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Original Research

Measurement of Noise Levels in Pakistani Residential Societies at Source and Receiver Locations

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Abstract

Escalating transportation demands have mandated extensive construction of highways in proximity to residential zones, culminating in heightened vehicular noise levels. This investigation centered on the assessment of noise pollution across diverse sites in Lahore, Pakistan, with a specific focus on the Lahore Ring Road (LRR) and surrounding regions. Variables including land utilization, road categorization, arboreal presence, physical impediments, and distances between noise sources and receivers were meticulously analyzed. Utilizing a UNI-T-MS6700 sound level meter, measurements spanning LA99, LA90, LA50, LA10, and LA1 exposed concerning findings, notably recording 80.5 dB from motorcycles in Township (Ali Road) and peaking at 86.5 dB from trucks in Model Town (Ferozepur Road) and Township (Ali Road). While Sui Gas Society demonstrated an 8 dB(A) noise reduction via purposeful tree planting (15 feet), DHA Phase V exhibited a marginal 3 dB(A) decrease due to the absence of such interventions (20 feet). Strikingly, Ashiana-E-Quaid displayed a substantial 19 dB(A) reduction attributed to a considerable distance between noise sources and receivers (300 feet), notwithstanding the absence of trees and barriers. All surveyed locations surpassed the Punjab EPD-prescribed limit of 45-55 dBA, resulting in stress (62.5%) and sleep disruptions (43.3%) among residents. This study underscores the critical roles of tree plantation and source-receiver distance in noise abatement, underscoring the necessity for urban architecture designed with noise barriers to efficaciously manage traffic-related noise.

Keywords: noise barrier, traffic noise, health impacts, noise source and receiver, sound level meter

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Introduction

A rise in urban population leads to an increase in transportation demand all over the world. More roads are being built as a result of increased transportation demand. The same is true for Pakistan, where more mobility implies increased infrastructure. Noise is defined as any unpleasant sound. Highway vehicular traffic is a major source of noise in urban areas, which causes stress and annoyance. According to WHO community noise recommendations, around 20% of European Union populations are exposed to levels surpassing 65 dB(A) during the day, while 30% are exposed to levels greater than 55 dB(A) during the night. Because of increased vehicle traffic, traffic-related noise is becoming a public health hazard in both emerging and industrialized countries. According to WHO community noise standards, roughly 20% of European Union populations are exposed to levels greater than 65 dB(A) during the day, while 30% are exposed to levels greater than 55 dB(A) during the night [1]. Concerns about the detrimental health impacts of transportation-related noise have prompted legislative attempts to mitigate noise as the number of cars and vehicle kilometers traveled has risen in urban environments. The Federal Highway Administration (FHWA) in the United States published rule 23 CFR772 in 1973, which mandates noise assessment and abatement in areas affected by highway traffic and construction [1]. At a distance of 15 meters (50 feet) from the highway, highway traffic noise levels normally vary from 70 to 80 dB(A). These levels impact the majority of people, interfering with focus, raising heart rates, and restricting one's capacity to converse (FHWA 2003) [2].

For community annoyance in cities with business, trade, and administration, Lahore ISO - 1996 (1982) suggested a maximum limit of 55-65, 50-60, and 40-50 dB(A) L_{Aeq} for daytime, evening time, and night, respectively, whereas the World Health Organization (WHO 1980) allows 55 dB(A) L_{Aeq} [3]. According to the World Health Organization's (WHO-2009) noise guidelines, continuous outdoor noise in residential areas should not exceed 55 dB(A) (16 hours average, day and evening) [1]. The Environment Protection Department (EPD), Government of Punjab was notified in 2013 regarding quality standards for noise [dB(A) L_{eq}] as follows: (i) residential areas: 55 dB(A) = day time; 45 dB(A) = night time, (ii) commercial areas: 65 dB(A) = day time; 55 dB(A) = night time, (iii) industrial areas: 75 dB(A) = day time; 65 dB(A) = night time and (iv) silence zones: 50 dB(A) = day time; 45 dB(A) = night time. dB(A) L_{eq} corresponds to a time-weighted average of the level of sound in decibels on scale A, which is relatable to human hearing [4]. The US Environmental Protection Agency (EPA) has identified noise levels required to protect public health and welfare against hearing loss, annoyance, and activity interference. The document identifies a 24-hour exposure level of 70 decibels as the level of environmental noise that will prevent any measurable hearing loss over a lifetime. The levels are not a single event, or "peak", but rather averages of acoustic energy over time, such as one day [5].

