The Scientific Temper (2023) Vol. 14 (3): 909-915
E-ISSN: 2231-6396, ISSN: 0976-8653
Doi: 10.58414/SCIENTIFICTEMPER.2023.14.3.54
https://scientifictemper.com/
RESEARCH ARTICLE

Assessment of noise levels by using noise prediction modeling

Santosh K. Sahu[1*], B. R. S. Kumar[2], Y. A. Parvez[3], Ashish Verma[4]

Abstract

The third-most dangerous type of pollution, after air and water pollution, according to the World Health Organization, is noise pollution. Brief and prolonged exposure to noise pollution can have negative consequences on people, including psychological disorders, including anxiety and depression, hypertension, hormonal imbalances, and a rise in blood pressure that can result in cardiovascular disease. The WHO estimates that up to 40% of individuals in Europe are currently exposed to loud noises. This study makes an effort to predict noise levels in and around the School of Architecture and Planning (SAP) campus using data on traffic volume and flow, vehicle speed, and geometric mean of the road. Additionally, it does a comparison between the expected and actual noise levels and offers workable noise reduction techniques. A mathematical model that takes into consideration has been used to forecast the equivalent noise level. By comparing the expected and actual noise levels, it was found that all values are beyond the permitted limits. Five different locations within SAP were used to assess the amount of noise present. The Lobby recorded the highest and lowest noise levels, respectively, at 75.63 and 74.15 dB (A). There were 73.05, 71.01, 71.81, and 70.5 dB (A) accordingly as the strongest noises in the classroom and auditorium. The maximum noise levels in the library was 63.76 and 64.54 dB (A), respectively. A maximum noise level of 75.29 and 68.14 dB (A) was recorded for the studio.

Keywords: Observed and predicted noise levels, Noise pollution, Modeling.

Introduction

The majority of vehicle noise emissions that harm people's physical and mental health are traffic noise emissions, which are on the rise due to increased car ownership and urbanization. Ondo's central business district (CBD) has been continuously subjected to commercial activity and road traffic due to the growth and expansion of the economy, which has raised the traffic noise level. The amount of traffic was found to be greater than the WHO-permitted level, which resulted in an increase in traffic noise. At the ondo CBD, traffic noise models were created using empirical methods from the calculation of road traffic noise (CoRTN) model and the statistical multiple linear regression (MLR) modeling approaches where the roadside location has been evaluated at 90% more than the allowed limit by the WHO (Fidem 2022).

The increase in urban populations worldwide has led to the growth of cities that are essential for offering employment, housing, and sustainable livelihoods. Sun, He, Zhang, & Wang (2016); Zhou, Chen, & Zhang (2016); Forman & Wu (2016); He *et al.* (2018); Peng (1997). It is not always given the attention it needs to the impacts of noise pollution on a healthy urban lifestyle. The increasing noise levels in urban settings require greater investigation due to their site-specific character to apply efficient control measures or enhance municipal land use planning (Masum 2021). The annex III rule, which was created in response to the most recent WHO recommendations about the negative health impacts of noise pollution, also specifies procedures for determining the severity of sickness brought on by exposure to various levels of noisy surroundings. Policymakers now have a new concern: the estimation of the disease burden related to background noise. The cost of this problem has not yet been completely understood, and interdisciplinary approaches and solutions will be necessary to address it 2020 for Caesar Asensi.

[1]Department of Mechanical Engineering, Veer Surendra Sai University of Technology, Burla, Odisha, India.

[2]Department of Aeronautical Engineering, Nehru Institute of Engineering And Technology, Coimbatore, Tamil Nadu, India.

[3]Department of Mechanical Engineering, SNS College of Technology, Coimbatore, Tamil Nadu, India.

[4]Department of Physics, Dr. Harisingh Gour Vishwavidyalaya, Sagar, Madhya Pradesh, India.

