

Noise Monitoring and Perception Survey of Urban Road Traffic Noise in Silence Zones of a Tier II City—Surat, India

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Abstract This study evaluated the impact of urban road traffic noise on roadside schools, colleges, hospitals, and a court through both in-field measurements and an on-site questionnaire survey. It demonstrates that there are problems and non-compliance, and that the high levels of noise cause annoyance. Three secondary schools, three colleges, three hospitals, and one court building designated as a silence zone under CPCB standards were targeted, located near various roads in the Surat city in Western India. Noise levels were measured within the 100 m of silence zone. The results demonstrated that noise pollution at roadside schools, colleges, and hospitals was reasonably severe, school and college noise levels considerably correlated with the road traffic noise. The study area's equivalent noise level was 79.0 dBA, and the maximum noise level across all ten roads is 111.6 dB (A). During the evening (peak) hours, the road is a flexible pavement (Dumas-Athwa line Road). The minimum noise level measured across all ten location roads is 48.4 dB (A). It is during the evening hours at Lancer army school road. The difference between the maximum and minimum noise levels is very high at all locations. The minimum noise level is still more significant than the permissible noise level of 50 dB (A) across all locations. The on-site questionnaires revealed that people in this area, students, lawyers, and teachers, felt disturbed by the road traffic noise, and that the intensity of disturbance increased with the increase in traffic levels.

Keywords Silence zone · Urban road traffic noise · Noise monitoring · Perception survey

Introduction

Noise pollution (environmental noise) can be defined as noise propagation having adverse effects on humans and the surrounding environment [1]. Traffic noise is an extent source of noise in urban cities in a country like India. Poor urban planning may increase noise pollution, side-by-side construction, and other activities, resulting in noise pollution in residential areas [2]. The city has so many suburban and arterial roads that help in the efficient connectivity of each part of Surat city. Surface transportation plays a vital role in the generation of traffic noise [3]. In Surat city, several silence zones like schools, colleges, hospitals, and courts lie in heavily congested traffic areas, where noise levels frequently exceed the permissible limit given by CPCB [4]. Noise control is an environmental problem of the first magnitude nowadays [5]. This study's main purpose is to investigate the noise levels at various silence zones of Surat city by noise monitoring and study the perception of people working in these schools, colleges, and hospitals in the form of a perception-based social survey questionnaire [6]. In this study, noise monitoring and its analysis of the roadside schools, colleges, hospitals, and a court have been done in the Surat city of Gujarat state, India. A crowded and busy stretch has been selected for noise monitoring, and assessment is done for morning, afternoon, and evening sessions. Urban traffic noise can cause hazardous health problems in human beings, not only in the form of auditory impairment but also in hypertension, high-stress levels, tinnitus, sleep disturbances, etc. [7, 8]. Exposure to traffic noise is a risk factor for people's

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Fig. 1 Photographs of Signboard of Silence Zone, indicating prohibition of horn near Sarvajani College of Engineering & Technology and a signboard indicating Hospital building



health and substantially impacts life quality [9]. A very significant impact of noise is the impairment in cognitive learning of children going to schools. Therefore, urban road traffic noise level is a crucial factor affecting roadside schools, colleges, and hospitals' well-being. A paradigm policy focus is needed to reduce traffic noise in these silence zones.

Road Traffic Noise

Vehicles, driver behaviours, friction between tires, road surfaces, and various maintenance activities on the road are some of the primary sources of urban road traffic noise [10, 11]. The majority of vehicle noise generation in urban road traffic is noise from the transmission, engine, suspension, and exhaust. Also, it is greatest during engine braking, upon acceleration, in stop-and-go traffic conditions, and due to rough surfaces of the prevailing road conditions [12, 13]. The non-maintenance of poor vehicles and present road surface conditions contribute to a high noise source [14]. Noise is also contributed from contact between pavement and tires. The noise generation depends upon the prevailing conditions of pavement and tires [15]. Driver behaviors contribute significantly by excessive use of horns, loud music, verbal quarrels, and other activities causing vehicles' improper operation, leading to high noise generation [14, 16, 17]. Excessive noise is generated during the repair and maintenance of roads due to heavy equipment and machinery [11, 18].

Study Area and Methodology

Site Selection

Surat city is located in the western part of India in the state of Gujarat. $21^{\circ}12'00.00''N$ and $72^{\circ}52'00.00''E$ is the geographical location of the Surat city, near the Tapi river (Figs. 1, 2 and 3).

Ten monitoring stations near urban roads in the Surat city were selected for the field survey. The selection of the monitoring station was based on location and road function levels. Out of ten locations, three are roadside secondary schools, three are hospitals, three are colleges, and one is the district court. These mentioned locations are coming under the silence zone as per the CPCB Noise Rule-2000 [4]. The school and college buildings have a similar

Fig. 2 KIMO DB 300 Sound level meter



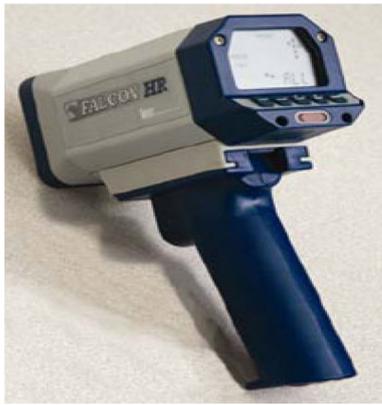


Fig. 3 Falcon HR Radar Gun

population (1000–2000), design, and constructional characteristics (height, orientation, dimension, etc.) Almost all monitoring points are located near a significant suburban road of the Surat city. Seven monitoring stations (MP₁, MP₂, MP₃, MP₅, MP₇, MP₈, and MP₁₀) are located near heavy traffic flow stretch that produces a remarkable noise level; three of the monitoring stations are alongside arterial roads. Figure 4 presents the google map of ten locations, and Table 2 gives the preliminary information of the ten selected roadside monitoring stations.

