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Spatial Assessment and Frequency Analysis of Noise Pollution and its Impact on Human Health: A Case Study of Iqbal Town-Lahore

Malaika Muzaffar
Institute of Geography, University of the Punjab, Lahore 54000, Pakistan.
Sumaira Kousar*
Institute of Geography, University of the Punjab, Lahore 54000, Pakistan
Sumaira.geog@pu.edu.pk
Zaid Bin Javaid
Department of Electrical and Computer Engineering, COMSATS University Islamabad, Lahore Campus, Lahore 54000, Pakistan
Faiza Sarwar
Institute of Geography, University of the Punjab, Lahore 54000, Pakistan

ABSTRACT
Noise pollution refers to unwanted or disturbing sound that adversely affects the health and quality of life for humans and other organisms. Noise impacts many aspects of the environment, including noise from transportation, industry, and neighbors. Human health is adversely affected by noise associated with transportation. Noise pollution distracts from routine work activity, depresses performance on various tasks, alters social behavior, and annoys. The primary aim of this study was to assess, the effect of noise pollution on human health, classify the different parameters contributing to heightened noise pollution, consequences in the shape of others disorders like; osteoporosis, annoyance, hypertension, hair fall, depression, etc., and how we can control this by some authenticated preventive measures. This was a cross-sectional survey that was conducted in the administrative division ofa Lahore Iqbal Town. The data was collected by digital noise meter (range 30db-100db). Almost 250 questionnaires were filled by population of Lahore including children, traffic wardens, old aged peoples and students. Research was completed using Arc Map 10.5 and Python, while the statistical data was analyzed with SPSS software. Using Python programming the three types of noise spectrum analysis using Fast Fourier Transform (FFT) identified the major noise sources for an arbitrary series of frequencies. The high frequency noise was filtered by applying a low-pass filter, which allowed for the most impactful frequencies to be analyzed. To validate the filtering process, the original and post-filter spectra were compared. Arc GIS reveal that the noise pollution is maximum in Raiwind and minimum in Bakar Mandi. The results illustrate that noise pollution also represents a significant challenge, with 94.5% of participants recognizing noise pollution as a major problem. Complaints to the administration and police have been accepted to resolve the issue. Public education seems to be the best option according to the respondents; however, the government and NGOs can also aid in the process.

Keywords: *Digital Noise Meter, SPSS, Decibel (db), GIS, Noise Pollution, Arc Map, Fast Fourier, Python Transform*

Introduction

Noise, derived from the Latin word *nausea*, refers to unpleasant and unwanted sound that causes discomfort. Measured in decibels (dB), noise pollution can severely affect both mental and physical health. Prolonged exposure to loud noise can damage the delicate inner ear structures, leading to permanent hearing loss. According to the World Health Organization (WHO), noise pollution is an often-overlooked environmental hazard with significant health implications, regardless of its source—be it traffic, industrial activity, or urban living. Among these, traffic noise is the most dominant contributor, especially in densely populated urban areas, and is mainly generated by tire friction, engine sounds, and honking.

WHO estimates that noise pollution contributes to over a million deaths annually, with traffic noise accounting for a large proportion. In Asia, rapid urbanization and population growth have intensified the impacts of noise pollution, particularly from traffic. Major cities in China, India, and Japan face alarming levels of noise-related health concerns such as stress and cardiovascular diseases. Pakistan, including cities like Karachi, Islamabad, and especially Lahore, also ranks among the world's most polluted areas in terms of noise. Lahore, the second-largest city in Pakistan, is critically affected, with its dense traffic and poor noise control measures contributing to widespread health problems for its residents.

Noise pollution affects more than hearing; it disrupts sleep, causes mood and cognitive disorders, and is linked to conditions like hypertension, depression, and even hair loss. These health effects stem from continuous exposure to elevated noise levels, particularly in urban environments. The broader definition of health—encompassing mental, physical, and social well-being—highlights the multifaceted harm noise pollution inflicts. The study aims to assess these health impacts, identify major contributors to noise, and explore preventative measures to reduce its effects and safeguard public health.

Study area:

The research was conducted in Lahore, Iqbal Town, a well-known urban place characterized by relatively high ambient population density and a mixture of socioeconomic attributes. It is one of the 10 zones of the Lahore metropolitan area. Iqbal Town is situated in the southeastern part of Lahore and encompasses an estimated 46 square kilometers. It contains multilayered types of land uses: residential, commercial and industrial.