***Corresponding Author:** Santosh K. Sahu, Department of Mechanical Engineering, Veer Surendra Sai University of Technology, Burla, Odisha, India, E-Mail: sahunitrkl@gmail.com

How to cite this article: Sahu, S.K., Kumar, B.R.S., Parvez, Y.A., Verma, A. (2023). Assessment of noise levels by using noise prediction modeling. The Scientific Temper, **14**(3): 909-915.

Doi: 10.58414/SCIENTIFICTEMPER.2023.14.3.54

Source of support: Nil

Conflict of interest: None.

Received: 10/07/2023 **Accepted:** 05/08/2023 **Published** : 25/09/2023

Furthermore, according to forecasts from the European Union, a third of the population, or approximately 30%, is exposed to similar noise levels at night. Also, according to the World Health Organization [WHO], Pitchika *et al.*, Basner & McGuire, and the WHO (2017), more than 40% of the population of Europe is exposed to noise levels over 55 dB during the day. Around 40 billion euros are predicted to be the yearly societal cost of environmental noise across the EU, with road traffic (including passenger vehicles and large trucks) accounting for 90% of this sum. About 0.4% of the EU's GDP is represented by this. According to the European Commission's 2011 white paper on transport (Directorate General for Mobility European Commission and Transport, 2011; European Economic and Social Committee, 2015), the external costs related to transportation noise are expected to reach nearly 20 billion euros annually by 2050 if nothing is done.

The WHO and the European Environment Agency have recently conducted analyses that show that road traffic noise reduces healthy life expectancy by 1.6 million DALYs annually in urban areas of Western Europe (Basner and McGuire, 2018). This is based on estimates from these organizations and the European Environment Agency. Currently, many approaches are being used to reduce traffic-related noise in metropolitan areas in Europe. A few examples include a study of vehicle acoustics, the application of sound-absorbing pavement, tire noise models, the creation of acoustic barriers, the incorporation of acoustic insulation into facades, the use of absorbent plant facades, the adoption of urban planning techniques, and the enforcement of traffic restrictions. (Vazquez *et al.*, 2020; Lavrentjev and Rämmal, 2020; Licita *et al.*, 2017, 2019, Fredianelli *et al.*, 2019, Del Pizzo *et al.*, 2019, and 2020;

Urban environmental pollution is persistent and regularly rates higher when compared to dispersed urban pollution. Pollution of the air, water, soil, and noise are only a few of the numerous problems that are widespread, particularly in metropolitan areas in developing countries that are poorly constructed. Although air, water, and soil contamination have gotten less attention, particularly in Asian cities, noise pollution is well known. Every activity has been seen to create noise, including domestic duties, commercial and industrial operations, transportation-related activities, building and development projects, leisure activities, etc. One of the biggest sources of pollution in metropolitan areas, among other things, is noise from the traffic (Grubesa, 2020).

According to the WHO in 2021, noise pollution puts 1.1 billion people (aged 12–35) at risk for hearing loss. Wokekoro (2020) claims that the detrimental effects of noise on human and aquatic well-being, which impair quality of life, include headache, sleeplessness, mental health issues, decreased attention, hearing loss, difficulty learning, stroke, and hypertension. The majority of those impacted by these problems live in large cities, particularly in Asia. In addition, some well-known international cities face similar issues with excessive noise (WHO 2021, Wokekoro 2020).

While industrialized countries like the USA, UK, and Europe have extensive noise abatement paperwork, the comparable legal documentation in Asia is still glaringly undeveloped. The noise levels recorded by the aforementioned research frequently exceed the established limitations in their individual situations, notwithstanding the restricted availability of noise level regulations for various metropolitan environments (as illustrated in Table 1) received from various nations. This emphasizes the need for further multifaceted research to encourage the adoption of measures for environmental noise reduction or mitigation in urban environments.

Furthermore, it's important to point out that legislation addressing the issue is still primarily theoretical, with real enforcement still being controversial, even in developing countries like Bangladesh, where noise pollution is already a serious problem in Table 1, several sources (Shalini and Ku-Mar, 2018, BECR 1997; Singh and Pandey, 2013; Berglund *et al.*, 2000; IS, 1968) establish noise level standards (dBA) for various metropolitan contexts.

