynamic noise.<sup>5</sup> Assessing traffic noise levels in Indian cities pose a challenge due to the diverse traffic condition characterized by Jam-packed vehicles of various types, varied road conditions, and a lack of traffic discipline.<sup>6</sup> Many cities and towns in India have

encountered significant traffic noise pollution, attributed to a substantial increase in new vehicles, limited turnover of older vehicles, inadequate road infrastructure, and urbanization. In the majority of residential area of Indian cities (Mumbai, Delhi, Kolkata, Chennai, Kerala, Jaipur) the road traffic noise levels typically surpass 70 dB (A).<sup>7</sup>

Higher road traffic sound levels within residential areas were correlated with increased probabilities of headache or migraine, annoyance, dizziness, pressure in ears, impaired hearing, heart palpitations or, tachycardia and heart disease.<sup>8</sup> Traffic noise from roads, airways, and railways induces irritation and discomfort, particularly while engaging in activities that demand focus and concentration.<sup>9</sup> The incessant noise from traffic poses a significant annoyance to individuals seeking rest at home, especially when it disrupts sleep, an essential element of human well-being, ultimately contributing to a decline in their quality of life.<sup>1</sup> Environmental noise leads to a sense of discomfort that is evaluated as perceived noise annoyance.<sup>10</sup> Annoyance, as a subjective and emotionally charged reaction to noise, encompasses feelings of irritation, frustration, and discomfort.<sup>11,12</sup> Noise annoyance stands out as the predominant external sign of accumulated stress in humans. It can be seen as a potential symptom of

\* Author for Correspondence E-mail: phuleria@iitb.ac.in

significant health issues and is generally described as a sensation of unhappiness that is thought to have an adverse impact on an individual or a group of individuals. The World Health Organization (WHO) recommends assessing the prevalence of noise annoyance and noise sensitivity by calculating the percentage of respondents highly bothered by the noise.<sup>10</sup>

Numerous global studies have identified a significant relationship between traffic noise exposure and various aspects of human health, including sensitivity to noise, feelings of annoyance, and overall quality of life.<sup>8,13,14</sup> Prolonged exposure to elevated noise levels leads to both physical and physiological harm, contributing to mental stress and overall well-being disruption. Traffic noise exposure may result in various negative health impacts, including sleep disorders with frequent awakenings, cognitive impairments such as learning difficulties and short-term memory issues,<sup>15,16</sup> raised potential for ischemic heart disease and hypertension,<sup>7</sup> elevated blood pressure, and decreased motivation and concentration, prevalence of tinnitus and its associated distress.<sup>8</sup> Despite relatively lower noise levels, individuals diagnosed with diabetes may still demonstrate increased blood pressure<sup>10</sup> in response to traffic noise exposure.<sup>5</sup> Even in cases where there is an rise of 5 dB (A) in night-time noise correlated with a higher prevalence of elevated diastolic blood pressure, particularly among individuals over the age of 65 and those more sensitive to noise.<sup>17</sup> Traffic noise also impacts children, as evidenced by a survey of 112 children in the UK, which indicates that noise induces annoyance and distraction, leading to mind-wandering during classes.<sup>15</sup> Moreover, recent findings by *González et al.*<sup>18</sup> have revealed a significant negative impact on pedestrians in urban areas in Spain, where traffic noise serves as the primary source of disturbance. The efficiency of human work in office spaces and commercial business centres located near busy roads is also negatively influenced by traffic noise. Recent research conducted in Jammu and Kashmir, India, indicates that the work efficiency of housewives is adversely impacted by higher perceived levels of traffic noise.<sup>19</sup> However, in India, few studies have been conducted related to traffic noise and annoyance. Research conducted in several cities, including Kolkata, Delhi, Jalgaon, Balasore, Ahmedabad, Jaipur, Chennai, and Bhubaneswar, reported that a high percentage (70 to 80%) of respondents expressed high annoyance due to traffic

noise and exhibited various symptoms such as sleep disturbances, mild hearing impairment, tinnitus, loss of concentration, frequent irritation, and hypertension.<sup>20</sup>