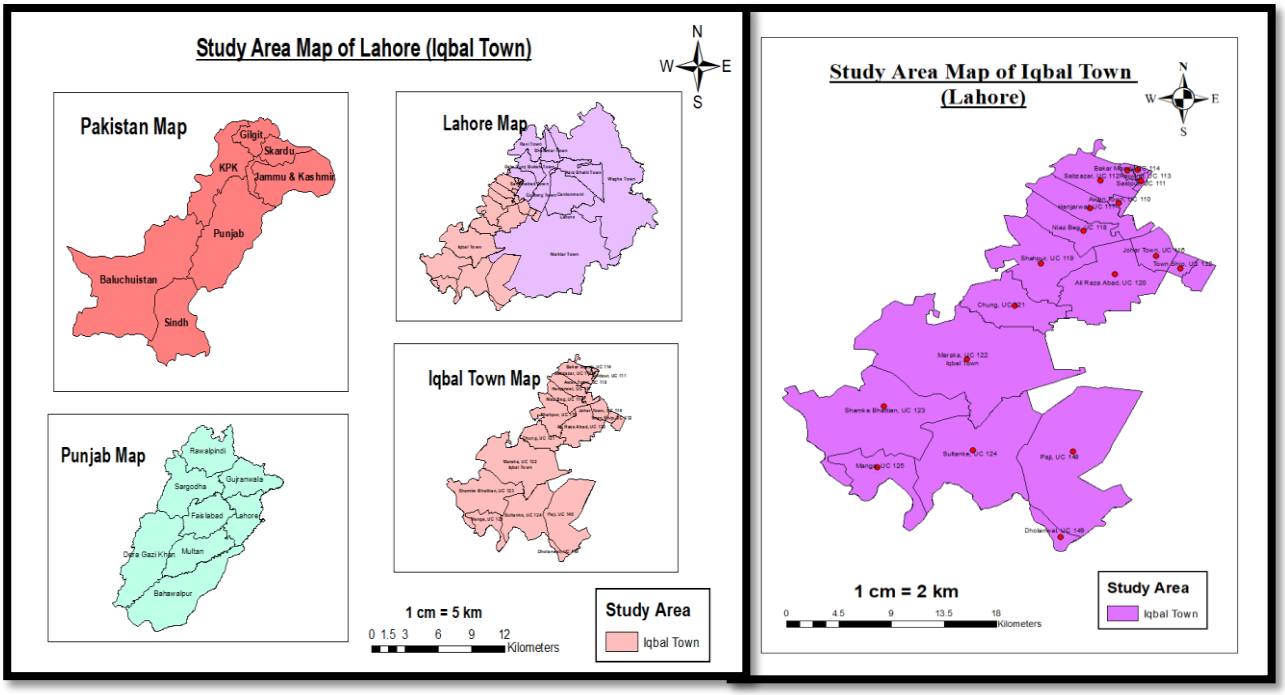

Figure 1: Study areas Map of Iqbal town Lahore.

Methodology

This research uses a mixed methods approach to evaluate the spatial distribution of noise pollution and its effects on human health in Iqbal Town, Lahore. The research methodology includes several key components: data collection, noise mapping, data analysis, and interpretation. By using quantitative and qualitative data together, a multi-faceted understanding of the relationship between noise pollution and human health is achieved.

Materials

In the study, we investigate how traffic volume is related to noise pollution, identify key sources of noise pollution, determine the effects of noise pollution on human health, compare noise pollution and its effects on human health in multiple towns in Lahore, provide recommendations for reducing noise pollution and its health effects in Iqbal Town and then compare original and filtered noise then provide a health non-hazardous plot using Python. Below is the primary data recorded onsite using a digital meter.

Table 1: Iqbal Town areas (noise level)

Name	Noise(DB)
Ali Raza Abad, UC 120	50.2
Awan Town, UC 110	60.9
Bakar Mandi, UC 114	48.9
Chung, UC 121	55.9

Dholanwal, UC 149	53.7
Hanjarwal, UC 117	58.9
Iqbal town	57.7
Johar Town, UC 116	55.2
Manga, UC 125	50
Maraka, UC 122	56.1
Niaz Beg, UC 118	60.8
Paji, UC 148	54.5
Raiwind, UC 113	61.2
Sabzazar, UC 112	56.2
Saidpur, UC 111	56.1
Shahpur, UC 119	54.3
Shamke Bhattian, UC 123	58.3
Sultanke, UC 124	51.2
Town Ship, UC 132	58.2

Measurement tools:

Sound meters were utilized to monitor levels of noise. The proper testing conditions were predetermined by several aspects. The aspects that were considered included (a) time of day, i.e. peak traffic hours (12:00 to 3:00) vs. non-peak traffic hours; (b) day of the week, i.e. weekday vs. weekend; and (c) the relative dB noise level, i.e. weather patterns at each site that were sufficiently different in noise levels to show a relationship between a person having increased dB levels correlated to higher hearing loss as well as increased disturbance of sleep. Although peak traffic hours can differ by country, city, and season, this interval was selected for the study in order to maximize the range of peak traffic. A baseline dB level was recorded at each site. The values were accumulated over the length of the five-minute measurement; average decibels, the minimum dB, and the maximum decibels. The final data included a summary of this data which was averaged over all subjects at each site. However, the maximum and minimum dB values were only included as "faxed" values from each site, and were not to be relied upon for supporting any conclusion.

Statistical and mapping tools:

The noise pollution study in Iqbal Town used ArcGIS for spatial mapping and Google Forms to survey 200 residents and 50 traffic wardens about health impacts. A set of 25 questions was divided into various themes, such as sleep, concentration, and work. Using SPSS, the raw data was analyzed, with regression analysis performed to determine the relationships between the noise levels and any health issues. The three types of noise spectrum analysis using Fast Fourier Transform (FFT) identified the major noise sources for an arbitrary series of frequencies. The high frequency noise was filtered by applying a low-pass filter, which allowed for the most impactful frequencies to be analyzed. To validate the filtering process, the original and post-filter spectra were compared. Finally, the study began to synthesize the results to characterize and report on the health effects of noise pollution in the area.

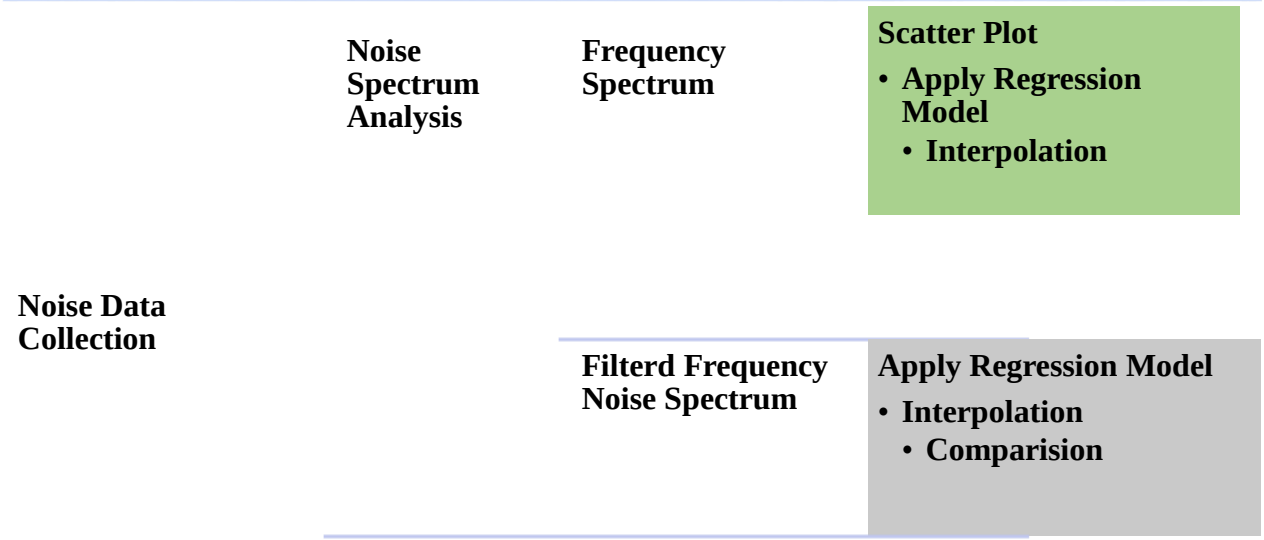

Figure 2 Shows how to make noise spectrum

Algorithms

The Fast Fourier Transform (FFT) algorithm: **1**

$$X(k) = \sum_{n=0}^{N-1} x(n) \cdot e^{-i2\pi kn/N}$$

Where:

- X (k) is the k-th element of the DFT, representing the frequency component.
- x (n) is the n-th element of the input sequence in the time domain.
- N is the total number of samples.
- i is the imaginary unit (i=√ −1).
- e is the base of the natural logarithm.
- k is the index of the frequency component, ranging from 0 to N−1.
- n is the time domain sample index, ranging from 0 to N−1.