In addition to increased traffic volume, motorized mass transit, industrial and construction activities, and amplified sound from loudspeakers used at different social and recreational gatherings, there are a number of other significant sources of noise pollution that are frequently mentioned and reported to the City Council (Chowdhury *et al.*, 2010; Muhit and Chowdhury, 2013).

As a result of urbanization, population expansion, and greater car use, traffic noise may continue to rise in frequency and severity. The factors that affect modeling traffic noise include the sources of the noise, its distance from the source, and other pertinent factors. Two of these stand out as being particularly important: the travel time to the destination and the traffic. It is, therefore, simpler to calculate, evaluate, and forecast traffic-related noise patterns when access to such data is available.

Sound Level Measurement

Sound Pressure Level

Pascal (Pa) unit of pressure are used to indicate the measurement of sound wave amplitude. Sound pressure level (Lp) measurements are used to measure amplitude, which denotes how loud a sound is. In order to calculate this metric, you must compare the wave's sound pressure as it was measured to a predetermined reference pressure.

In this context, the equation for Lp is defined as follows:
Where:
Lp = Sound Pressure Level (dB)
P = Measured pressure of the sound wave (μPa)
Pref = Reference Pressure (μPa)

Table 1: Noise level regulations for metropolitan environments

Standards	*Area of Tranquility*		*Housing Zone*		*Diverse Zone*		*Business Zone*		*Manufacturing Zone*	
	Day	*Night*	*Day*	*Night*	*Day*	*Night*	*Day*	*Night*	*Day*	*Night*
FHA	52		47-62		62		67		57	
AASHTO	47-55		47-62		62		67		57	
WHO	37	27	47	37	-	-	57	47	57	57
India	32	42	47	37	-	-	57	47	67	63
Malaysia	42	32	52	42	-	-	57	47	63	57
Bangladesh	37	27	42	32	52	42	62	52	67	62

The threshold of hearing, which is frequently set at 20 Pa, is the standard reference pressure that is most frequently employed. The Lp is depicted using a logarithmic scale since the ratio of real sound pressures can frequently be fairly large. The vast range of sound intensities and fluctuations are more precisely captured with this logarithmic format.

$L_p = 20 \log_{10}(P/P_{ref})$

of course, the formula for determining Lp looks like this:

Where:

Lp = Sound Pressure Level (dB)

P = Measured pressure of the sound wave (μPa)

Pref = Reference Pressure (μPa)

The threshold of hearing, which is fixed at 20 Pa, is a reference pressure that is frequently used for standardization. By providing a baseline, this reference pressure aids in determining the sound's strength. In order to appropriately depict the Lp, a logarithmic scale must be used because there may be large variances between individual real sound pressures. This logarithmic approach successfully facilitates the depiction of a broad range of sound intensities.

Average Sound Pressure Level

The logarithmic structure of their numbers necessitates a more sophisticated method than basic arithmetic averaging for calculating the average sound pressure level at a particular place. Following is a formula that describes the computation:

Where:

LAP stands for "average sound pressure level (dB)".

n = The overall number of sound pressure levels that were recorded

Li = Individual sound pressure level measurements in decibels, where i = 1, 2, 3,..., n

In this computation, the logarithmic scaling of the sound pressure levels and the intricacy of their accumulation are taken into account. By combining the Li values, each of which represents a recorded sound pressure level, the formula successfully approximates the average sound pressure level at the location in question.

Equivalent Sound Pressure Level

According to White (1986), the comparable sound pressure level (Leq) is the sound pressure level that is comparable to many various sound pressure levels generated at a location during a period of time. According to Baxa (1982), Leq is defined as the constant sound pressure level that will have the same impact over a certain period of time as an unpredictable sound pressure level.It may alternatively be described as the consistent sound pressure level that will use about as much energy over a certain period of time as an unpredictable sound pressure level does during the same period. It is comparable to

$L_{eq} = 10 \log_{10} 1/T (10^{Li/10} \times t_i)$

Where,

L_{eq} = Equivalent Sound Pressure Level (dB)

Li = Values of sound pressure levels recorded in dB, with i=1,2,3,….n

T = Total time duration

t_i = Time duration of different sound pressure levels expressed as fraction of the

total measuring or recording time.