Field Measurement Along with Questionnaire Survey

This analysis was carried out through the integration of objective in-field measurements and a perception-based subjective questionnaire survey. Fifteen days of continuous noise monitoring were done in October 2020 after the end of the

monsoon. Noise monitoring was done at the roadside schools, colleges, and hospitals. The social survey questionnaire of traffic noise-exposed persons in silence zones was carried out to establish the relationship between noise levels and the percentage of annoyed persons during their working times. The traffic count, vehicle speed, classified traffic volume count, and other meteorological parameters were collected at each location. Only daytime monitoring has been done as defined by CPCB protocol from 6:00 am to 10:00 pm [19].

Instruments and Devices

A multifunctioning sound level meter (KIMO DB 300/2) was used as it provides accurate noise readings. KIMO DB300/2 covers major applications in finding solutions to a comprehensive noise environment scenario (Fig. 2). The vehicle speed measurement was done by using a Radar gun (Kustom Signals-Falcon HR) (Fig. 3). It is a hand-held radar gun used to measure the spot speed of a vehicle by just aiming it towards the vehicle and triggering it. The traffic volume count was done using videography with the help of a Sony HD handycam with a tripod stand, and later on, counting was done by playing the video in the laboratory. The road dimensions were measured with measuring steel tape [4] (Table 1).

Data Collection

In this survey, readings were taken for three periods, i.e., morning & evening peak and afternoon off-peak periods at all the 10 Surat city locations (Table 2).

The parameters collected in the survey are noise levels (dBA), categorized traffic volume count of one-way traffic,

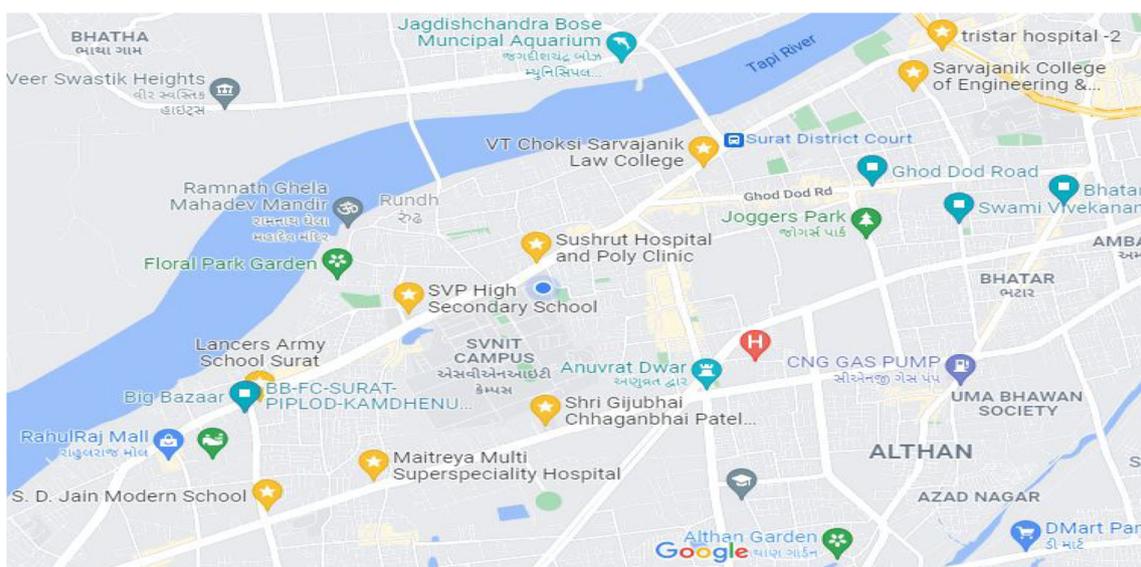


Fig. 4 10 Noise monitoring locations in Surat city marked with star in the yellow colour palette in google map

Table 1 CPCB standards for noise in ambient air

Area code	Category of area/zone	Limits in dB (A) L_{eq} *	
		Daytime	Nighttime
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence zone	50	40

i.e., two-wheeler, three-wheeler, four-wheeler & heavy vehicles, average speed measurements of one-way traffic for these vehicles, the width of the lane, and an average building height near the collection point [20].

Noise level readings were collected for each minute interval for 3 h monitoring (3 h. L_{eq}) with a sound level meter. The noise level meter was kept on a tripod stand such that the microphone sensor was elevated at 1.2 to 1.5 m height from ground level, which is the average height of human ears in India. A handycam was used to record the videos continuously for 3 h. After that, the traffic was counted by playing the videos on the computer, i.e., manual counting for different vehicle categories. The average speed for different vehicle categories was measured by a radar gun, i.e., on-spot measurement. The road width was measured by meter tape and the average building height was measured by counting the floors. (Assuming 1 floor = 3 m). At least 4–5 people were involved in the survey for various data collections. Two people for noise

data collection (one person for the noise level meter and one for noting down the readings), and other two people collected the traffic speed measurements using the radar gun and one person with handycam (Fig. 5).

Traffic Survey

A traffic survey was carried out along with noise monitoring, as traffic is the principal source of noise pollution. At ten locations, road traffic was counted per hour for the morning peak, afternoon non-peak, and again for the evening peak. The traffic count was carried out by videography with a quantitative count of two-wheelers, three-wheelers, four-wheelers, and heavy vehicles.

