NOISE LEVEL VARIATION AT A CONSTRUCTION SITE OF DOUBLE- DECKER FLYOVER AND ITS PHYSIOLOGICAL CONSEQUENCES

Khushbu Kumari[1]*, Bijay Kumar Das[2], Avi Kush[3], Anjali Pathak[4], Arpita Srivastava[5], Supriya Kumari[6]

[1]*Independent researcher, Patna, India.
Email: drkhushbukumari22@gmail.com
[2]Associate Professor, Department of Architecture and Planning, NIT Patna.
Email: bijay@nitp.ac.in
[3]B. Tech (4th Sem.) Civil Engineering, SMVDU, Katra, Jammu and Kashmir, India.
Email: avikush99@gmail.com
[4]Assistant Professor, Department of Architecture and Planning, BIT Mesra, Ranchi.
Email: ar.anjali.pathak@bitmesra.ac.in
[5]M. Arch (4th Sem) Department of Architecture and Planning, NIT Patna.
Email: arpitas.pg21.ar@nitp.ac.in
[6]Assistant Professor, SPA Bhopal.
Email: supriya0458@gmail.com
*Corresponding Author: - Khushbu Kumari

DOI: 10.47750/pnr.2023.14.03.37

Abstract

The world is witnessing an unprecedented growth in urban population with huge pressure on infrastructure. Urban transportation is facing challenges of increased trips and thereby growth of vehicles on the streets. Massive infrastructure works of highway construction, road widening, flyovers, MRTS are in progress. A considerable amount of infrastructure development is required to mitigate the surge of increased trips and urbanmobility. Heavy construction equipment operate on these sites with diverted traffic during the construction of these infrastructure. Many of these sites are in the residential and commercial built-up areas. At several times abutting land-use are in silence zone (Hospital, Educational institutions, courts). Vehicular traffic is the main source of noise on streets. During construction phase, noise pollution is often associated with operating heavy equipment on site of construction. Several ill effects of constant exposure to noise pollution has been recorded. This research paper examines the temporal variation of Noise level at a double decker fly-over construction sitein the city of Patna, India and it's physiological consequences.

Key words: Noise pollution, Heavy construction equipment, Double decker flyover,

HIGHLIGHTS

1. Maximum noise is at 9 AM on Ashok Rajpath (Patna College site)
2. Noise from construction activities at pedestrian level camouflage with traffic noise during day time.
3. Effective noise from construction activity at day time at pedestrian level is less than that of traffic noise.
4. Construction activity is prohibited during night time in Residential and silence zone.

1. INTRODUCTION

By the year 2050, around 876 million people (52.8 %) of India's population will reside in cities.(UN, 2018) A revamp of physical infrastructure is in process for all the metropolitan cities of India to cater this challenge of urbanization. These include the construction of roads, railways and airways infrastructure to connect the major cities of India. Noise pollution in India is gradually increasing in recent years, especially in urban centres (Ising& Kruppa, 2004). The city of developing nations need a fast, affordable and safe transportation system that caters to the mobility requirement of its residents. Arterial roads serve a variety of functions inside the suburb and are an essential part of the transportation system that carries both private and public vehicles (N & Jem, 2013; Ranpise et al., 2021). Development of infrastructure projects deploy heavy equipment's at site which notonly pollute the site (air pollution) but are also source of noise pollution. Road traffic, luxury sedans, industrial, construction equipment, industrial activities, and power equipment are common sources of these undesirable noises that are continuously released into the surrounding environment (Berglund et al., 1995). A significant portion of the overall traffic noise is created by the friction between vehicle tyres and the road surface (Freitas et al., 2018; Jamrah et al., 2006; Licitra et al., 2017; Ranpise et al., 2021). Vehicular traffic noise and the noisefrom heavy equipment add together with other sound sources to give a combined effect of total noise at a site. The most significant cause of ambient outdoor noise pollution is road traffic (Ranpise et al., 2021; Zambon et al., 2018). Although noise pollution is a subtle and slow killer, relatively less has been done to mitigate it. It hasrisen to the level of a threat to of life quality (Mishra et al., 2010; Sharifzadeh Mirshekarloo et al., 2018).

Noise has seldom a catastrophic effect, but constant exposure of more than eight hours and often high level of prolonged transitory exposure to noise can have adverse effect on health. Sleep disruption, masking of electronic instrument sound like TV, mobile phones and disturbance in normal conversation reduce the quality of life and effects the happiness level. Noise pollution reduces the abutting property value and it hinders the personal life of the residents. Noise can interfere the teaching learning process in the educational zones and disrupt the patients' health in the hospital zone. It increases the incidence of negative social behaviour and emotional symptoms. (Jariawala, 2017) and Miguel et.al. 2018 have also concluded the adverse effect of sound intensity on the nearby community. Industrial and traffic noise affects both auditory and non-auditory physiology in humans including hearing loss (Halonen et al. 2016), irregular heartbeat pattern, high blood pressure, psychological problems, irritation and stress, reduction in work efficiency, difficulty in sleeping, understanding the topics of conversation(Kageyama TT, Yano S, Kuwano T, Sueoka S, 2016).

As per Occupational Safety and Health Administration (OSHA) regulation, for heavy equipment operators, 85 dB(A) or higher for 8 hours of constant exposure, without protection can cause permanent damage to ear. It's not only the operator of heavy equipment but also the workers on the site along with the people on the road areexposed to these noise pollution.