If the amount of traffic noise exceeds this limit, noise barriers should be placed along highways and important arterials. Lahore is Pakistan's fastest-growing metropolitan city, with several professional, industrial, educational, and medical organizations. People residing near Lahore are drawn to it because of the additional amenities accessible there. Lahore is plagued by severe noise pollution from the noise of motorcycles, auto-rickshaws, cars, and increased traffic volumes. A study reported a direct relationship between noise-induced hearing loss and the length of noise exposure exceeding permitted limits [6, 7]. Continuous or intermittent noise disrupts sleep, resulting in a variety of psychological repercussions. Continuous exposure to noise levels above 30 decibels has been shown in studies to disrupt sleep. Noise can influence one's cognitive judgments, prompting the brain to respond with distress or anxiety. Noise exposure increases the level of response to a stimulus by releasing adrenalin hormone into the bloodstream, causing an increase in heart rate and muscle strain [8, 9]. Researchers [10] demonstrated the cause-and-effect link between the level of pollution and the prevalence of illnesses among selected Delhi homes. The key causes that have generated and exacerbated the problem of pollution in the study region are the massive rise in population, industrial activity, unrestrained development in motor traffic, and fast-changing living styles.

The current study aimed to calculate noise levels at the source, as well as at receiver junctions at various places around Lahore, to compare and examine the causes of exceeding noise levels. The following locations were selected to calculate the traffic noise intensity along residential societies linking to the Lahore Ring Road (LRR): Sui Gas Society near Kamahan Interchange, DHA Phase V, and Ashiana-E-Quaid interchange. The other locations selected were: Modal Town (Ferozepur Link Road), Township (Ali Road), and Johar Town (Ghazan Road). The study also included a short survey from the residents on noise health impacts. Vegetation can reduce noise levels effectively if it blocks the line of sight of sound. Trees can reduce noise levels, for example, 100 feet of thick plantation along the road can reduce noise by 5-10 decibels. However, it is not always practical to plant trees or vegetation along every road due to space issues. Noise barriers are solid barriers built between the highway and the homes along the highway. Effective noise barriers typically reduce noise levels by 5-10 decibels (dB), reducing the loudness of traffic noise by as much as one-half. Barriers can be made up of earth embankments or berms along the shoulder of the road. Earth berms typically require more space to construct. The biggest challenge with building earth berms most of the time is a lack of sufficient area [11]. Noise levels should be estimated throughout the project's planning phase. Traffic impact assessment studies and environmental impact assessment (EIA) reports are generated during the design of each infrastructure project. If the expected noise level exceeds the threshold, a noise barrier should be included in the project's design [12]. The study has the following contributions:

- Calculates the traffic noise intensity and provides a comparison of noise levels at the receiver as well as the source.
- Examines the causes of exceeded noise levels and presents recommendations that can effectively reduce noise levels if implemented.
- Includes a short survey from the residents on noise health impacts.

The rest of the study is structured as follows: Section 2 provides the details of the materials and methods used. Section 3 presents the results in detail, while Section 4 critically analyzes and discusses the obtained results. Finally, the study concludes with recommendations in Section 5.

Materials and Methods

Study Areas

Six different locations in Lahore were selected to evaluate the traffic noise levels. Three locations were along the Lahore Ring Road (LRR) highway, that is, (i) Sui gas society, (ii) Ashiana-E-Quaid housing scheme, and (iii) DHA phase V. These societies were selected based on their location, tree plantation, and their distance from LRR MCW (main carriageway). Lahore Ring Road (LRR) encircles Lahore and consists of two loops: southern and northern. The northern loop is 48 Km, and the southern loop is 22.4 Km. The northern loop starts from Azadi Chowk and ends at Kamahan Interchange Lahore. The southern loop starts from DHA phase V and ends at Raiwind Interchange. It is estimated that 425,000 vehicles pass through daily. LRR is a six-lane divided highway with both inner and outer shoulders. LRR was selected for study, as it passes through commercial, residential, and recreational areas of Lahore city. Because these three societies are built near roads, it was expected that noise pollution would be a problem. Lahore Ring Road is a limited-access highway with a design speed of 110 Kilometers per hour. There is no access for autorickshaws and motorbikes to LRR, therefore, cars, buses, and trucks were considered for the noise measurement in locations (i) to (iii).

Location #1: Lahore Ring Road - Sui-Gas Society

This society is situated at 34 Km, around 50-70 feet from Lahore Ring Road near Kamahan Interchange (Fig. 1(a-b)). This society is situated very close to the LRR highway, so it was perceived that people in this society could be vulnerable to traffic intensity. Kamahan interchange was selected for the study, because societies are constructed along the highway, having the same distance from LRR, but with varied noise intensities. This society is affiliated with the Northern Sui Gas department as well. Most people living in this society are educated and belong to the upper middle and rich classes of society. This society was selected for this research pertaining to its location importance. Lahore Ring Road – Kamahan interchange ramp 2 passes through block B of this society. Half of the residences in Block B are on one side of the road, and the other is on the opposite side of the LRR. Noise level measurement was done in this specific location.

Location #2: Lahore Ring Road - Defense Housing Authority (DHA) Phase V

DHA Phase 5 is selected as it is constructed along LRR. It is located on the LRR's 33-kilometer road (Fig. 1(c-d)). Sectors A and J of this are built relatively closer to the LRR. These phases are well-known for their economic activity and the presence of a university. The majority of residents in this neighborhood are from the upper middle and wealthy classes of society. This society is located near the Kamahan junction, and many of its residents follow the Lahore Ring Road regularly.