Previous research has predominantly focused on assessing the overall impact of noise in terms of annoyance and sensitivity. Further investigation into specific aspects of the impact of noise on individuals is necessary. The aim of the present study is to examine the influence of distance from noise sources, assess sensitivity and annoyance levels, and examine the correlation between these factors. This is particularly relevant in reference to rapidly growing countries like India. Given the limited research on the Indian context, this study introduces a novel perspective and aims to enhance understanding of the impact of noise pollution, considering the distance from noise sources. It acknowledges that the road network structure in rapidly growing countries differs from that of high-income countries, potentially leading to varied impacts of noise pollution. Consequently, it becomes essential to thoroughly investigate noise annoyance and sensitivity within the context of the association between noise and health. Understanding the intricate connection between noise levels and annoyance is essential in developing effective mitigation plans and ensuring the comfort and quality of life for communities. The current study is conducted to examine how varying levels of noise exposure impact degree of the annoyance and sensitivity in a residential community.

## Methodology

### Study Area

Mumbai serves as the administrative center of the Indian state of Maharashtra, situated along the Konkan coast on the western shoreline of India and characterized by a substantial natural harbor. The city is demarcated into two discrete regions, namely the Mumbai City district and the Mumbai Suburban district. The Indian Institute of Technology, Bombay (IIT Bombay), constitutes a prominent educational institution situated in the Mumbai Suburban district, with geographic coordinates at latitude of 19°7'50.18"N and a longitude of 72°54'53.84"E. The campus is characterized by abundant greenery, flanked by a hill on one side and Powai Lake on the other, while the Jogeshwari Vikroli Link Road (JVLR) serves as a main road. Functioning as a sizable township, the institute provides accommodation for both students and staff within its extensive residential area. For the purposes of this study, the entire residential area was categorically outlined into three segments,