Noise Questionnaire Survey

To study the attitudes and thinking tendencies of the people and recognize the perspectives and viewpoints towards the noise level in that area. The questionnaire survey has been done. Responses from students of schools and colleges, faculties of colleges, doctors in hospitals, and lawyers of courts were collected using the direct interview method. The questionnaire was designed in the local language Gujarati and kept simple questions to maintain the genuineness of responses and avoid complexities. A questionnaire of six major items was designed to assess the perception and attitudes towards traffic noise. The questionnaire survey was done using a personal interview, and answers were collected.

Table 2 Location-wise monitoring points selected for the study

Sr. No	Type/commodity	Name/location/address	Category	Monitoring point
1	Court	Surat City Court, Lal Bungalow, Surat—Dumas Rd, Near, Athwalines, Athwa, Surat, Gujarat 395,001	Silence zone	MP-8
2	Hospital	Tristar Hospital, Opp. T & TV High School, Athwagate, Surat, Gujarat 395,001	Silence zone	MP-6
3		Sushrut Hospital, SVNIT Campus, Athwa, Surat, Gujarat 395,007	Silence zone	MP-1
4		Maitreya Multispeciality Hospital, Opp. Vatsalya Bungalows, Near Gujrat Gas Station, Udhana-Madgulla, Road, Megh Dhanush Society, Piplod, Surat, Gujarat 395,007	Silence zone	MP-2
5	Colleges	Sarvajanik College of Engineering and technology, Athwa, Surat, Gujarat 395,001	Silence zone	MP-5
6		Shri Gijubhai Chhaganbhai Patel Institute of Architecture, Interior Design & Fine Arts Vesu, Surat	Silence zone	MP-10
7		V.T. Choksi Sarvajanik Law College, Surat, Gujarat 395,007	Silence zone	MP-9
8	Schools	S.V.P. Higher Secondary, SVP School, Subhash Nagar, Athwa, Surat, Gujarat 395,007	Silence zone	MP-4
9		S. D. Jain Modern School, Udhana—Magdalla Road nr. Vesu Char Rasta Opp Bank Of India, Western Business Park, Piplod, Surat, Gujarat 395,007	Silence zone	MP-7
10		Lancers Army School, London House, Dumas Rd, Piplod, Surat, Gujarat 395,007	Silence zone	MP-3



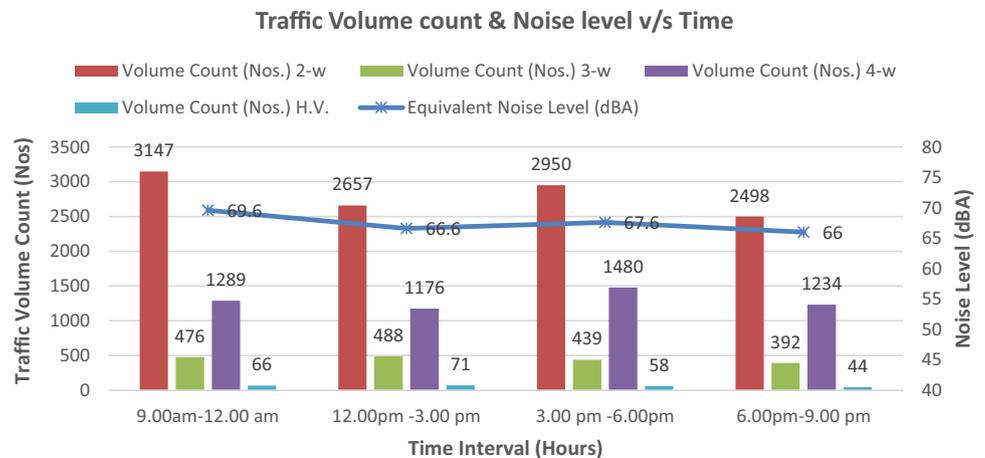
(a) Position of an instrument at SVP School near the compound wall



(b) Choksi Law College, Surat.

Fig. 5 a SVP School, Surat and b Choksi Law College, Surat

Fig. 6 Graph of traffic volume count and noise level versus time in morning, afternoon, evening at SVP School, Surat



One question is designed with a Likert scale (1 denotes low annoyance, and 10 represents high annoyance). The sample size of the questionnaire was calculated as per the Krejcie formula. The base sample size obtained from the procedure is 250, and around 400 reactions were gathered [21].

Results and Discussion

The difference between the maximum and minimum noise levels is very high at all locations. The minimum noise level is still more significant than the permissible noise level of 50 dB (A). The maximum traffic count of vehicles is found per hour during the evening peak (6 pm to 9 pm) and the morning peak (9 am to 12 am). Traffic volume count is a critical parameter to address the noise generated from a particular place or road or any defined area. The traffic volume count has a direct correlation with intensity and the amount of noise generated.

Schools and Colleges

It can be seen from the graph; the traffic pattern and noise levels of the afternoon and evening noise levels are the same. Number of vehicles' count and the noise readings are higher in the morning peak hours than in the afternoon hours. Many locations had higher noise generation even though the number of vehicles was less. The reason can be due to the road's geometry, the importance of the location, and the time of the study. Narrower the width, the higher the noise generation due to increased traffic congestion. Another reason could be the type of vehicles (Fig. 6) (Table 3).