Location #3: Lahore Ring Road – Ashiana-E-Quaid Housing Scheme

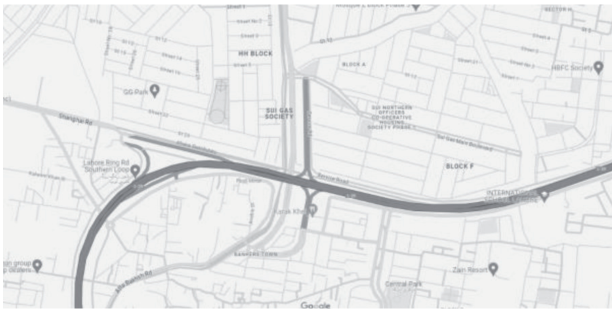
Ashiana-E-Quaid Housing Society is constructed near Lahore Ring Road, Col. Arif Shaheed Interchange (Fig. 1(e-f)). This society comprises approximately 350 houses, three schools, a family park, a cricket stadium, and two mosques. This society is constructed about 200 to 300 feet from LRR MCW. The society was selected to study the difference in noise level between the society constructed near LRR and the society constructed 200 to 300 feet away from LRR.

Location #4: Model Town, Ferozepur Link Road

The road is a significant thoroughfare that connects the Model Town roundabout to the Ferozepur Road (Fig. 1(g)). Because houses are built on both sides of the road, this region is classified as a residential area, however, this road is also a major artery with heavy traffic. The road is a four-lane divided road with a 0.8-foot median. Traffic on this road comprises 65% cars, 22% bikes, 10% public transport, and 3% rickshaws. Peak hours on this road are normally from 8 am to 10 am and from 6 pm to 9 pm. The majority of cars are spotted on the road at all hours of the day. In terms of area, the houses built on this route range from two to three canals. This road was selected as a study area because traffic intensity is very high here, and on both sides of the road, houses are constructed.

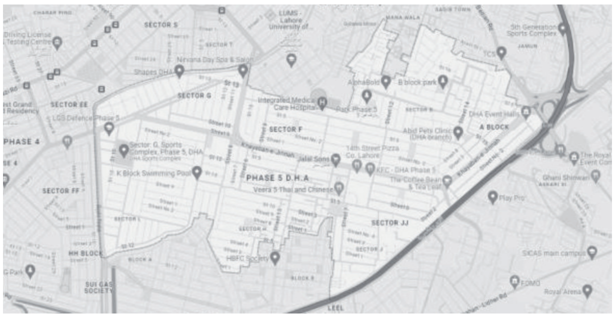
Location #5: Township, Ali Road

The Township is located in Iqbal Tehsil, Lahore, Punjab (Fig. 1(h)). Ali Road Township passes through the commercial and residential areas of the town. On one side of the road, there are houses and educational institutes. On the other side of the road, there is a commercial zone. That's why this area was included in a commercial and residential zone. The commercial zone includes a famous cinema, marriage halls, and banks. This is a high-traffic intensity road. Traffic on this road comprises 45% cars,



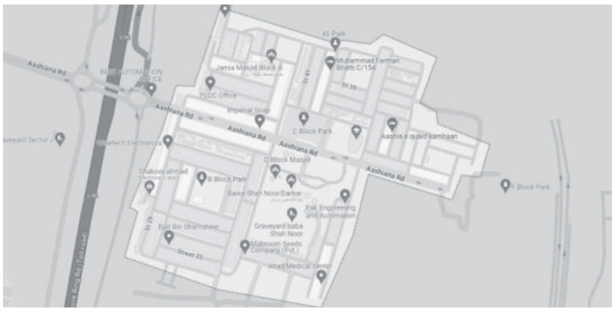
(a)

(b)



(c)

(d)



(e)

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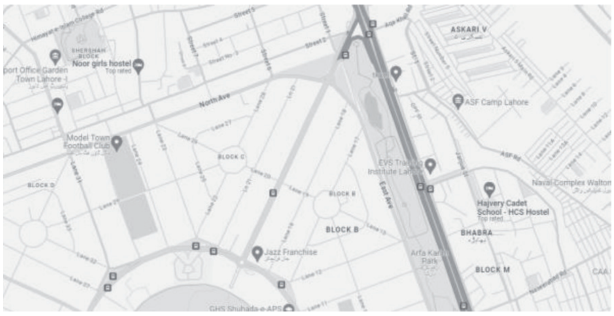
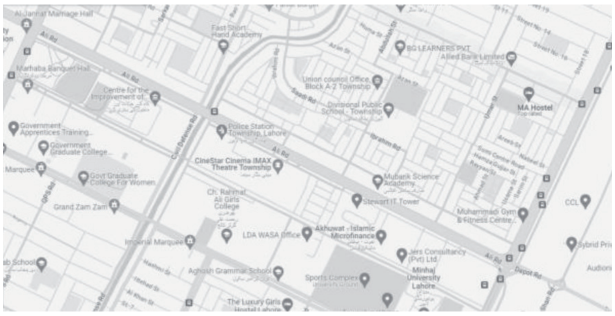
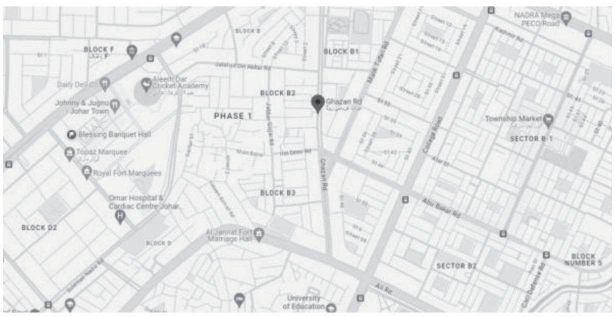