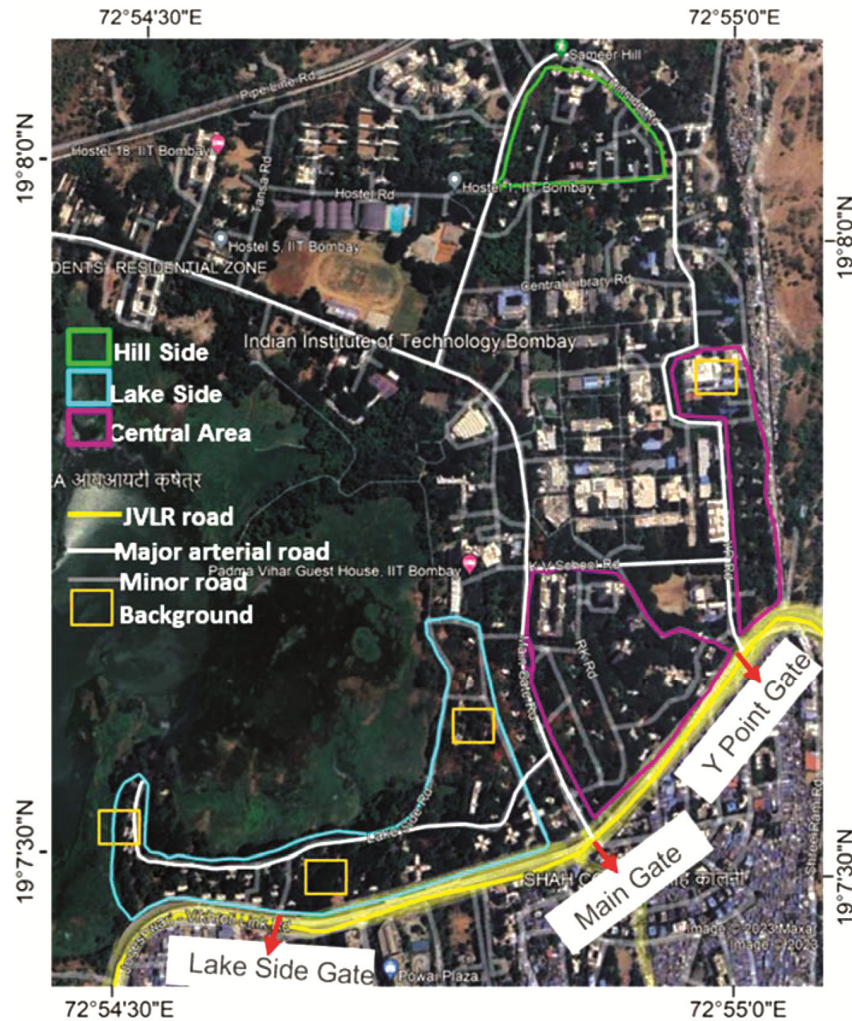


Fig. 1 — Location map of the study area

specifically identified as the Lake Side, Hill Side, and Central Area, as shown in Fig. 1.

#### Data Collection

This section encompasses both the collection of noise data through noise monitoring and a questionnaire survey.

#### Noise Level Measurements

Noise monitoring was conducted according to regulatory guidelines at specific locations utilizing a tripod-mounted sound level meter. A total of 35 sites (Near JVL main road, Major arterial road, Minor road and Background) were selected where short-term noise measurements were carried out for a day inside the campus during rush hour (08:00 to 11:00 and 17:00 to 20:00) and non-rush hour (14:00 to 17:00). These 35 sites were selected to give a good spatial variability covering all the 3 (Lakeside, Hillside, Central area)

locations of the residences. Some measurements were taken at the quieter locations near the lakeside and hillside to record background noise levels.

#### Survey of Social Attitudes towards Noise

A detailed questionnaire was conducted in the residential area of the campus to assess levels of annoyance and sensitivity related to road traffic noise amongst 61 individuals and at the same time information regarding home characteristics and individual behaviour that may affect noise exposure was collected. Target participants were of age in the range of 18–70 years. Community noise surveys were conducted following the guidelines set forth by the International Commission on the Biological Effects of Noise (ICBEN). Sampling locations for the urban noise survey were selected using a receptor-oriented method. Noise sensitivity and annoyance are analyzed by using the Noise-Sensitivity and Annoyance-Questionnaire scales respectively.

In the present study, noise annoyance was evaluated through a questionnaire survey. The questionnaire consists of 19 questions (total 64 including sub-questions) which are divided into 4 sections, House characteristics, work & education, exposure and disturbance. The questionnaire was given to participants with some guidelines and a consent letter. After a sufficient time or time given by the respondents, these residences were revisited and the questionnaire and consent letter were collected. Noise annoyance was evaluated by utilizing a scale with 11 points, ranging from 0 to 10.<sup>(21)</sup> The midpoint of a range from 0 to 10 is easily and accurately assumed to be 5, unlike for 1 – 10 where it is 5.5. Responses to annoyance were hence categorized as not annoyed (0–2), moderately annoyed (3–4), annoyed (5–7), and highly annoyed (8–10). Participants indicated their sensitivity to noise using the well-established 11-point IC BEN scale and responded to 10 questions having an overall score of 60. Based on their participant's noise sensitivity scores (out of 61) were categorized into 4 types not sensitive (0–14), moderately sensitive (15–29), sensitive (30–44), and highly sensitive (45–60).

#### Noise Data Analysis

Many kinds of statistical methods have been applied to analyze the community's reaction to noise. Simple regression models only take into account factors affecting directly and neglect factors affecting indirectly.<sup>22</sup> RStudio version 0.98.1091 which is open-source software was used for analysis and creating plots along with Microsoft Excel. In the current study, data was first analyzed to give a descriptive summary like mean, median, Inter-Quartile Range (IQR) etc. Direct correlation between noise levels (both subjective and objective) and traffic data was calculated using Pearson's regression coefficient and graphs. In some cases, Spearman's correlation coefficient was used. Relation between categorical variables was assessed using the Chi-squared test.

#### Results

This section provides an overview of noise levels during both rush and non-rush hours at all locations. It also discusses the effect of noise levels on annoyance and sensitivity, explains the correlation between noise levels and traffic attributes, and elaborates on the connection between annoyance and various factors, including both acoustic and non-acoustic aspects.