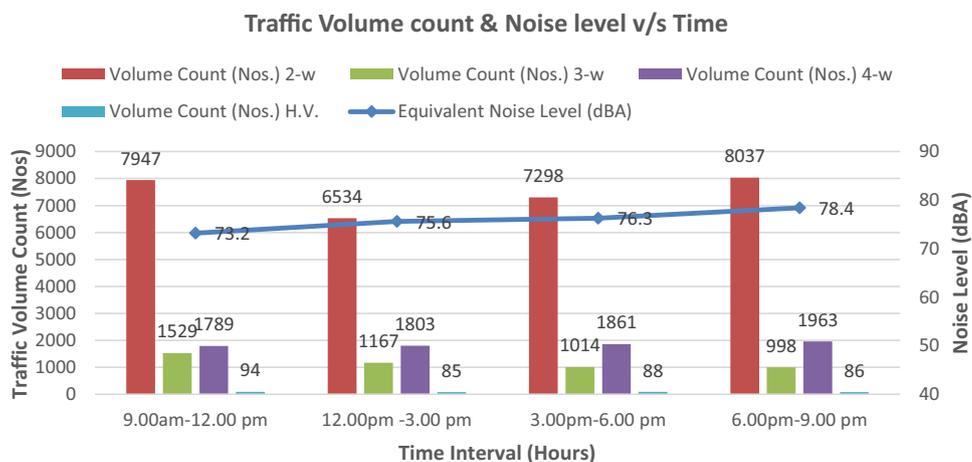
Colleges

Noise level near V.T. Choksi law college road was observed to follow a gradual increasing in noise with the passage of time. The lowest noise level was observed in the morning and the highest in the evening. The total change in

Table 3 Noise level, traffic count, and average speed of the vehicle at Sardar Vallabhbhai Patel Secondary School (MP-4)

Time interval	Equivalent noise level (dBA)	Volume count (Nos.)				Avg. Speed (km/h)				Avg. Building height (meter)	Road width (meter)
		2-w	3-w	4-w	H.V	2-w	3-w	4-w	H.V		
9.00–12.00 am	69.6	3147	476	1289	66	28	19	25	19	18	9
12.00–3.00 pm	66.6	2657	488	1176	71	27	18	25	18	18	9
3.00–6.00 pm	67.6	2950	439	1480	58	26	19	24	18	18	9
6.00–9.00 pm	66.0	2498	392	1234	44	28	17	22	18	18	9

Fig. 7 Graph of traffic volume count and noise level versus time in morning, afternoon, and evening at V. T. Choksi Law College, Surat



noise level is about 5 dB from morning to evening periods. The trend could be due to the increasing number of vehicles with the passage of time at MP-9 (Fig. 7).

At MP-3, the afternoon and evening periods, the noise levels are less than the morning readings. There is no significant difference between afternoon and evening noise levels. Number of two-wheelers in the morning and afternoon is almost the same, but number of two-wheelers increased in the evening. The evening noise level was 57.4 dBA, which is very much less as compared to all other locations (Table 4).

At MP-5, there is no significant difference between morning, afternoon, and evening noise levels; it was almost the same, i.e., 72 dBA for a peak as well as non-peak period. Number of two-wheelers, three-wheelers, four-wheelers, and heavy vehicles in the morning are higher than in the afternoon and evening. The noise levels were observed to be the same due to the road width, which also comes under the sub-arterial road. Again, not being a commercial road, the vehicle’s density is low compared to other roads.

At MP-7, during evening peak hours, due to the increased traffic volume, noise levels are increasing at a very high rate. Number of heavy vehicles are almost doubled in the morning compared to the evening time. Still, the number of heavy vehicles in the afternoon was higher

than morning and evening heavy vehicles. In the evening, the noise levels are high, due to the total number of vehicles’ count.

At MP-10, the noise level around the Chagan Patel Architectural Institute was observed on the lower side of noise generation compared to other locations. The noise generation observed varied insignificantly from morning to evening. The road width and low traffic count are some of the significant reasons.

Hospitals

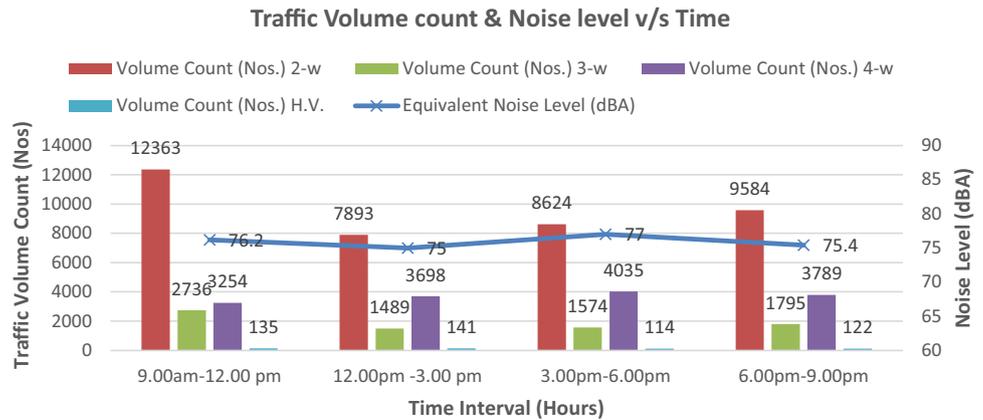
At MP-6, in the morning peak hours, noise levels are increasing at a very high rate due to the increased traffic volume. The number of two-wheelers and three-wheelers almost doubled in the morning as compared to the afternoon. The noise level in the morning and evening is nearly the same, i.e., 76.2 dBA and 75.4 dBA, respectively. The heavy vehicles were very limited due to restrictions imposed on heavy vehicles for traveling inside the city (Fig. 8).