Low-pass Butter's mathematical expression: **2**

$$Hz = \frac{b0+b1z\,1+\cdots.bn\,z\,n}{1+a1z\,1+\cdots.an\,z\,n}$$

Where:

- b0, b1,….,bnb_0, b_1, \ldots, b_nb0,b1,…,bn are the numerator coefficients (related to the filter's characteristics such as cutoff frequency and order).
- a1,a2,…,ana_1, a_2, \ldots, a_na1,a2,…,an are the denominator coefficients.

Result and Discussion:

We can consider our results to be perfect as WHO average traffic noise is <53db, and our measurement for traffic noise is also close to it. Following the procedure for interpolation on the noise data measured from the sound digital meter, this map in Arc GIS reveal that the noise pollution is maximum in Raiwind and minimum in Bakar Mandi.

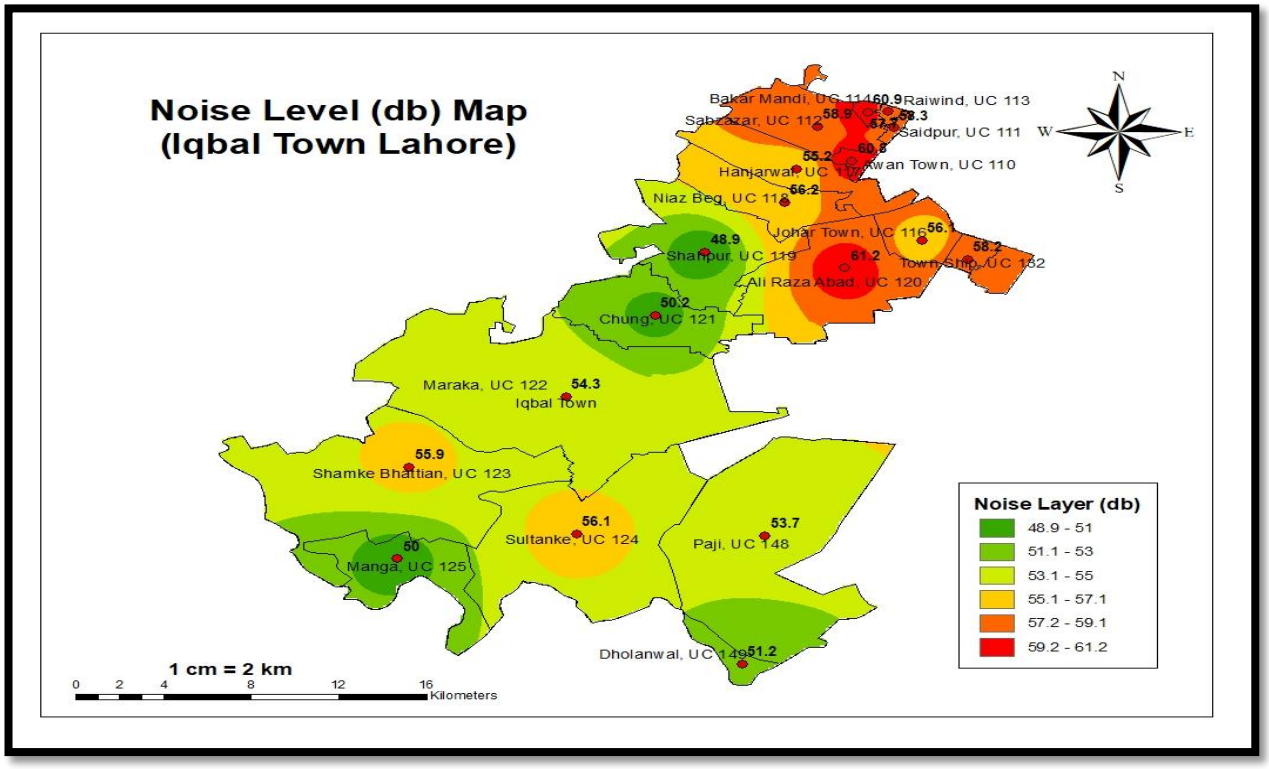

Figure 3: Interpolation Map shows the noise pollution of Iqbal Town, Lahore

Table 2 Public Frequency Table in Percentage

Statement	Yes	No	May be
Noise Pollution as a problem	94.5	5.5	0.0
Disturbance in the workplace	68.0	3.0	29.0
Disturbance during sleep	53.5	8.0	38.5
Effect Concentration in Studies	63.0	2.5	34.5
Influenced decision making	54.5	7.5	38.0
Effect Physical Health	65.5	7.0	38.0
Effect Mental health	70.5	2.0	27.5
Communication Difficulty	73.0	2.0	25.0
Respiratory Problem	54.5	11.5	34.5
Disrupt Daily Activities	54.5	8.0	37.5
Impact on Vulnerable People	73.0	1.5	25.5
Use of noisy vehicle	76.0	1.0	23.0