(g)



(h)



(i)

Fig. 1. Site locations and their aerial views: (a) site location Sui Gas Society, (b) aerial view Sui Gas Society, (c) site location DHA Phase 5, (d) aerial view DHA Phase 5 and Lahore Ring Road, (e) site location Ashiana-E-Quaid Society, (f) aerial view of Ashiana-E-Quiad Interchange LRR, (g) site location Model Town Ferozepur Link Road, (h) site location Ali Road [sound level: 91db(A) and 90% people indicate stress], (i) site location Ghazan Road [sound level: 83 dB(A) and 80% of the people indicate need of barrier while 70% of the people indicate disturbance in sleep). The images were taken in November 2023.

22% bikes, 15% public transport, and 18% rikshaws. On the residential side of the road, there are few trees planted, which are not sufficient to resist noise pollution. This road is a four-lane divided highway with a median of 6 feet.

Location #6: Johar Town, Ghazan Road

This road leads through the residential area of Johar Town, with houses constructed on both sides of the road (see Fig. 1(i)). This is considered a major road because it connects the Township and PIA main boulevard to Johar Town main boulevard. On this road, a mosque is situated. Traffic on this road comprises 36% cars, 28% bikes, 28% public transport, and 8% rickshaws. On both sides of the road, only houses are constructed. There is no commercial zone.

Noise Level Threshold

The results of noise levels were compared as per the recommendation of the US EPA. The US Ambient Protection Agency defines an 8 and 24-hour exposure threshold of 70 dB as the amount of ambient noise that will avoid any demonstrable hearing damage over a lifetime. Noise levels for various regions are established based on their utilization. Indoor residential areas, hospitals, and schools have decibel levels of 45, whereas certain outdoor areas with human activity have decibel levels of 55. To reduce noise pollution, a standard of 70 decibels has been established for all places, as per the US EPA. The levels are not "peak" or "single event" levels. Instead, they represent acoustic energy averages over short periods, such as 8 hours or 24 hours, as well as long periods, such as years [5].

Physical Characteristics of Selected Locations

Information on the following physical attribution (Table 1) of the selected areas was noted: land use type, road type, the existence of trees, the presence of physics hindrance, and the distance (in feet) between the source and the receiver. For Location 1, the distance between the source and receiver was 15 feet on average. Tree plantation and thick vegetation were present between the source and receiver, which play an important role in noise detection. A boundary wall between roads and houses is present, which further reduces noise intensity for inhabitants of society. For Location 2, the distance between the source and receiver was 20 feet on average. There was no tree plantation or thick vegetation between the source and receiver. A boundary wall between the road and houses was present, which reduced noise intensity for the inhabitants of society. For location 3, the distance between the source and receiver was 300 feet on average. There was no tree plantation or thick vegetation between the source and receiver. The receiver point was 300 feet from the source; that's why the reduction in sound pressure level between the source and receiver was observed. For Location 4, the distance between the source and the receiver was 10 to 15 feet on average. Tree plantation and thick vegetation were present between the source and receiver, which play an important role in noise detection. For Location 5, the distance between the source and receiver was 15 to 20 feet on average. There was neither a tree plantation nor a boundary wall existing between the source and receiver. For Location 6, the distance between the source and receiver was 10 to 15 feet on average. There was neither a tree plantation nor a boundary wall existing between the source and receiver.

Noise Levels Measurements

The UNI-T-MS6700 sound level meter was used for measuring the sound pressure level. This comprises a series of digital sound level meters that gather data with stable performance, safety, and reliability. For Locations 1, 2, and 3, the source measurement point was a barrier along the road. The barrier was 7 feet from the center of the nearby travel lane. For Locations 4, 5, and 6, the source measurement point was the edge of the shoulder of the road, which was approximately 5 feet from the center of the near travel lane. The UNI-T-MS6700 sound level meter is designed to measure environmental noise measurement, machinery equipment noise measurement, traffic noise measurement, and architectural acoustics measurement. The sound level meter can measure sound range from 40 dB -130 dB(A) with ±1.5 dB accuracy. This sound meter was regularly calibrated against an acoustic calibrator and checked before and after each series of measurements. The study was focused on analyzing how noise affects people living in surrounding areas. During all the measurements, the meter was kept at 1.5 m above ground level. Noise data was collected at the source and receiver for all six locations from 0900 to 2100 hours. The distance between the source and receiver in these locations was approximately 5 to 15 feet.