At Sushrut Hospital (MP-1), the number of two-wheelers is high in the evening period’s traffic composition; after that, three-wheelers and four-wheelers come into the picture. The number of heavy vehicles is significantly less in comparison with the other vehicle categories. Noise

Table 4 Noise level, traffic count, and average speed of the vehicle at V. T. Choksi Sarvajanik Law College, Surat (MP-9)

Time interval	Equivalent noise level (dBA)	Volume count (Nos.)				Avg. Speed (km/h)				Avg. building height (meter)	Road width (meter)
		2-w	3-w	4-w	H.V	2-w	3-w	4-w	H.V		
9.00 am–12.00 pm	73.2	7947	1529	1789	94	42	33	37	28	30	9
12.00–3.00 pm	75.6	6534	1167	1803	85	50	36	50	40	30	9
3.00–6.00 pm	76.3	7298	1014	1861	88	49	37	49	39	30	9
6.00–9.00 pm	78.4	8037	998	1963	86	49	37	49	39	30	9

Fig. 8 Graph of traffic volume count and noise level versus time at Tristar Hospital, Surat



readings shown in the graph are of a 1 h interval in dBA. It is clear that the noise level is increasing with the increasing no. of vehicles (Table 5).

At Maitreya hospital (MP-2), during the non-peak period, the number of vehicles reduced; the noise level readings were lowest in the afternoon and highest in the evening hours. In the morning, the noise level increased with the increase in the total number of vehicles, i.e., 71.9 dBA.

Courts

The reverse scenario is that the noise levels are less in the morning and evening but more in the afternoon. The first reason may be due to higher vehicular movement during the afternoon due to the 12.00 pm to 4.00 pm working hours of the court (Fig. 9) (Table 6).

Surat district court (MP-8), a government premise, was observed with one of the highest noise generation levels of 78.6 dBA. The afternoon time with maximum traffic counts and a huge crowd surrounding the court could be one reason for the high noise level. Also, in the morning and evening hours had fewer vehicle counts and low noise generation than the afternoon period—noise levels for all three periods exceeding the permissible limit. This building’s distance is

approximately 80–85 m, but it should be away 100 m from the main road as per CPCB rules [4]. The generation of noise depends on the type and condition of vehicles, road importance and width, the importance of cross-section, and its history, mind-set, and behavior [22]. Other reasons could be the entry of heavy vehicles during the afternoon as Surat Municipal Corporation allowed to maintain traffic congestion in the evening period (Fig. 10) (Table 7).

The above noise level trend shows the present scenario of noise generation exceeding the 50 dBA standards. It was observed that the minimum noise level also exceeds the 50 dB (A) mark and remains below the normal only for lancer army school (MP-3). Also, MP-1 was found to cross 100 dBA. The data shows that all Surat city silence zones are not following standard practices of noise control, which will eventually affect the hearing capacity of the majority of the population. Hence, immediate and strategic actions are required to be followed by Municipal Corporation authorities in the form of paradigm policy focus shifts to reduce traffic noise in these silence zones [23] (Fig. 11).

Table 5 Noise level, traffic count, and average speed of the vehicle at Tristar Hospital, Surat (MP-6)

Time interval	Equivalent noise level (dBA)	Volume count (Nos.)				Avg. speed (km/h)				Avg. building height (meter)	Road width (meter)
		2-w	3-w	4-w	H.V	2-w	3-w	4-w	H.V		
9.00 am–12.00 pm	76.2	12,363	2736	3254	135	32	25	30	22	35	14
12.00–3.00 pm	75.0	7893	1489	3698	141	32	24	30	24	35	14
3.00–6.00 pm	77.0	8624	1574	4035	114	30	24	30	22	35	14
6.00–9.00 pm	75.4	9584	1795	3789	122	30	25	32	20	35	14

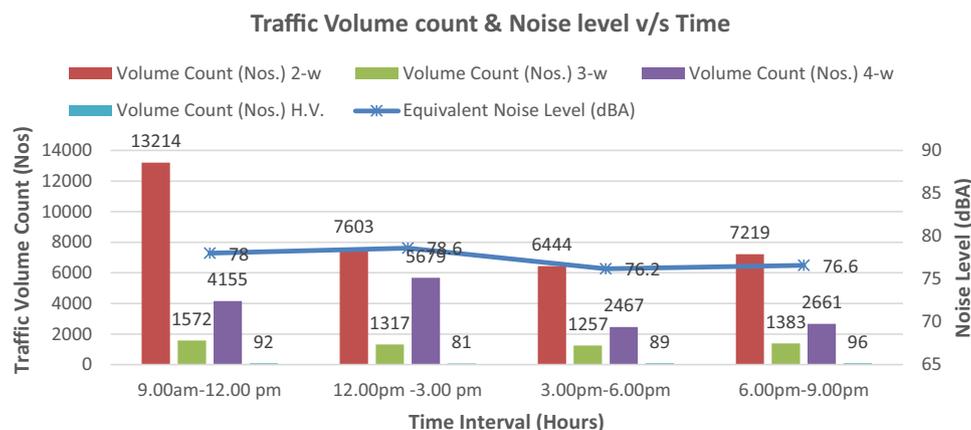


Fig. 9 Graph of volume count and noise level versus time in morning, afternoon, evening at Surat district Court, Surat

Table 6 Noise level, traffic count, and average speed of a vehicle at Surat District Court, Surat. (Approx. 90 m from the Main Road) MP-8