#### Noise Levels During Rush and Non-Rush Hour

Both rush and non-rush hour noise levels were monitored specifically at all sites and compared.

Mean noise levels during non-rush hour were 61.6 dB (A) with a median of 61.1 (IQR-5.28) whereas during rush hour mean noise levels were 62.7 dB (A) with a median value of 62.2 dB (A) (IQR – 5). Pearson's correlation R between rush and non-rush hour noise levels at these sites was 0.9 thereby displaying a strong correlation between rush and non-rush hour noise levels at a given point. A strong correlation between rush hour and non-rush hour noise levels can conclude that noise levels measured during any one-time window are enough to represent the noise levels at that point and compare it with other points.

The variations in noise levels across different areas during both rush and non-rush hours are illustrated in Fig. 2. It shows that noise levels are higher at the JVLR area which is close to the main road followed by major arterial road, minor arterial road and background. This spatial variability in noise levels is exhibited due to varying distances from the road and measuring site, presence of trees, volume, width of the road, and number of lanes.

It is also observed that the difference between rush hour and non-rush hour noise levels is not much at JVLR sites but the difference increases as we go to major road and even more at minor road sites. It can be said that as noise levels are logarithmic and as seen previously are better correlated with a log of traffic volume, a change in traffic volume when it's already high won't make much difference in noise as compared to that when it is extremely low. A map depicting the spatial variation in noise levels within the campus is presented in Fig. 3. It is observed that noise levels ranged between 55 dB (A) and 65 dB (A).

#### Survey of Social Attitudes towards Noise

Around 130 questionnaires were distributed in different residences of which only 61 filled questionnaires were returned with a response rate of