Materials and Methods

Sound Level Meter

A portable sound level meter, model SLM 340, was developed by M/s AZ Instruments in Germany to measure noise levels. This meter uses an inbuilt capacitor microphone to detect sound levels and displays results with an accuracy of 0.1 dB on a digital LC display. It has two different modes for evaluating time (fast/slow) and two different modes for evaluating frequency (dB (A) or dB (C)). Temperatures ranging from 4 to 50°C and relative humidity ranging from 10 to 90% are the measured environmental factors.

Methodology

The School of Architecture and Planning (SAP) at Alagappa College of Technology (AC TECH) carried out experimental investigations to determine the noise levels caused by road noise. The advancement of road transportation is crucial for a country's economic success. All around the world, the number of cars on the road is constantly expanding. It has been suggested that to verify the noise prediction model, research should be done in the area around the aforementioned locations to measure noise levels. Measurements were made of traffic volume, vehicle speed, and the geometric mean of the route. It was also suggested to suggest suitable actions to reduce noise levels.

Assessment of Noise Level

Worldwide, the number of cars on the road is expanding quite quickly. It is well recognized that the majority of developing activities have some detrimental effects on the environment. One of them is noise pollution. Vehicle noise is believed to be the primary cause of noise pollution. Vehicle noise is believed to be the primary cause of noise pollution. Traffic noise considerably influences the atmosphere at the SAP. Most of the responsibility for the SAP rising noise pollution may be placed on the dense traffic on the nearby roads, at intersections, and on flyovers. Sardar Patel Road, Gandhi Mandapam Road, and the route connecting the School of Architecture and Planning and Alagappa College of Technology are some of the nearby SAP. Academic endeavors are hampered by traffic in a learning environment.

The measuring setup and guidelines for interior noise measurements are described in Indian standard IS: 9989 (1981). Sound level meters are used as the measurement tool. The A-weighting network and quick response are both recommended. The irritability point should be used to calculate the volume level. A tripod or a person's hand was used to hold the sound level meter microphone, which was positioned 1.2 meters above the ground. Only the operator should be near the microphone to reduce the impact of reflection during measurements. Everyone who is taking the measurements must keep a distance of at least 0.5 meters from the microphone, including the operator.

Model validation at locations

The hourly observed and forecasted noise levels for each location were compared to the acceptable noise levels listed for auditoriums, libraries, and classrooms in IS: 4954 (1968). Charts that show the hourly variance between the measured and projected Leq values were also created. The gap between the actual and predicted noise levels is one of the model acceptance criteria. The "t" test is yet another method. The forecast accuracy of the model could not be ensured by any one factor alone.

Traffic volume measurement

Manual methods were used to gauge the volume of traffic. Data at this site were collected from 8:30 am to 4:30 pm. Simultaneously tallied at the junction were the number of various types of vehicles. The cars' travel speeds along the stretch of Gandhi Mandapam and Sardar Patel roads that lead to the crossroads were also recorded.

Noise Prediction Model

$$Leq = 47.332 - 18.398\log C + 6.015\log L - 8.575\log B + 3.608\log T + 20.596\log A + 0.590\log S + 19.028\log R - 0.111Dg$$

where

Leq=Equivalent noise level dB

C = number of cars multiplied by sound emitted by one car

L = number of lorries multiplied by sound emitted by one lorry

B = number of buses multiplied by a sound emitted by one bus

T = number of two-wheelers multiplied by a sound emitted by one-two wheelers

A =Number of Auto rickshaws multiplied by sound emitted by one Auto rickshaw

S =Speed of the vehicle

R =Ratio of the road with to the height of buildings

Dg =Geometric mean of the road

$$D_g = D_f * D_n$$

where

D_f= Distance from the observer to the center line of far side roadway, m

D_n = Distance from the observer to center line of near side roadway, m

D_f= Distance from the observer to the center line of far side roadway, m

D_n = Distance from the observer to center line of near side roadway, m

Results and Discussion

A.C.Tech and SAP were the subjects of experiments to gauge the noise levels brought on by road traffic noise from Sardar Patel road, Gandhi Mandapam road, intersections, and flyovers. A number of locations in the research region had their noise levels measured. In the junction and flyover, vehicle speeds as well as traffic volume, were measured. Later, the noise prediction model's validation was completed. Here are the findings and their discussion.