Increase of noise in last few years	75.0	0.5	24.5
Hearing Loss	39.0	21.5	39.5
Irritation	74.5	1.0	24.5
Mood Swings	63.0	5.5	31.5
Community effort to reduce noise	70.5	2.5	27.0
Plant more trees to reduce noise	70.0	1.0	29.0
Efforts of the community to control noise	30.0	29.0	41.0
Government work	73.0	1.5	25.5
Govt. penalties to violence creator	77.0	0.5	22.5

The results illustrate that noise pollution also represents a significant challenge, with 94.5% of participants recognizing noise pollution as a major problem. Noise levels were shown to change by level of concern by color coding from green (low: 48.9–51 dB) to red (high: 59.2–61.2 dB). As for the survey questions, many reported significant effects to daily living, including work (68%), sleeping (53.5%), studying (63%), ability to make decisions (54.5%), physical health (65.5%), and mental health (70.5%). Communication problems were for (n=73) all 73% participants, and respiratory problems (n=54.5) 54.5% reported, and disruptions in daily living; noises been suggested higher encountered by (n=75) 75% of participants influence noise levels.

Table 3 Traffic Wardens response frequency table

Statement	Yes	No	May be
Work in a highly noise area	94.0	0.0	6.0
Construction areas near traffic increase more noise	74.0	2.0	24.0
Noise increases at peak times	100.0	0.0	0.0
Headaches due to noise	90.0	0.0	10.0
Hearing loss	72.0	4.0	24.0
Honking increases more noise	100.0	0.0	0.0
Mental Health Impact	52.0	4.0	44.0
Loss of Sleep at Night	42.0	16.0	42.0
Noise depends on the time of day	84.0	6.0	10.0
My environment is noisy	94.0	0.0	6.0
Headphones help to reduce noise	78.0	16.0	6.0
Training helps to deal with noise	0.0	100.0	0.0
Noise control measures help	84.0	12.0	4.0
Resources protect against noise	0.0	98.0	2.0
Noise is a significant issue in my area	98.0	0.0	2.0

The findings of the study provide a lot of useful insights on noise pollution and how it impacts humans. Most responders (94%) work in very loud environments and indicated that during more

peak times, noise levels increase and that honking has a notable impact on reducing noise pollution. Construction near traffic was perceived to greatly impact noise levels by 74%. Noise pollution was positively related to 90% of headaches and 72% of hearing loss. 52% indicated impacts to mental health and 42% stated sleep loss at night due to noise exposure, as illustrated in Table 4.5.