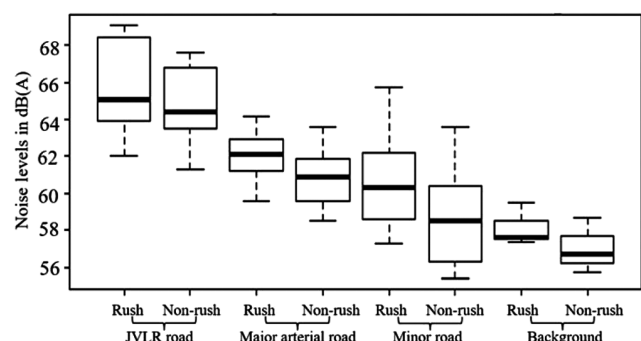


Fig. 2 — Noise levels in various locations during both rush and non-rush hours

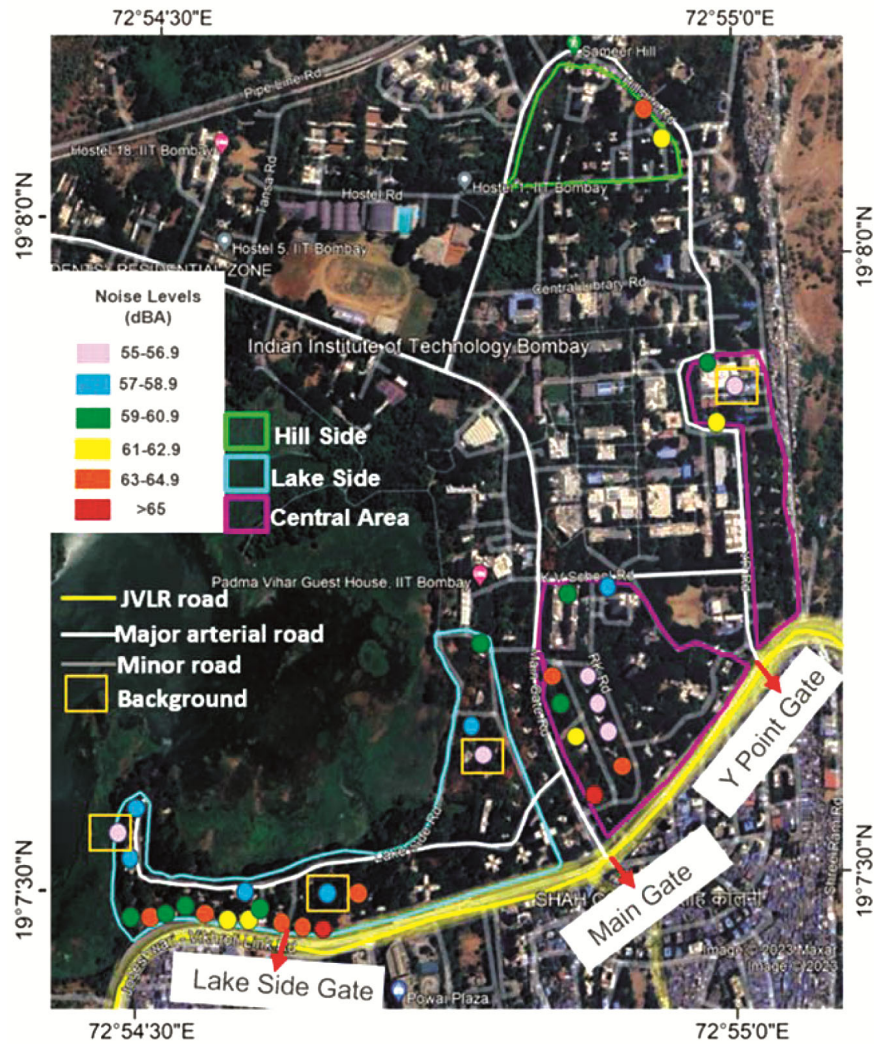


Fig. 3 — Map of the study area showing spatial variation in noise levels

47%. Out of all the participants 60.6% were full-time employed, 3.2% had worked part-time, 8.2 % were self-employed, 1.6% were students and 6.5% were retired while 16.4% were housewives. Out of the total participants, 37.7% reported experiencing disruptions and waking up at least once every night. Among these individuals, 43.5% considered traffic noise as the reason for the disturbance while 13% and 39.1% stated neighbourhood noise and other reasons respectively. Whereas 47.5% claim to wake up rarely during the night of which 20% considered traffic noise as the reason for their disturbance.

A total of 36% of participants closed their windows always during sleeping hours while 23% rarely closed their windows during sleeping hours and 29.5% never closed their windows. Only 5% population often used earplugs to reduce noise during nighttime.

#### Noise Annoyance

Based on the differentiation scale out of the entire sample size 32.8% of people are highly annoyed, 18% are annoyed, 9.8% are moderately annoyed and 39.3% are not annoyed due to traffic noise. Apart from traffic noise, 22.9% and 8.2% sample population claimed to be highly annoyed due to construction and commercial or neighbourhood activities respectively. Approximately 9.8% of the population reported feeling annoyed because of permanent indoor installations such as ventilation fans, plumbing, snoring from other members and any other indoor sources. The total annoyance rating attributable to traffic noise among participants was distributed as 59% for males and 41% for females. After traffic noise, the construction noise was ranked as the second most annoying, followed by commercial and neighbourhood noise.

**Noise Annoyance with Acoustic Factors**

Annoyance amongst participants is also assessed based on the traffic noise exposure and towards various types of locations, as exemplified by the case of campus noise distinctions. Non-rush hour traffic noise measured at the façade of a given apartment was assigned to the annoyance response of the participants staying in that apartment. Mean non-rush hour noise level exposure to the participants at varying annoyance ratings was calculated and plotted. A good positive Pearson's correlation coefficient R of 0.83 was found between mean noise levels and annoyance rating which demonstrates a clear positive relationship between noise levels and noise annoyance. So, this study concludes that the noise levels increase is accompanied by noise annoyance.

Annoyance amongst the population for different categories of sites as differentiated in the case of campus noise is shown in Fig. 4. It unveils that as the distance of the home from the main road decreases, there is a corresponding increase % in the highly annoyed population. Reduction in annoyance can be the presence of green cover, noise barrier along the periphery and also dominance of constructional or neighbourhood noise as we move away from the main road which might overshadow annoyance due to traffic noise.