Mean Traffic Volume at Intersection

This location was on one of Chennai's busiest and most crowded roadways. Gandhi Mandapam road and Sardar Patel road are the busiest roadways. Data for this site was collected from 8:30 am to 4:30 pm. Simultaneously tallied at the junction were the number of various types of cars. It was discovered that the average travel speed of the cars on the stretches of Sardar Patel and Gandhi Mandapam roads leading up to the crossroads was 32.45 and 40.28 km/hr, respectively. Figures 1 to 3 display specifics on the volume of traffic.

Sound from Different Modes of Traffic

A primary survey was conducted to determine the volume of sound released for the various traffic modes, and the average values were calculated. The sound emission from each kind of vehicle was measured separately without interference from any other source. The sound output from the various vehicle categories is depicted in Table 2.

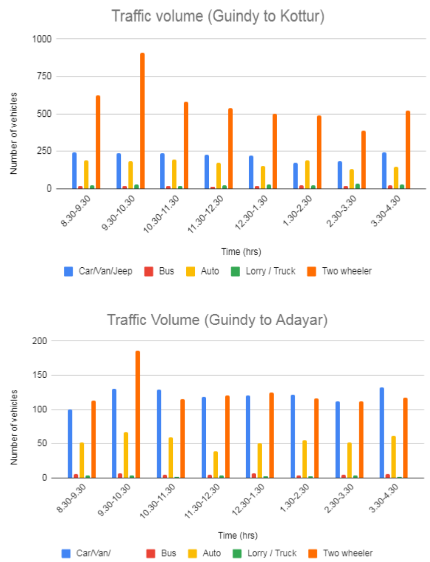

Figure 1: Traffic volume data for Sardar Patel Road 1

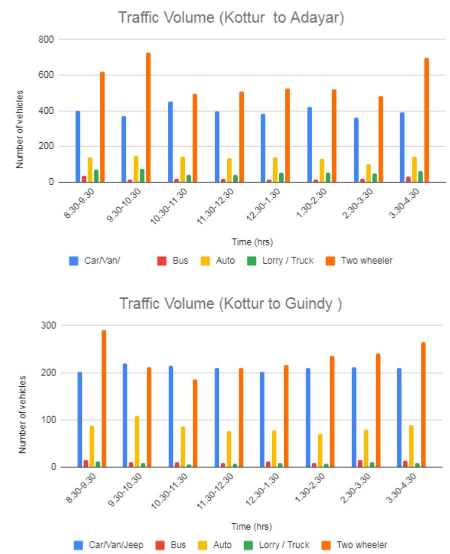

Figure 3: Traffic volume data for Gandhi Mandapam Road

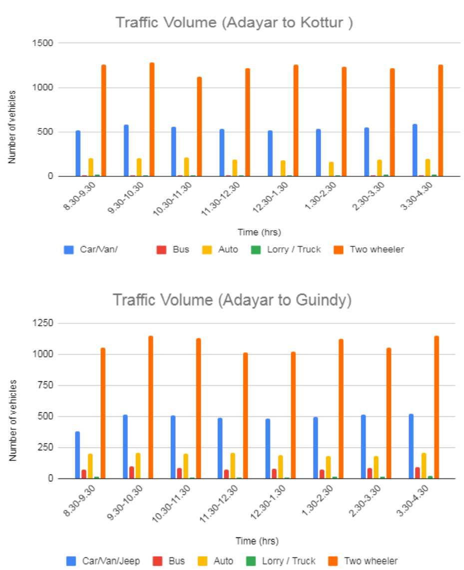

Figure 2: Traffic volume data for Sardar Patel Road 2

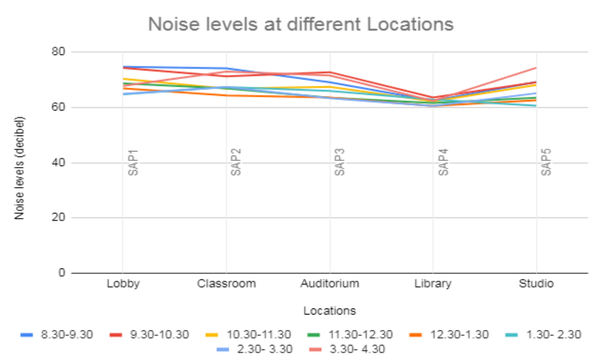

Figure 4: Noise levels at different locations in the school of architecture and planning

Table 2: Sound emission from different categories of vehicles

Type of vehicle	*Sound level in dB*
Bus	87.21
Lorry/Truck	85.51
Auto rickshaw	78.31
Car	77.08
Two wheeler	73.65

Noise Level at Locations

Noise levels in SAP

The permitted by IS: 4954-1968 noise levels were compared to the tested noise levels. Using the main survey, the hourly equivalent noise was calculated after measuring noise levels every 10 minutes. Noise levels were collected from 8:00 am to 4:00 pm. This outcome demonstrates that the noise levels were outside of what was required by IS: 4954-1968. This guideline defines tolerable noise levels of 35 to 40 dB (A) and 40 to 45 dB (A) for auditoriums, classrooms, and libraries. Figure 4 provides more information on the noise levels in several schools of architecture and planning areas. In Table 3, the SAP observed and projected values are displayed.