Time interval	Equivalent noise level (dBA)	Volume count (Nos.)				Avg. speed (km/h)				Avg. building height (m)	Road width (m)
		2-w	3-w	4-w	H.V	2-w	3-w	4-w	H.V		
9.00 am–12.00 pm	78.0	13,214	1572	4155	92	30	23	26	19	40	14
12.00–3.00 pm	78.6	7603	1317	5679	81	28	20	25	18	40	14
3.00–6.00 pm	76.2	6444	1257	2467	89	30	22	24	17	40	14
6.00–9.00 pm	76.6	7219	1383	2661	96	29	24	26	18	40	14

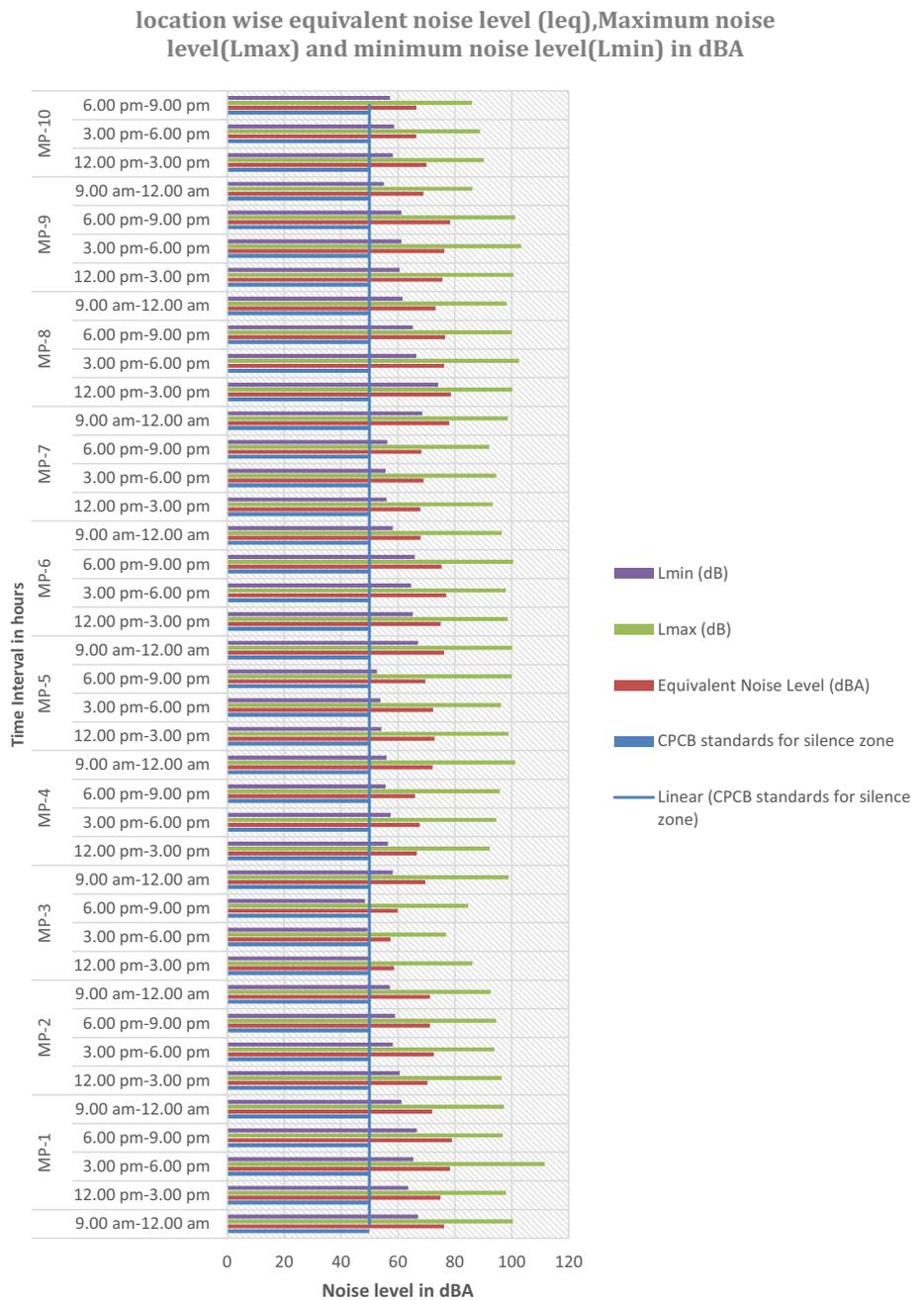
Questionnaire Survey

As explained in the above methodology, a questionnaire survey was carried out with a prepared questionnaire of only six essential questions. A questionnaire survey was carried out in the form of personal interviews of students, faculties, lawyers, and doctors inside the building, which comes under the study area’s silence zone. The respondents were asked to express their views regarding the noise generated from traffic flow; the respondents are asked to

scale the answers based on a given visual analog scale prescribed (Fig. 12).

Respondents were free to express his/her views and ideas. Some points that have emerged from the questionnaire survey are: (1) Several people are not aware of noise pollution and its effects. (2) Most people said that the traffic noise in Surat city is increasing day by day. (3) Majority of people do not know about the silence zone and its rules. (4) Faculties of colleges and lawyers of courts expressed higher annoyance due to noise exposure. Several

Fig. 10 L_{eq} , L_{min} , and L_{max} noise level for all ten locations



students drive the bike very rashly. Some faculty members suggested that the speed breaker and horn ban signboards to be installed in front of the college gate [24].