Calculations of L_{Aeq8h}

The data was collected in the following percentiles: L_{A99}, L_{A90}, L_{A50}, L_{A10}, and L_{A1}, and approximate values of L_{Aeq8h} for each selected site from the formula indicated in Equation 1 [3, 13]. The L_{A1} represents the noise level exceeding 1%, L_{A10} represents exceeding 10%, L_{A50} represents exceeding 50%, L_{A90} represents exceeding 90%, and L_{A99} represents exceeding 90% of the measurement period.

$$LAeq = \frac{LA50 + (LA10 - LA90)^2}{56}$$

Resident Survey on Noise Impacts

A short public survey was undertaken to determine the response of the residents to noise pollution. The survey was carried out with the approval of the relevant authorities in each society. Twenty people from each location completed the survey to determine the influence of noise on stress/anxiety, sleep, and the requirement of the noise barrier. The

Table 1. Physical characteristics of selected location.

Location and Road	Land Use	Road Type	Tree Plantation	Physical Hindrance	Distance (Source to receiver)
#1) Sui Gas Society, Lahore Rind Road	Society situated along the ring road	Highway	Yes	Boundary Wall	15 feet
#2) DHA Phase V, Lahore Rind Road	Society situated along the ring road	Highway	No	Boundary wall	20 feet
#3) Ashiana-E-Quaid, Lahore Rind Road	Society situated along the ring road	Highway	No	No	300 feet
#4) Model Town, Ferozepur Road	Study road connects Model town residential zone with commercial zone	Collector Road	Yes	No	10 to 15 feet
#5) Township, Ali Road	Ali road connects the Township residential zone with the commercial zone	Collector Road	No	No	15 to 20 feet
#6) Johar Town, Ghazan Road	Ghazan road passes through the residential area and connects with the commercial zone of Johar town.	Local Road	No	No	10 to 15 feet

Table 2. Noise levels in dB.

Vehicular Type/Locations	Car	Auto Rikshaws	Motor Bikes	Buses	Trucks
Sui Gas Society, Lahore Rind Road	56.5	*	*	72	75.5
DHA Phase V, Lahore Rind Road	78	*	*	81	82
Ashiana-E-Quaid Scheme, Lahore Rind Road	67.5	*	*	73.5	80.5
Model Town, Ferozepur Road	65	76	71.5	77.5	86.5
Township, Ali Road	73.5	77	80.5	81	86.5
Johar Town, Ghazan Road	77.5	81.5	75	83.5	85

*Auto rikshaws and motorbikes are not allowed to follow the Lahore Ring Road

questions asked through the proforma were related to the presence/absence of stress/anxiety, an indication of sleep disturbances, and the need for noise barriers (yes/no).

Results

Noise Levels from Different Vehicles

Table 2 shows the details of average noise levels for all locations related to different vehicles. Raised noise levels were reported from cars (77.5 dB-A), auto-rickshaws (81.5 dB-A), and buses (83.5 dB-A) in Johar Town (Ghazan Road). 80.5 dB(A) was reported from motorbikes in the Township (Ali Road). Maximum decibels were reported from the trucks (86.5 dB-A) from Model Town (Ferozepur Road) and Township (Ali Road). The noise levels in the societies near Lahore Ring Road (Sui Gas Society, DHA Phase 5, and Ashiana-E-Quaid Scheme) were low for cars, buses, and trucks. Auto rikshaws and motorbikes are not allowed to follow the Lahore Ring Road.

Noise Levels at Source and Receiver Distances

Table 3 provides details on road traffic noise levels in the following percentiles: L_{A99}, L_{A90}, L_{A50}, L_{A10}, and L_{A1} and approximate values of L_{Aeq8h} at the source and the receiver. All percentile values at the source exceeded the threshold limit of 70 dB(A). However, at the receiver junctions, only the Ashiana-E-Quaid at LRR (61-68 dBA) had less than 70dB(A).

Table 4 provides details on the noise levels at the source and the receiver for all locations during 0900-2100. LAeq values exceeded the limit (>70 dBA) in all locations at source points. At the source, the highest L_{Aeq} was reported from the Township (93 dBA). L_{Aeq} at source was 82 dB(A) at Sui-gas society, Ashiana-E-Quaid and Model Town, 86 dB(A) at DHA phase V, 87 dB(A) at Johar Town, and 93 dB(A) at Township. L_{Aeq} values exceeded the limit (>70 dBA) in all locations at the receiver point except Ashiana-E-Quaid society (63.5 dBA). L_{Aeq} at receiver was 83 at DHA phase V, and at Johar Town, 74 dB(A) at Sui-gas society, 72 dB(A) at the Model Town, 91 dB(A) at Township, and 63.5 dB(A) at Ashiana-E-Quaid society. At the receiver, the highest L_{Aeq} was reported from the Township (91 dBA).