Model Validation for SAP

All five of the indicated sites' Leq values have been compared, both those that have been observed and those that have been approximated on an hourly basis. Additionally, graphs showing the hourly variations between the measured and predicted values of Leq have been created. The graph in Figures 4.1 through 4.5 shows the relationship between the measured Leq and the computed Leq for each of the five sites. The results of measuring this model's performance against several acceptability criteria are as follows:

The observed reading is 74.64 dB (A), but the computed equivalent noise level after value replacement reaches 68.72 dB (A) in classroom circumstances. The difference

Table 3: Comparison of observed data and predicted data for the school of architecture and planning (SAP)

Selected locations		*Noise levels (dBA) IS: 4954-1968*								*Acceptable noise levels (dBA) according to*
		08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-1.00	1.00- 2.00	2.00- 3.00	3.00- 4.00	
Lobby	OBS	85.8256	83.048	78.7024	76.8544	74.872	72.4192	72.632	75.824	37–47
	PRE	81.144	81.2672	81.144	81.1104	81.0992	81.0768	81.0208	81.1104	
Classroom	OBS	81.816	79.7552	74.7936	74.8384	71.9936	75.376	75.376	79.5312	27–37
	PRE	80.192	80.304	80.1808	80.1472	80.136	80.1248	80.0576	80.1584	
Auditorium	OBS	77.3696	80.4272	75.4544	71.064	71.1872	73.864	70.8512	78.96	37–47
	PRE	80.9312	81.0544	80.9312	80.8976	80.8864	80.8752	80.808	80.9088	
Library	OBS	69.888	72.2848	69.5856	68.9472	67.7376	70.2912	67.7936	71.4112	35–40
	PRE	78.6576	78.7696	78.6464	78.6128	78.6016	78.5904	78.5344	78.624	
Studio	OBS	76.3168	77.3024	76.2272	71.0976	70.1008	67.8048	72.8672	84.3248	40–45
	PRE	77.9408	78.064	77.9408	77.9072	77.896	77.8848	77.8176	77.9184	

between anticipated and actual values is 5.92 dB(A), which is well within the allowable tolerance range.

The Leq values observed and anticipated were compared using a paired t-test, which produced a t-value of 0.38. At a significance level of 5%, this t-value is less than the essential tabulated t-value.