**Noise Annoyance with Non-Acoustic Factors**

An analysis is carried out to assess the level of annoyance among participants, taking into consideration both gender differences and the presence of quieter surroundings. The percentage of males highly annoyed was 33.3% whereas females were 32% such case of males being highly annoyed.

A study was conducted to examine the relationship between noise annoyance and the proximity of roads in front of both the living room and bedroom. It was found that for the presence of a major road in front of the living room, the P value of 0.0142 while in the case of the presence of a major road in front of the bedroom and annoyance, the P value of 0.0025, both the results giving statistics significance. An assessment was also conducted to check the correlation between noise annoyance and the visibility of a park or lake in front of the living room and bedroom. The investigation of whether there was a park or lake in front of the living room resulted in a P value of 0.0277, while the assessment of whether there was a view of a park or lake from the bedroom window produced a P value of 0.0166. Study reveals

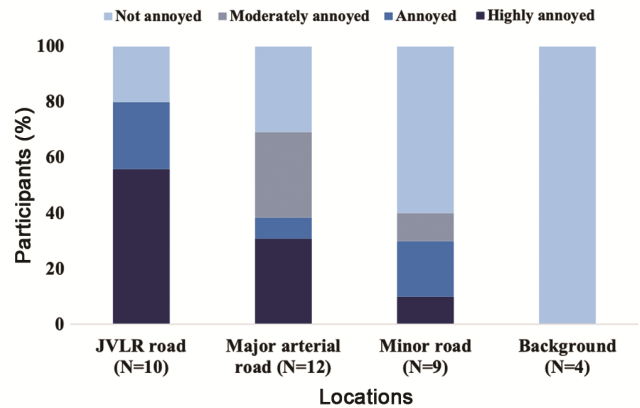


Fig. 4 — Responses to annoyance from road traffic noise sources

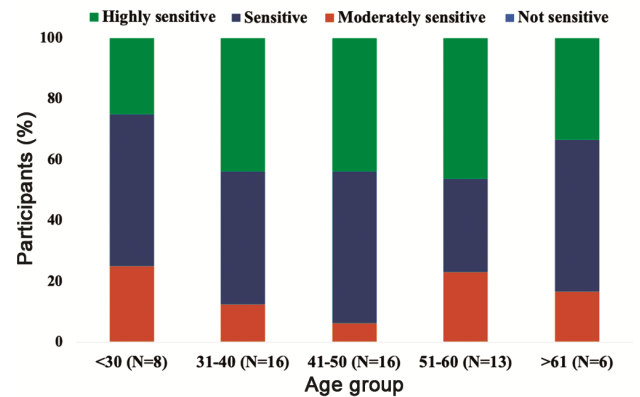


Fig. 5 — Average noise sensitivity across various age groups

that access to the quieter side of residence or visibility of noise sources affects noise annoyance.

**Noise Sensitivity**

Sensitivity expressed as a percentage of the population for different age groups is shown in Fig. 5. It provides a clearer view of the data, making it easier to understand the sensitivity levels across different age groups. In all age groups, there are no individuals categorized as "Not sensitive." In the under-30 age group, 25% of individuals show moderate sensitivity, 25% display high sensitivity, and the remaining 50% fall into the category of being sensitive to noise. In both the 31–40 and 41–50 age groups, 43.75% of individuals are highly sensitive. It is noteworthy that the highest percentage, 46.2%, of highly sensitive individuals is observed in the 51–60 age group, while in the age group above 61, the percentage of highly sensitive individuals decreases to 33.3%. In the 51 to 60 age group, 30.8% of individuals are classified as sensitive, and this percentage increases in the age group above 61 to 50%. Mid-aged (34 to 56 years old) people are comparatively more sensitive to noise levels as compared to young and elderly people.

Table 1 — Percentage of participants experiencing annoyance and sensitivity

	Highly annoyed	Annoyed	Moderately annoyed	Not annoyed	Total
Highly sensitive	16.4	6.5	4.9	11.5	39.3
Sensitive	14.8	8.3	4.9	18.0	46.0
Moderately sensitive	1.6	3.3	0	9.8	14.7
Not sensitive	0	0	0	0	0
Total	32.8	18.1	9.8	39.3	100

Noise sensitivity is considered as a function of age and gender. Study reveals that for the lower age group difference between sensitivity for the two genders is not much and that men are more sensitive to noise, but for mid age group and upper age group difference in noise sensitivity for both genders is higher and females are more noise sensitive. Women in the mid and high age group are mainly housewives and hence spend the majority of their time indoors which can be attributed to them being more noise-sensitive than their counterparts in the same age group.