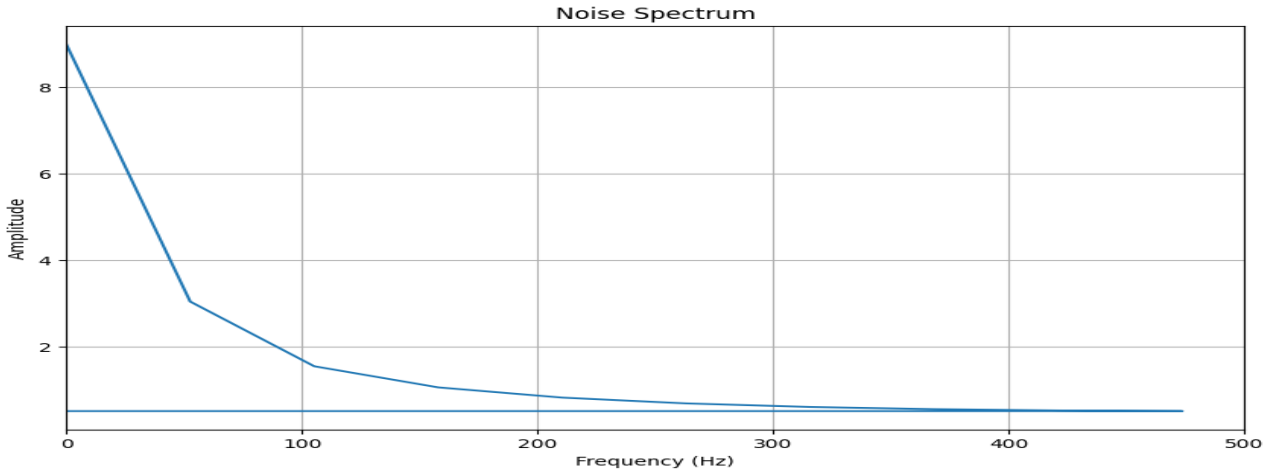

Figure 4: Noise Spectrum Graph

Using Python programming Noise spectrum map was applied to health and noise data which generated this Noise spectrum graph. The graph illustrates the noise spectrum of a frequency study using the Fast Fourier Transform (FFT). The graph indicates that the noise contributes to low frequency and noise energy sharply decreases as frequency increases. This pattern indicates that low frequency noise pollution which is likely to have a noteworthy negative impact on human health represents most of the noise pollution in the area of health and noise study.

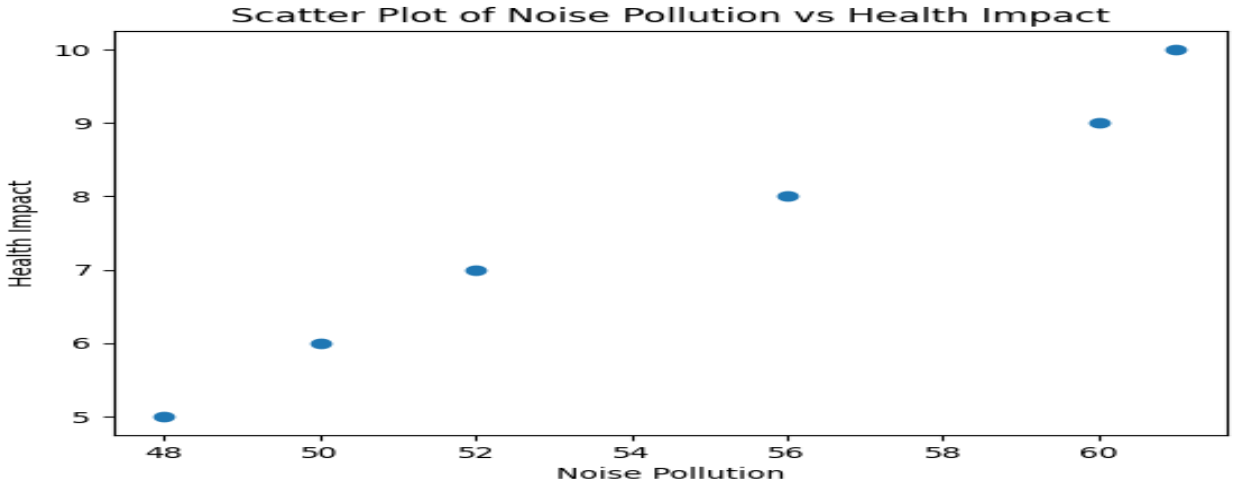

Figure 5: Scatter Plot of Noise Pollution vs Health Impact

The above graph represents the scatter plot of Noise Pollution and Health impact. The points demonstrate the significant relationship between noise and human health impact. It is conclusive that noise pollution directly impacts human health. P-value for the noise impact on health is 0.319. Therefore the impact of noise on health is not statistically significant. As a whole the model explains 5.83 % of the variation in health impact due to noise.

Regression Analysis

OLS Regression Results

Dep. Variable:	Health Impact	R-squared:	0.058
Model:	OLS	Adj. R-squared:	0.003
Method:	Least Squares	F-statistic:	1.052
const	54.7306	noise	0.3449

coef	1.71	std err	t	P>|t|	[0.025	0.975]
Skew:	0.321		Kurtosis:		2.571	

The coefficient for the noise impact on health: is 1.7177850829463757, the P-value for the noise impact on health: is 0.3194925260271925, R-squared value of the model: is 0.05825938834081168. So, we can say that the impact of noise on health is not statistically significant. Overall, the model explains 5.83 % of the variance in health impact due to noise.