At Location 1 (Sui Gas Society - LRR), a reduction of 8 decibels in sound pressure level was observed. The reason for this detection is the tree plantation between the source and receiver points (15 feet). But in Location 2 (DHA phase V LRR) only a 3 dB(A) reduction was observed, mainly due to no plantation between the source and receiver (20 feet). For Locations 1 and 2 (along LRR), there is a physical hindrance of a boundary wall.

Table 3. Road traffic noise level.

Location	LA99 db(A)		LA90 dB(A)		LA50 dB(A)		LA10 dB(A)		LA1 dB(A)		LAeq	
	S	R	S	R	S	R	S	R	S	R	S	R
Sui Gas Society, Lahore Rind Road	78	72	80	73	82	74	83	76	84	77	82	74
DHA Phase V, Lahore Rind Road	82	80	84	82	86	83	88	84	89	84	86	83
Ashiana-E-Quaid, Lahore Rind Road	79	61	81	62	82	63	85	67	85	68	82	63.5
Model Town, Ferozepur Road	78	71	80	73	82	72	85	74	85	74	82.5	72
Township, Ali Road	88	83	89	85	92	89	95	95	96	96	93	91
Johar Town, Ghazan Road	85	78	86	80	87	81	90	88	92	90	87	83

* Note: Threshold limit of 70 dB(A) as per US EPA; and 45 (night)-55(day) dB(A) as per Punjab EPD; S: Source; R: Receiver

Exceeds limits — Acceptable

Table 4. Measurement of Noise Levels at the Source and the Receiver.

Noise Level/ Locations	Source Noise level measurement in decibels								Receiver Noise level measurement in decibels							
	Time of measurement (0900 to 2100)															
	0900	1100	1300	1500	1700	1900	2100	L_{Aeq}	0900	1100	1300	1500	1700	1900	2100	L_{Aeq}
Sui Gas Society, Lahore Rind Road	78	81	84	83	85	80	82	82	72	74	73	72	75	74	76	74
DHA Phase V, Lahore Rind Road	83	82	85	87	87	87	88	86	84	82	83	84	81	85	80	83
Ashiana-E-Quaid, Lahore Rind Road	82	79	85	82	81	82	82	82	61	61	63	62	62	62	67	63.5
Model Town, Ferozepur Road	78	78	81	85	82	82	85	82	71	70	69	71	74	72	74	72
Township, Ali Road	88	95	95	92	95	90	92	93	83	92	93	92	88	94	95	91
Johar Town, Ghazan Road	86	85	89	89	88	88	90	87	85	78	80	82	82	85	88	83

* Note: 70 dB(A) is considered a threshold level (as per US EPA)

Not acceptable, barrier needed — Acceptable, no barrier needed

Table 5. A public survey on noise pollution's impacts.

Questions/Locations N=120	Indication of Stress/Anxiety		Sleep Disturbance		Need for Noise Barrier	
	Yes	No	Yes	No	Yes	No
Sui Gas Society, Lahore Rind Road (n=20)	5 (25%)	15 (75%)	2 (10%)	18 (90%)	1 (5%)	19 (95%)
DHA Phase V, Lahore Rind Road (n=20)	15 (75%)	5 (25%)	11 (55%)	9 (45%)	7 (35%)	13 (65%)
Ashiana-E-Quaid, Lahore Rind Road (n=20)	5 (75%)	15 (75%)	1 (5%)	19 (95%)	1 (5%)	19 (95%)
Model Town, Ferozepur Road (n=20)	15 (75%)	5 (25%)	11 (55%)	9 (45%)	12 (60%)	8 (40%)
Township, Ali Road (n=20)	18 (90%)	2 (10%)	13 (65%)	7 (35%)	15 (75%)	5 (25%)
Johar Town, Ghazan Road (n=20)	17 (85%)	3 (15%)	14 (70%)	6 (30%)	16 (80%)	4 (20%)
Total	75(62.5%)	45(37.5%)	52(43.3%)	68(56.6%)	52(43.3%)	68(56.6%)

Both locations were situated at almost the same distance from the Lahore Ring Road (LRR) and had almost the same traffic and site geometries. Trees were present in Location 1 but not in Location 2.

At Location 3 (Ashiana-E-Quaid LRR), a marked reduction of 18.5 dB(A) was observed. The main reason is the distance between the source and the receiver was very large (300 feet), although there was neither a tree plantation nor a boundary wall between the source and receiver. It means the distance from the source to the receiver plays an important role in noise detection. More distance, more reduction.

At Locations 4, 5, and 6 (Ferozepur Road, Ali Road and Ghazan Road), the distance between the source and receiver was 10 to 20 feet. A 10 dB(A) reduction in noise level was observed at the Model Town (Ferozepur Road) due to trees. There were no trees/vegetation and no physical hindrance; therefore, only a 2 dB(A) reduction and a 4 dB(A) reduction were observed along the Township and Johar Towns, respectively.