#### Noise Sensitivity and Annoyance

Noise annoyance and sensitivity were categorized and the percentage of participants falling in each category is mentioned in Table 1. The percentage of highly annoyed and annoyed participants being highly sensitive and sensitive is high. The value of  $R^2$  between annoyance and mean noise sensitivity is 0.15. By normal standards, the association between the two variables would not be considered statistically significant.

#### Discussion

Traffic-related noise has been a major source of environmental noise. Noise pollution has adverse effects on living organisms and stands as a significant source of annoyance and nuisance.<sup>4</sup> As there is a scarcity of literature pertaining to the Indian context, this research study introduces a fresh perspective and intends to contribute to a better comprehension of the impacts of noise pollution. This study aimed at carrying out noise exposure in residential apartments within an educational institution. Objective as well as subjective noise was assessed inside campus. Objective noise assessment reveals that average non-rush hours noise levels inside campus were 61.2 dB(A) which is above the prescribed limit by regulations of 55 dB(A) for residential areas. In a study conducted by the Maharashtra Pollution Control

Board (MPCB), India in 2021, it was found that residential areas in Antop Hill and Shivaji Park, Mumbai, experienced higher daytime noise levels compared to residential apartments within an educational institution. Additionally, several residential areas in Pune, Thane, Kalyan, Kolhapur, Mira-Bhayander, and Vasai-Virar also exhibited higher noise levels, while Amravati and Nashik recorded slightly lower noise levels.<sup>23</sup> Residential noise levels reported in the current study were higher than those in Toronto Canada,<sup>24</sup> and outdoor noise levels in Beascon, France while lower than those reported in residential areas of Assuit, Egypt, Dalin in China.<sup>25</sup> Noise levels in university campuses in Brazil studied by Vijay *et al.*,<sup>6</sup> were found to be equal. The higher noise levels in the vicinity may be linked to the traffic noise from the neighbouring JVLR road. The leading contributors to this noise pollution include large vehicles, excessive horn usage, and the constrained width of the road.<sup>26,27</sup> Noise levels in the residential area of the current study were found to be lower than noise levels in the residential zone of many of the Indian cities and a few global cities which may be attributed to good coverage of trees inside the campus which helps in reducing noise levels.

Furthermore, Spatial variability is exhibited in noise levels due to the presence of noise barriers at the periphery, arterial road and green coverage inside the campus. This pattern has also been observed and documented in studies conducted by Baclet *et al.*<sup>28</sup> This study demonstrates how crucial it is to take geographic diversity in noise levels into account when developing, regulating, and planning urban and campus environments. It encourages more practical methods for reducing noise, which helps to improve the quality of living and working environments.

Subsequently, a questionnaire survey was conducted to assess noise annoyance and sensitivity amongst 61 adult residents (aged 18 to 70). Out of the total participants, 32.8% were highly annoyed due to traffic noise and 18% were annoyed thereby summing up to 50% of the population who are annoyed due to traffic noise thereby making it a cause of concern. Amongst Indian cities, Gwalior had a similar % of highly annoyed due to traffic noise while Varanasi,<sup>29</sup> Nagpur,<sup>30</sup> Roorkela,<sup>31</sup> Asansol<sup>32</sup> had a higher percentage of annoyed subjects. The reduced percentage of individuals experiencing high levels of annoyance in the present study may be attributed to the presence of green spaces and a lake within the

campus, which contribute to stress reduction and lower noise levels. Additionally, the noise barrier constructed within the campus along the JVLR serves to diminish noise levels and, consequently, lessen annoyance.