It was observed in the questionnaire survey that many people were unaware of the noise generation problem [24]. Also, noise has not been seriously taken as pollution compared to water, land, and air pollution. However, noise pollution has a direct relation to the rise in other pollution parameters. In India, noise is like a new-born baby when compared with other forms of pollution. Also, the amount of work done to study, understand, and reduce noise is

comparatively less in India when compared with other countries.

In India, work done in silence zones to understand and mitigate noise is significantly less [25]. Most people do not consider the noise as one of the primary sources of mental and physical strain and do not give it its due credit [24]. However, recently, scientists and researchers have realized the impact of noise on humans' overall health and surroundings.

The lifestyle of individuals, prevailing environmental conditions, and economic conditions of the area are directly correlated with the amount of noise generation.

Table 7 Shows Leq (dB), Lmax (dB), and Lmin (dB) of each location in the Surat city

Time interval	Equivalent noise level (dBA)	L_{\max} (dB)	L_{\min} (dB)
<i>MP-1 Sushrut Hospital Surat</i>			
9.00–12.00 am	76.2	100.4	67.0
12.00–3.00 pm	74.9	98.0	63.6
3.00–6.00 pm	78.3	111.6	65.4
6.00–9.00 pm	79.0	96.8	66.6
<i>MP-2 Maitrey Hospital Surat</i>			
9.00–12.00 am	72.0	97.2	61.2
12.00–3.00 pm	70.4	96.5	60.6
3.00–6.00 pm	72.6	93.9	58.2
6.00–9.00 pm	71.2	94.5	59.0
<i>MP-3 Lancer Army School, Surat</i>			
9.00–12.00 am	71.2	92.6	57.2
12.00–3.00 pm	58.6	86.2	50.0
3.00–6.00 pm	57.4	76.9	49.3
6.00–9.00 pm	59.9	84.7	48.4
<i>MP-4 Sardar Vallabhbhai Patel School, Surat</i>			
9.00–12.00 am	69.6	98.9	58.2
12.00–3.00 pm	66.6	92.3	56.5
3.00–6.00 pm	67.6	94.6	57.4
6.00–9.00 pm	66.0	95.8	55.6
<i>MP-5 Sarvajani Engineering College, Surat</i>			
9.00–12.00 am	72.2	101.2	56.0
12.00–3.00 pm	72.9	98.9	54.2
3.00–6.00 pm	72.4	96.2	53.8
6.00–9.00 pm	69.6	100.0	52.6
<i>MP-6 Tristar Hospital, Surat</i>			
9.00–12.00 am	76.2	100.2	67.0
12.00–3.00 pm	75	98.6	65.2
3.00–6.00 pm	77	97.9	64.6
6.00–9.00 pm	75.4	100.5	65.9
<i>MP-7 S.D. Jain Modern School, Surat</i>			
9.00–12.00 am	68.0	96.5	58.2
12.00–3.00 pm	67.9	93.3	56.0
3.00–6.00 pm	69	94.6	55.6
6.00–9.00 pm	68.2	92.1	56.2
<i>MP-8 Surat district court, Surat</i>			
9.00–12.00 am	78.0	98.6	68.6
12.00–3.00 pm	78.6	100.2	74.2
3.00–6.00 pm	76.2	102.6	66.4
6.00–9.00 pm	76.6	100.0	65.2
<i>MP-9 Choksi Law College, Surat</i>			
9.00 am–12.00 am	73.2	98.2	61.6
12.00–3.00 pm	75.6	100.6	60.6
3.00–6.00 pm	76.3	103.3	61.2
6.00–9.00 pm	78.4	101.2	61.2
<i>MP-10 Shri Gijubhai Chhaganbhai Patel Institute of Architecture, Interior Design & Fine Arts, Surat</i>			
9.00–12.00 am	68.9	86.2	55.0
12.00–3.00 pm	70.0	90.2	58.2

Table 7 continued

Time interval	Equivalent noise level (dBA)	L_{max} (dB)	L_{min} (dB)
3.00–6.00 pm	66.4	88.9	58.6
6.00–9.00 pm	66.4	86.0	57.2

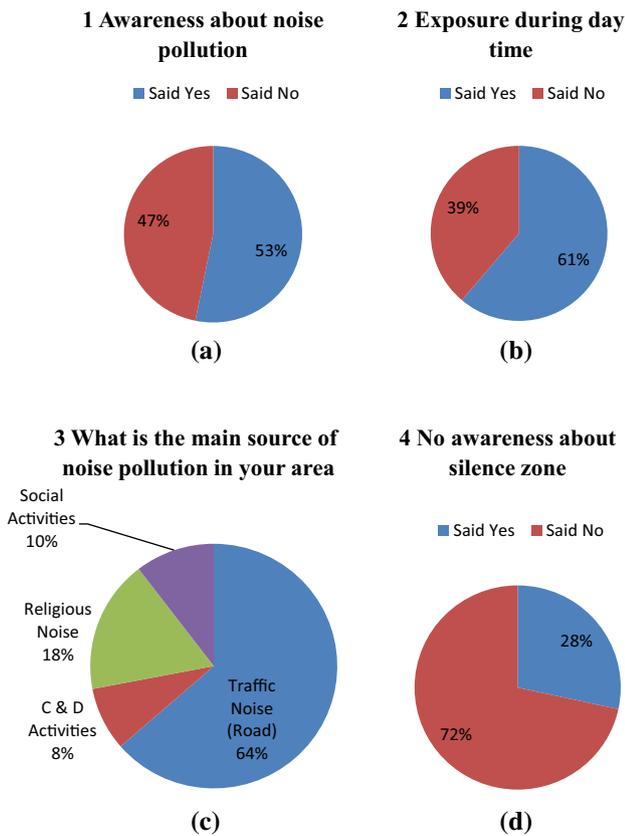


Fig. 11 a–d shows percentage-wise response and awareness of people towards noise pollution

Better the lifestyle, more the number of vehicles, vis-a-vis higher the noise generation [26]. A better economy would lead to better-performing sectors, leading to a rise in the total number of vehicles, which would lead to noise generation. So many schools, colleges, hospitals designed as silence zones are not treated as silence zones. Most people are not aware of the hospital or any educational building under the silence zone [27]. It may happen due to improper land use patterns practiced by Municipal Corporation authorities.