Results of the Noise Health Impact Survey

Table 5 gives the details of the survey. A total of 20 individuals (one person from each family) participated in this survey. The presence (or absence) of stress and anxiety was self-reported by the respondent. The survey was taken based on the individual's responses; medical reports were not collected due to privacy issues. The majority (90%) of residents from the Township reported stress and anxiety from the noise. The majority (70%) of Johar town residents reported sleep disturbances from the noise. 62.5% of residents reported stress and anxiety, and 43.3% mentioned sleep disturbances. Overall, 43.3% of people indicated the need for noise barriers.

Discussion

Controlling noise pollution is challenging due to the rapid growth in transportation demand. Highways such as the LRR (Lahore Ring Road) also traverse residential and business districts. The government should take steps to reduce noise pollution. The World Health Organization (WHO) stated in 2011 that noise pollution cost Europe 1.0-1.6 million disability-adjusted life-years (DALYs) [14]. The distance between the source and receiver is a major factor in reducing noise levels. In our study, in the case of the Ashiana-E-Quaid housing scheme, the distance between LRR (Lahore Ring Road) and the boundary wall of society is 200 to 400 feet. This distance reduced the noise level by 18.5 decibels. However, in the case of DHA phase 5, the distance between the source and receiver was 20 feet, which prevented any effective noise level from being reduced. The distance between the source and receiver, as well as the intensity of the noise, are inversely proportional to each other. Another important factor in reducing noise pollution is tree plantation. Out of six locations, tree plantations along the road are present only in two locations. Due to the plantation of trees at Sui Gas Society, a greater reduction in decibels (8 dBA) was observed as compared to DHA phase V (3 dBA), although both societies are almost at the same distance between the source and the receiver. This demonstrates that tree planting is the mechanism that decreases noise levels to that amount. On the Model Town Ferozepur Link Road, the noise level was drastically reduced (10 dBA) due to tree plantation along the road, however, the distance between the source and receiver was the same in the case of Ali Road and Ghazan Road.

At the source, all percentile values (L_{A99}, L_{A90}, L_{A50}, L_{A10}, and L_{A1}) exceeded the threshold limit of 70 dB(A). Only the Ashiana-E-Quaid at LRR (61-68 dBA) had less than 70dB(A) at the receiver junctions. L_{Aeq} values surpassed the limit (>70 dBA) in all source point locations. Township had the greatest L_{Aeq} (93 dBA) at the source. L_{Aeq} values exceeded the limit (>70 dBA) for all receiver point sites except Ashiana-E-Quaid society (63.5 dBA). Township had the greatest L_{Aeq} (91 dBA) at the receiver. Overall, less than 70 dB(A) was only observed at the receiver point at the Ashiana-E-Quaid scheme. The highest noise level (91 dBA) at the receiver was reported from Township, Ali Road. However, according to the Punjab Environment Protection Department (2013), the quality standards for noise (L_{eq}) in residential areas are 55 dB(A) during the day and 45 dB(A) during the night; hence, all recorded noise levels of the study sites exceeded the limit explained by the Punjab EPD. Therefore, there is an urgent need to mitigate noise pollution to protect the population from health impacts.

Through a public survey, it was observed that people living in areas where the noise level is above 65 dB, reported stress and anxiety from noise pollution. Noise levels above the threshold value affected the sleep of the residents. The cars created less noise as compared to bikes, rickshaws, buses, and trucks. Buses and trucks are major sources of noise, followed by rickshaws and motorbikes. An increase in traffic daily inevitably increases noise pollution. Peak hours on the road created more noise pollution. Outdated vehicles on the road also created more noise than vehicles in good positions. Just providing noise barriers along roads is not a vital step; the focus should be on reducing the source of noise pollution as well. The public transport system should be improved, so that the general public will prefer to use public transport over private transport. To maximize land utilization, an efficient land development and building plan must be implemented. As a result, increased highway building along residential areas exposes more inhabitants to traffic noise, raising concerns about the negative effects of traffic noise on the quality of life in a residential neighborhood. According to research published by Singapore's National Environment Agency (NEA), measures such as emission control, noise barrier installation, building placement strategy, and building design strategy are used to decrease residents' exposure to traffic noise [15].

A commonly used noise abutment method involves creating a noise barrier along the highway. As per basic noise acoustic standards and the design of the noise, a barrier plays a vital role in reducing noise levels. These barriers are composed of various materials and are built to minimize noise levels in impacted regions near the highway as well as to obstruct the line of sight between residences (built along roads) and automobiles on the highway. The cost of the construction of noise barriers should be considered when designing any highway construction project. The material used for noise barriers should be economical, environmentally friendly, and long-lasting. To control noise, the source of the sound, the direction the sound takes, and the receiver of the sound must all be considered. To successfully manage noise pollution, the most crucial area to erect a noise barrier is at the source or near the source. The second option for noise level reduction is between the source and receiver. This position is regarded as the second-best in terms of noise reduction. The transmission route should be controlled so that the noise level reaching the receiver is reduced. The third option to control the noise barrier is at the receiver. Typically, a noise-reducing barrier is installed near the receiver [16].