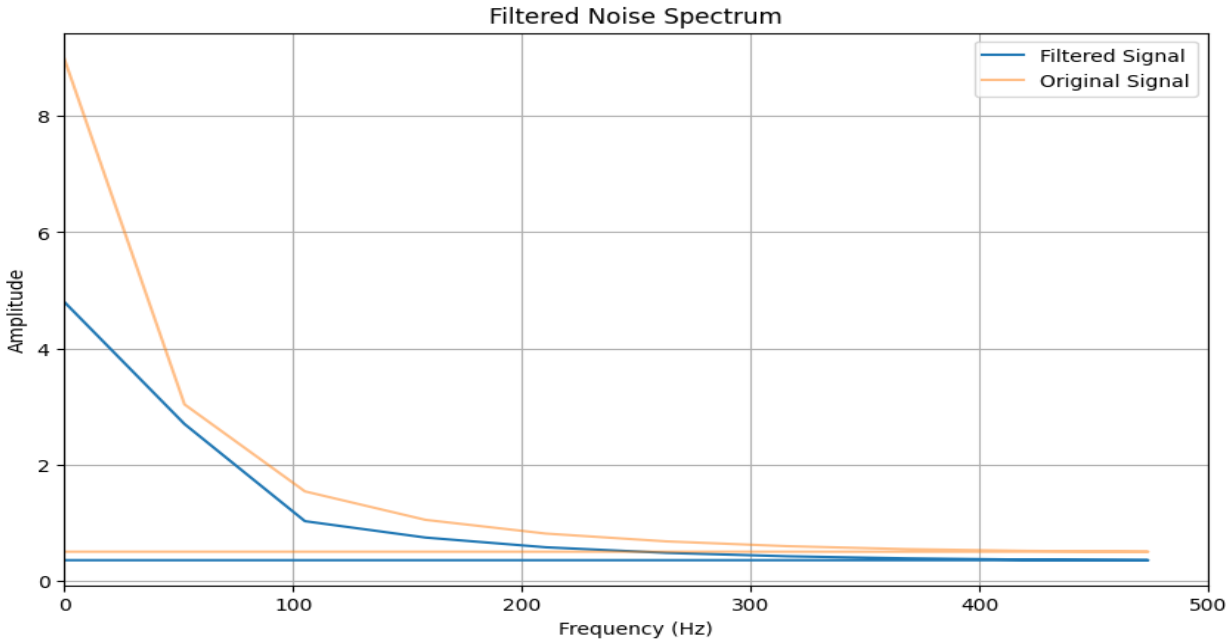

Figure 6: Filtered Noise Spectrum

The filtered noise spectrum graph shows the frequency content of the noise signal after it has been filtered to remove unwanted frequencies. The blue line represents Filtered Signal and the Yellow line is the original signal. The filtering process is effective as it attenuated unwanted frequencies outside of the desired range producing a cleaner representation of the spectral characteristics of the noise signal itself. P-value for noise impacts on health: 0.000. Clearly the impact of noise, when filtered, is statistically significant to health. The overall model is explaining 97.57% of the variance in health impacts due to noise. The impact of noise, when not filtered, in the regression result was not statistically significant. Yet, after filtering the noise and then presenting the result statistically significant to noise not being harmful to human health.

Regression Analysis

OLS Regression Results

Dep. Variable:	Health Impact	R-squared:	0.976
Model:	OLS	Adj. R-squared:	0.970
Method:	Least Squares	F-statistic:	160.7
const	-11.2997	noise	0.3449

coef	std err	t	P>|t|	[0.025	0.975]
Skew:	-0.132		Kurtosis:		1.693

After performing regression analysis all variables exhibit a significant relationship from which we can say that human health is directly affected due to the increase in noise pollution. The predictor (noise pollution) has a positive coefficient ($p < 0.001$) with a positive effect on the dependent variable with little likelihood that a classification rule will be made incorrectly: "the predicted outcome will be negative, but the real outcome is positive." The predictor is not statistically significant ($p > 0.05$) and this means it does not allow a sufficiently precise prediction of the dependent variable. The t-value for the significant predictor indicates that the finding is statistically significant and provides strong evidence against the null hypothesis.

Comparison

When we do not filter the noise, the statistical significance of the regression impact of noise is insignificant, but when we filtered the noise, statistically significant and the noise is not harmful to human health.

Discussion

Noise pollution, especially from road traffic, is still the most significant environmental nuisance in major cities. Floroian et al. (2022) find that road traffic is the highest contributor of noise in metropolitan cities. This conclusion is echoed in our research in Iqbal Town, Lahore, where the main contributor to outdoor noise was also traffic. Almost 70% of surveyed residents claimed that they were stressed, and that they experienced anger, from constant traffic noise. These levels of noise exposure have serious impacts on health and can contribute to stress disorders, hearing loss, mood changes, hypertension, and even cardiovascular disease (Ali & Zohra, 2022).

The use of GIS-based methods in this study is suitable for measuring noise pollution spatially. Using buffer zones, we performed proximity analysis in Iqbal Town, following Ghaffar (2012). They allowed for mapping the impacted zones and assessing noise levels correlated with proximity to vehicular traffic densities and road networks.