Government institutions, prevailing infrastructure, vehicular control officers also control the noise generation. An area with better traffic officers can efficiently dissipate noise generation by guiding the crowd. The majority of the higher noise is observed at cross-sections where most vehicles become a hindrance to each other.

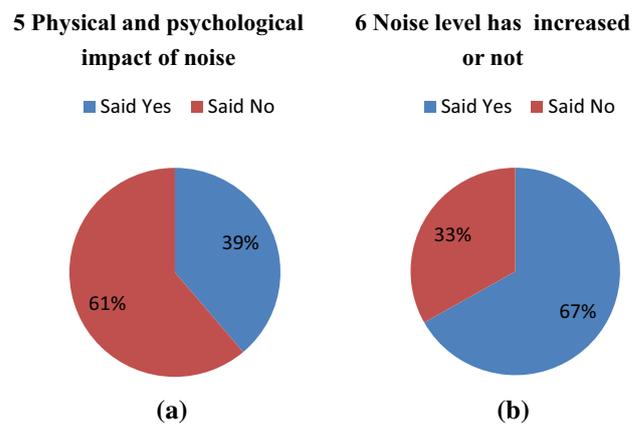


Fig. 12 a–b Percentage-wise response

According to the data obtained from the survey, it is found that the minimum equivalent traffic noise level is exceeding the permissible limits at all locations. Various noise mitigation strategies need to be explored, investigated, and properly executed to overcome this problem.

Proposed Solutions for Noise Mitigation in Silence Zones

According to the CPCB norms, the sound level in silence zones should not exceed 50 dB during the day and 40 dB during the night [4]. Noise levels vary from 55 to 79 dB for the daytime. The noise monitoring station should be further enlarged, which will help develop noise maps and apply a mitigation strategy.

Noise control strategies like installation of noise barriers such as vegetative, partition wall, brick wall, steel railing, ground-mounted noise barriers, wooden barrier, noise reduction plates, etc., for hospitals, schools, colleges, and other sensitive buildings can apply [28, 29]. Municipal corporations and other authorities can strictly enforce speed limits for heavy vehicles passing through the silence zone, strict instruction and suggestions about the demarcation of no-honking zones, and the adoption of proper land use plans in the urban area [16, 26, 30].

The use of noise barriers can reduce roadway noise, limit vehicle speeds [30], alteration of roadway surface texture [31], regulation heavy vehicles, and traffic controls

that smooth vehicle flows to reduce braking and acceleration tire design. In urban residential areas and in the silent zone, trees' disposition around the buildings should be made for maximum noise reduction [31–33].

Conclusions

This study demonstrates a significant problem of high levels of road traffic noise and its non-compliance in some silence zones of the Surat city. Among all the study area locations, the maximum L_{eq} recorded was 79.0 dBA, and it is during evening peak hours and on a flexible pavement (SVNIT-Athwalines road). The minimum noise level measured across all ten locations was 48.4 dB (A) at Lancer's army school road, which is still above the permissible norms of the central pollution control board.

The equivalent noise level in the study area was 79.0 dBA, and the maximum noise level across all ten roads is 111.6 dB (A), and it is during evening (peak) hours, and the road is a flexible pavement (SVNIT-Athwa line Road). It is during the afternoon (off-peak) hours at Lancer army school road.

Heavy vehicles, horn honking, less width of the road, and unauthorized street parking are the main contributors to noise in the sensitive (silence) zones. Noise levels are high even during the afternoon at some study locations. During daytime, the Surat Municipal Corporation has permitted the entry of heavy vehicles in the municipal corporation limits from 1 to 5 pm only. This is a major reason for high noise levels during the afternoon in some locations.

Also, different vehicles generate different amounts and intensities of noise. Heavy vehicles generate maximum noise as compared to light vehicles. The peak value of noise generation varies for various locations at varying times. Morning time (9.00 am to 12.00 am) and evening time (6.00 pm to 9.00 pm) were higher noise-generating periods than afternoon during the entire daytime. One of the major reasons for this could be the lesser use of the public transportation systems for work trip commutation. The relation between noise and the number of vehicles also largely depends upon the landscape and the cross-section width of the road.

It was observed in the questionnaire survey that many people were unaware of the noise generation problem [24]. Also, noise has not been seriously taken as pollution compared to water, land, and air pollution. Most people do not consider noise as one of the primary sources of mental and physical strain and do not give it its due attention [24]. However, recently, scientists and researchers have realized the impact of noise on humans' overall health and surroundings.

Because of exponential increase in population, less availability of resources and continues addition of automobiles on the urban road leads to heavy traffic noise around the schools, colleges, and hospitals, which falls under the Silence Zone as prescribed by the Central Pollution Control Board, are not fulfilled.

Because of various constraints and poor land-use planning, silence zones are places with traffic abundance and significant noise, which required mitigation strategies in the form of policy interventions from urban and transportation planners.

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Declarations

Conflict of interest The authors declare no conflict of interest.

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