The equivalent noise levels recorded at several places in Delhi ranged from 53 dB(A) to 83 dB(A). In France, the noise intensity throughout the day ranged from 41.5 dB(A) to 68.5 dB(A). In Norway, around 33% of people are exposed to sound levels of more than 55 dB(A). The total traffic noise at night irritated 82 % of the selected persons (exposed to no more than 65 dB(A)). In Cairo, the average noise level in residential neighborhoods along a public route was roughly 76.5 decibels (A). In China, the study found that the average day-to-night noise level in rooms facing major traffic in Beijing was 79.2 dB (A), resulting in noise-induced hearing damage [17-22]. Scientists [1] investigated the connections between traffic and noise in three American cities. Noise measurements were taken in the downtown sections of three US cities: Atlanta, Los Angeles, and New York City. Ambient noise levels were associated with traffic statistics in all three locations, emphasizing the relevance of traffic planning to minimize noise-related health impacts. Authors in [23] investigated the urban noise levels and traffic density of Chiniot and Jhang to identify the nonauditory health impacts of noise levels on people in both cities. The urban noise data revealed that 82% of the locations in Jhang (103 dB) and 95% of the sites in Chiniot (120 dB) exceeded the noise limitations imposed by Pakistan's National Environment Quality Standard (NEQS-Pak) and the World Health Organization (WHO). They determined that noise levels in Chiniot are greater due to excessive road traffic and high population density. Vehicle maintenance, as well as family and urban planning, are suggested as viable strategies to lower urban noise levels. Noise reduction in the city should be helped by expanding the fleet of low-noise cars, particularly electric vehicles and vehicles with hybrid systems. Screens, soundproof structures, and windows are among the most effective noise-reduction construction and acoustic technologies. The reduction of noise penetrating buildings from outside sources should be assured by suitable design of premises, the execution of measures aimed at increasing the acoustic characteristics of enclosing structures, and public utilities. In situations where a residential building must be placed on the outskirts of a residential neighborhood, special soundproof residential structures should be built along the highways. To promote acoustic comfort, composition options such as clustering of residential structures to generate enclosed space in the residential neighborhood are recommended [24].

Researchers [25] investigated the relationship between levels of exposure to road traffic noise in residential areas and the ensuing discomfort using perception and sensitivity data. The study included noise assessments in the city of So Paulo, Brazil, as well as the administration of a questionnaire to evaluate the people's perceptions of the impacts of this exposure. The noise levels at all recorded places exceeded the critical limit for the region, 55 dB(A). 48.4% of respondents experienced noise-related aggravation. There were associations found between residing in places subjected to traffic noise and feeling irritated by it. They discovered a significant proportion of irritation complaints, as well as features indicative of noise sensitivity. The authors in [26] investigated the noise levels on Faisalabad's major highways. At two sites, the highest noise level was 107.9 dB(A), while the minimum noise level was 68.3 dB(A). The increased usage of the roads near it by all forms of public, commercial, loader trucks, and private transport vehicles has resulted in a high noise level. Researchers [27] performed road traffic noise research in Lahore at 18 busy intersections with heavy traffic flow during peak working hours. The average noise level during the day has been found to exceed the allowed limit of 85dB(A) in 90% of the city's busiest spots. In Lahore, the maximum average noise level measured was 104 dB(A). This high level is due to vehicular traffic, particularly auto-rickshaws with inefficient silencers and the frequent use of pressure horns by buses, wagons, and lorries, among other things. The study results give sufficient baseline data for engineering measures and interim laws against traffic noise pollution. Based on people's perceptions and reporting, researchers [28] established traffic noise levels in residential areas, including an assessment of irritation and health impacts. Nineteen percent of those interviewed reported sleeping difficulties, and 19.8% reported stress as a result of exposure to road traffic noise.

Conclusions and Recommendations

All percentile (L_{A99}, L_{A90}, L_{A50}, L_{A10}, and L_{A1}) values at the source exceeded the threshold limit of 70 dB(A). L_{Aeq} values exceeded the limit (>70 dBA) in all locations at source points. L_{Aeq} values exceeded the limit (>70 dBA) in all locations at the receiver point except Ashiana-E-Quaid society (63.5 dBA). All recorded noise levels at the study sites exceeded the limit explained by Punjab EPD (45-55 dBA). It is recommended that noise barriers be placed along highways to prevent traffic noise from reaching homes built near roadways. Tree plantation, precast reinforced cement concrete walls, and brick walls are some options for noise barriers. A tree plantation is considered a better alternative than all others since it has various environmental benefits. The government should take steps to counter noise pollution by planting trees along roads. The concerned department should consider noise barrier costs while planning infrastructure projects. The state should find areas where sound pressure levels are above the threshold level and take the necessary steps to cope with this issue. Traffic officials should take steps to lower noise levels in the city, particularly in congested areas. Conducting detailed investigations on noise pollution in major cities across Pakistan will provide a broader understanding of the issue's prevalence and variations. This research could lead to region-specific recommendations and policies tailored to address unique challenges in different urban settings. Changes in the design of vehicle engines should be considered. The design of the noise barrier and the material used for the noise barrier should be studied.

Conflict of Interest

The authors declare no conflict of interest.

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