Conclusion

Noise from the nearby roads had an impact on the atmosphere at the SAP. At five different SAP locations, noise evaluations were done and revealed a range of noise levels. With measurements of 75.63 and 74.15 dB (A), respectively, the Lobby had the highest and lowest noise levels. While the auditorium recorded peaks of 71.81 and 70.5 dB (A) and the classroom of 73.05 and 71.01 dB (A), respectively, the library of 64.54 and 63.76 dB (A), respectively, suffered the highest noise levels. A minimum of 68.14 dB (A) and a maximum of 75.29 dB (A) were recorded for the studio. The permitted noise levels are set forth in accordance with IS: 4954 (1968) regulations. According to these regulations, libraries should have noise levels between 40 and 45 dB (A) and auditoriums should be between 35 and 40 dB (A).

In-depth analyses were conducted to lower the noise level to within the school's allowable limits. If there are no lorries on the stretch, the equivalent noise level has been determined to decrease from 74.64 to 49.27 dB(A). The allowable noise level for a quiet zone during the day is set at 50 dB(A) in accordance with the Indian ambient noise standards published by CPCB 2000. The findings indicate that the noise level is within acceptable bounds when truckers are avoided on the stretch.

The study's findings led to the following deductions.

1. To solve the issue of noise pollution, the number of auto-rickshaws allowed on the roads in certain regions should be limited.
2. To eliminate the issue of noise pollution, the number of lorries allowed on the roads in certain regions should be limited.
3. In addition to pollution emission checks, noise pollution checks should be required.
4. Based on my survey, the next institution should be built 200 meters away from the edge of the road so that noise won't interfere with its ability to provide education.
5. Green belt development green belt has a significant role in reducing noise pollution. Controlling noise levels by infrastructure and vegetation is crucial for noise reduction. Plants capture dust and gases while also lowering noise levels. Some of the plants are *Magnifera indica*, *Acacia auriculiformis*, *Ailantuns cecelsa*, *Butea frondosa*, etc.

References

Basner, M., & McGuire, S. (2018). WHO environmental noise guidelines for the European region: A systematic review on environmental noise and effects on sleep. International Journal of Environmental Research and Public Health, v. 15, n.3, pp. 519.

BECR, (1997). The Environment Conservation Rules, 1997. Bangladesh Dep. Environ. Minist. Environ. For. Gov. People's Repub. Bangladesh pp. 179–227.

Berglund, B., Lindvall, T., Schwela, D.H., "WHO Guidelines for Community Noise," 2000.

Bidroha Basu.,Enda Murphy.,Arunima Sarkar Basu.,Srikanta Sannigrahi.,Miguel Belmonte., and Franceso Pilla. (2021). Investigating changes in noise pollution due to the COVID-19 lockdown: The case of Dublin, Ireland, Sustainable Cities and Society, v. 65, n. 2021, pp. 102597

Brueckner, J. K. (2000). Urban sprawl: Diagnosis and remedies. International Regional Science Review, v. 23(2), pp. 160–171.

César Asensi., Ignacio Pavón., Carlos Ramos., Juan Manuel López., Yolanda Pamiés., Diego Moreno., and Guillermo de Arcas. (2021), estimation of the noise emissions generated by a single vehicle while driving, Transportation Research Part D v. 95, n. 2021, pp. 102865

Chowdhury, S.C., Razzaque, M.M., Helali, M.M., Bodén, H., (2014). Assessment of noise pollution in Dhaka city. 17th Int. Congr. Sound Vib. 2010, ICSV 2010 v. 4, pp. 2490–2497.

Del Pizzo, Alessandro, Teti, Luca, Moro, Antonino, Bianco, Francesco, Fredianelli, Luca, Licitra, Gaetano, (2020). Influence of texture on tyre road noise spectrain rubberized pavements. Appl. Acoust. (ISSN: 0003-682X) v. 159, pp. 107080.

Directorate General for Mobility European Commission and Transport, (2011). White Paper on Transport : Roadmap to a Single European Transport Area : Towards a Competitive and Resource-Efficient Transport System. Publications Office of the European Union, Luxembourg, ISBN: 9789279182709, 9279182706. ID: 741532506.