The percentage of individuals highly annoyed by road traffic noise in the sampled population was greater than what was reported in various other locations, including Germany,<sup>33</sup> Auckland,<sup>34</sup> and Stockholm.<sup>35</sup> In contrast, the average annoyance level due to traffic noise among respondents in Amsterdam was lower than the findings of the current study. Moreover, the percentage of annoyed individuals was lower in Brazil.<sup>31</sup> It's worth noting that, with the exception of Calabar and Enugu, where 58 cities were studied in Nigeria, the remaining cities showed a higher percentage of highly annoyed individuals in the sample population, along with Auuist in Egypt.<sup>32</sup> Similarly, the percentage of people experiencing annoyance was also higher in Amman, Jordan.<sup>36</sup>

Moreover, it was found significant relationships between exposure and response for high levels of sleep disturbance caused by traffic noise, where the sleep-related questions specifically referenced noise. Chronic inadequate or disrupted sleep is thus a matter of public health concern, with sleep disturbance being recognized as a significant adverse outcome of exposure to environmental noise. There was a higher likelihood of experiencing awakenings, difficulty falling asleep, or disrupted sleep due to traffic noise and neighbourhood noise and other reasons.

There is limited literature available on the topic of how traffic noise and living close to roads are linked to feelings of annoyance. In our study, a positive connection was found between traffic noise annoyance and mean measured noise levels ( $R = 0.83$ ) along with the proximity of residences to the main road. This study reveals that the noise levels increase is accompanied by noise annoyance. It was also observed that categorizing noise annoyance gives a better correlation with noise levels rather than simply using the annoyance score. This outcome is consistent with the results stated by Pierrette *et al.* and Yildiz *et al.*<sup>34,37</sup> Among non-acoustic parameters association between noise annoyance and the presence of the main road in front of the living room or bedroom, visibility of a park or lake from the living room or bedroom was statistically significant. The research indicated that as the distance between houses and the main road decreases, the percentage of highly

annoyed individuals increases. The study emphasizes the influence of residential location on people's well-being and shows the potential need for urban planning measures, noise mitigation techniques, or policy considerations to mitigate the detrimental impacts of proximity to roads on inhabitants' quality of life. It provides insightful information for legislators, urban planners, and researchers in order to address noise-related problems and improve the livability of urban areas.

In addition to noise annoyance, it was observed that among the residents included in the sample, the average noise sensitivity score was 40.5 out of 60, with 39.3% of respondents classified as highly sensitive (with a noise sensitivity score exceeding 45). This high sensitivity to noise was particularly noticeable among middle-aged individuals, a finding that aligns with the results of studies conducted by Rompel *et al.*<sup>38</sup> The observation draws attention to a demographic-specific sensitivity to noise, which may have practical consequences for healthcare, urban planning, and policymakers to improve the well-being of middle-aged people and maybe enhance the quality of life in cities as a whole.

In terms of gender-based sensitivity distribution, it was observed that women who predominantly stay indoors (homemakers) exhibit higher sensitivity levels compared to men. This observation is consistent with the outcomes reported by Park *et al.*<sup>39</sup> It focuses attention on the need for more specialized and all-inclusive methods of addressing noise sensitivity. Furthermore, noise annoyance and sensitivity did not show a statistically significant correlation similarly reported that the degree of noise annoyance did not seem to be related to the degree of noise sensitivity, at least not in a way that could be regarded as statistically significant. Therefore, it is necessary to conduct further statistically relevant studies to investigate the association between noise annoyance and sensitivity, which will help in gaining a clearer understanding of this complex issue. For future research, it may be beneficial to incorporate a health impact assessment that considers real-time noise measurements as well as individuals' personal psychological reactions to noise during process of urban planning and management.

## Conclusions

This study assessed traffic noise impacts outside residential apartments through field observations. Around 50% of respondents reported high annoyance,

and 40% showed sensitivity, with middle-aged individuals and women being more sensitive. Noise annoyance was influenced by noise levels, proximity to roads, and nearby parks or lakes, decreasing with greater distance from roads. Despite vegetation and noise barriers, high noise levels persist. This research is the first in India to examine this relationship and promote noise management strategies. The study population was limited to residents of IIT Bombay.

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