The questionnaire analysis revealed that a significant portion of the population is exposed to disturbing noise either at home or in the workplace. Specifically, 31.28% of respondents reported "sometimes" experiencing high noise levels, followed by 24.10% who answered "usually," and 20.14% who said "often." Additionally, 13.34% claimed they are "always" affected, 9.74% "rarely," and only 1.53% "never." These findings underscore the pervasive nature of noise exposure in the urban environment. Furthermore, 34.35% of the respondents “sometimes” experienced annoyance, 28.71% faced decreased work efficiency, and 33.34% suffered from sleep loss due to noise.

The noise mapping conducted in this study revealed shocking outcomes: every single one of the 19 noise mapping positions in Iqbal Town exceeded WHO nominal ambient noise benchmarks, and comparable reports by Kumar et al. (2023) indicated violations at 18 locations per CPCB

benchmark. In addition to this, 89% of respondents reported they were "sometimes" exposed to excessive noise at work, and 92% reported experiencing mood swings and sleep loss.

Public transport drivers in Lahore are particularly affected. Aslam et al. (2008) found that 75% of drivers had Noise-Induced hearing Loss (NIHL) and 10% had disabling hearing impairment. Our results were very similar: 78% of drivers exhibited headaches and hearing loss, suggesting that occupational exposure to traffic noise was a serious issue.

Noise pollution affects hearing as well as health beyond hearing. Anderson (2022) reported that as ambient noise levels increased, the Negative Affect Scores (NAS) and Resting Heart Rates (RHR) increased, revealing a reciprocal relationship between noise exposure and disturbance(s) in mental and physical health. Our study shows that noise pollution is a major driver of emotional and mental health, thus supporting our assertion that it is a concern that we must consider from a public health perspective.

As seen in the above study, the field of noise reduction will need to advance in improving efficiencies and decreasing complexities moving forward. The audio communication techniques included in this article (e.g. spectral gating, fast fourier transformations (FFT), etc.) already portray clearly seen solutions to active noise cancellation. Examples would include urban common ambient noise from construction, or traffic horns/honking. Signal to noise ratio (SNR) assessments of the audio may be utilized before and after the various processing steps of SNR enhancement, and revealed in all of the studies completed here with no statistical significance between the different audio processing algorithms. The authors as Sudheer Kumar, et al., 2023) report present that with real time applications of noise suppression may certainly improve quality of life in the urban setting, engagement with stimulating and immersive harmonic vocal audio experiences should be a given as the means to analyse these advancing audio processing methodologies and add to the available literature.

To sum up, this research's results support that noise pollution, particularly from road traffic, represents a serious public health threat. We have shown, using GIS tools and perceptual survey data, its pervasiveness and damaging effects on urban noise. Effective policies, enforcement of noise regulations, and engineering innovations are essential to mitigating these impacts and providing healthier urban areas.

Limitations:

This study has a few limitations. First of all, the specific interpolation method in GIS - analysis method (IDW, Kriging, Spline, etc.) - can introduce bias. Use of one of these methods could create differences in the pattern of the way noise spatial concentration and distribution was represented, which could have affected the interpretation.

Second, there is unavoidable subjectivity in the health impact data that were constituted by (questionnaires or self-reported measures), there was always the possibility of personal bias that could diminish the reliability of regression analysis used to assess the overall relationship between levels of ambient noise and specific health effects.

Technically speaking, Python is considered slower than more recent versions of compiled languages like C or C++, which has implications for its efficiency in handling extremely large datasets. Error handling and debugging on Python is slow, especially against complicated scripts or inconsistent data or integration of a variety of libraries, and the speed or accuracy of analysis may suffer as a result.

Conclusion

Based on the results obtained, it can be verified that the affected people belong to these locations. Considering the level of awareness in regards to knowledge of noise pollution and the harmful effects on the human body, the differences in percentages between noise pollution and noise pollution levels affecting human health are comparative. People are aware of the hazards of noise, feel and experience the effects of noise pollution, but cannot be protected from the conditions of the environment they live in. Reducing noise pollution contributes to maintaining physical and mental well-being and the enhancement of quality of life. This requires the collaboration of all relevant actors, which includes managers, authorities, citizens, as well as legal entities. Noise pollution of any kind is a danger to the entire population. Noise pollution is extremely difficult to manage, and requires precise and practical regulations to minimise its extent. These minor steps can be included into programs aimed at improving road safety, air quality, bike lanes, and other aspects of society whilst the best and most critical method to reduce the amount of noise, is where it originates from.

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