European Economic and Social Committee, (2015). Draft Guidelines for Citizens and Civil Society Participation in EU Transport Policies and Projects. Technical report.

Fidelma Ibili., Adebayo O. Owolabi., Williams Ackaah., Amara Ballack Massaquoi. (2022). Statistical modelling for urban roads traffic noise levels,Scientific African v. 15, n. 2022.

Forman, R. T., & Wu, J. (2016). Where to put the next billion people. Nature, v. 537, n. 7622, pp. 608–611.

Fredianelli, Luca, Del Pizzo, Alessandro, Licitra, Gaetano, (2019). Recent developments in sonic crystals as barriers for road traffic noise mitigation. Environments (ISSN: 2076-3298) v. 6, n. 2.

He, Q., He, W., Song, Y., Wu, J., Yin, C., & Mou, Y. (2018). The impact of urban growth patterns on urban vitality in newly built-up areas based on an association rules analysis using geographical 'big data'. Land Use Policy, v. 78, pp. 726–738.

Lavrentjev, Jüri, Rämmal, Hans, (2020). Experimental study of noise barrier boards with increased acoustic performance by utilizing Helmholtz resonator effects.Mater. Today: Proc. (ISSN: 2214-7853) v. 28, pp. 2566–2571.

Licitra, Gaetano, Moro, Antonino, Teti, Luca, Del Pizzo, Alessandro, Bianco, Francesco, (2019). Modelling of acoustic ageing of rubberized pavements. Appl. Acoust. (ISSN: 0003-682X) v. 146, pp. 237–245.

Licitra, Gaetano, Teti, Luca, Cerchiai, Mauro, Bianco, Francesco, (2017). The influence of tyres on the use of the CPX method for evaluating the effectiveness of a noise mitigation action based on low-noise road surfaces. Transp. Res. D (ISSN: 1361-9209) v. 55, pp. 217–226

M.H. Masum. , S.K. Pal. , A.A. Akhie., I.J. Ruva .,N. Akter., and S. Nath (2021). Spatiotemporal monitoring and assessment of noise pollution in an urban setting, Environmental Challenges, v. 5, n. 2021, pp. 100218.

Muhit, I.B., Chowdhury, S.T., (2013). Magnitude and impact analysis of road traffic noise pollution at Port City Chittagong, Bangladesh. Am. J. Environ. Eng. v. 2013, n. 3, pp. 130– 146.

Pitchika, A., Hampel, R., Wolf, K., Kraus, U., Cyrys, J., Babisch, W., Peters, A., & Schneider, A. (2017). Long-term associations of modeled and self-reported measures of exposure to air pollution and noise at residence on prevalent hypertension and blood pressure. The Science of the Total Environment, v. 593, pp. 337–346.

Shalini, K., Kumar, B., (2018). Study of road traffic noise sound pressure levels in Varanasi City, India. Int. J. Appl. Eng. Res. v. 13, n. 8, pp. 6248–6252.

Singh, R., Pandey, G., (2013). A study of noise in Gorakhpur City, Uttar Pradesh (India). Int. J. Struct. Civ. Eng. Res. v. 2, n. 3, pp. 241–249.

Sun, B., He, Z., Zhang, T., & Wang, R. (2016). Urban spatial structure and commute duration: An empirical study of China. International Journal of Sustainable Transportation, v. 10, n. 7, pp. 638–644.

Vázquez, V.F., Hidalgo, M.E., García-Hoz, A.M., Camara, A., Terán, F., Ruiz-Teran, A.M., Paje, S.E., (2020). Tire/road noise, texture, and vertical accelerations:Surface assessment of an urban road. Appl. Acoust. (ISSN: 0003-682X) v. 160, pp. 107153.

WHO, (2021).Deafness and Hearing Loss.World Health Organization.

Wokekoro, E., (202). Public awareness of the impacts of noise pollution on human health. World J. Res. Rev. v. 10, n. 6, pp. 27–32.

World Health Organization (WHO). (2017). Night noise guide lines for Europe