1.1 Source of Noise

The main source of noise at a construction site is the sound emitted from construction machines (mainlymachines which produce impacts, e.g. devices for breaking concrete), earth-moving machines, pile drivers, pneumatically driven devices and combustion engines. For the purpose of noise studies these sources are considered as point or linear noise source (Kantova, 2017). Sound Power is a measure of the acoustic energy radiated from a noise source and is independent of variable that arise from the acoustic environment in which the source is located. The sound measuring instruments measure the combined effect of sound produced and sound reverberated in an acoustical environment. Acoustical environment on an existing site (road) consists ofurban canyon which comprises abutting building, street hardware, street furniture, boundary walls etc.

Table 1 Noise level at operator position

Heavy Equipment	Noise level (for operator)
Road Grader/Scraper	107 dBA
Jack hammer	102 dBA
Bulldozer	100 dBA
Back hoe	85 dBA

In India Central Pollution Control Board has laid down the norms for sound pollution. It categorises in four zones. Three of them are land-use zones (Industrial, Commercial and Residential) while fourth is specially designated ‘silence zone’ which is declared by the appropriate authority. An area comprising not less than 100 meters around hospitals, educational institutions and courts are known as silence areas or silence zones. "Court" means a governmental body consisting of one or more judges who sit to adjudicate disputes and administer justice and includes any court of law presided over by a judge, judges or a magistrate and acting as a tribunal incivil, taxation and criminal cases. "Educational institution" is defined as a school, seminary, college, university,professional academies, training institutes or other educational establishment, not necessarily a chartered institution and includes not only buildings, but also all grounds necessary for the accomplishment of the full scope of educational instruction, including those things essential to mental, moral and physical development. (CPCB, 2020) "Hospital" means an institution for the reception and care of sick, wounded, infirm or aged persons, and includes government or private hospitals, nursing homes and clinics; in a silent zone you cannot:

- Play any music
- Use a public address (PA) system
- Raise any sound amplifiers
- Beat a drum or tom-tom
- Blow a musical or pressure horn, or trumpet or
- Play sounds on any instrument, or
- Exhibit any mimetic, musical or other performances to attract crowds.

Table 2 Standards of Noise level as laid by CPCB and MoEF (Jan 2010)

Area Code	Category of Area/Zone	Limits in dB(A) Leq in day time	Limits in dB(A) Leq in night time
A	Industrial	75	70
B	Commercial	65	55
C	Residential	55	45
D	Silence	50	40

Note: Silence zone are sensitive areas up to 100 meter around such premises as hospitals, educational institutions, courts.

Table 3 Noise Risk zone criteria

Intensity of Noise in dB(A)	Zones
Less than 66	Safe
66 – 71	Tolerable
71 – 76	Low Risk
76-81	Moderate Risk
81 – 86	High Risk
Greater than 86	Extremely High Risk

For the noise index at construction site standard has been taken from the research at a shallow ware house on a port city of China (Huang, H.; Wang, J.; & Dong, n.d.) that is shown in Table No 4.

Table 4 Noise index for a construction site

Construction stage	Major noise source	Noise limits (dBA) (day-time)	Noise limits (dBA) (night-time)
Soil excavation	Bull dozers, excavators	75	55
Piling	Pile rig	85	prohibited
RCC Casting	Vibrating rods	70	55
Horizontal decking	Cranes	65	55

1.2 Study Area

Patna is the capital of Bihar state in India. It is a linear city situated on the bank of river Ganga.The Road, 'Ashok Rajpath' is an arterial road connecting East- West Patna. The study area lies between 25º.618N to 25º.619 N and 85º.165 E to 85º.158 E as taken from Google Map. Study is done for 2000 m stretch of Road length and around a public open space (Gandhi Maidan). The stretch of site in consideration is a commercial street with institutional (Public/ Semi-public) land-use on one side (North) and mixed land-use on the other (South). Heavy commercial vehicle is restricted in the day time on this road. The increased vehicular pressure on the road and frequent congestion forced the authority to go for flyover construction. The proposal is a two tier flyover with single lane on each tier. Width of the road (Ashok Rajpath) in the university area has been increased by land acquisition of Patna University. Boundary wall has been shifted up to 20 ft (6 m) to accommodate the flyover. Centenary gate of Patna University which was built in 2017 to commemorate the 100years of University (1917-2017) is demolished and new gates are constructed. Around ten banyan and peepal trees (old and fully grown) were uprooted and several structures were removed. People have protested when anold temple (in front of Patna College) a prominent landmark is under threat of removal. Even the main gate of Patna College is shifted 20 ft. away towards North. Urban expansion has destroyed the old fabric of this area and disturbed the green environment. The benefits of trees in curbing particulate matter is lost and the prominence will be the 'vehicles' as visual glare and air and noise pollution as the ill effects of urbanization.

Figure 1 Fly-over ramp lay-out.

Road geometry were modified temporarily converting footpath to the traffic lanes for the flow of vehicles. Street hardware was shifted, electric poles came too close to the abutting buildings. Vendors were removed and a magnificent footpath with lively activity is now converted as carriage-way. Concrete roads are constructed in place of asphalt road. During construction period the footpath has been removed and barricading done to demarcate the danger zone. The heterogeneity of vehicle which includes fossil fuel driven, electric and human powered public vehicle (Pedal rickshaw) causes additional hardship to the pedestrian. Visual investigation categorise the road in poor condition. The noise levels were measured at several sampling sites in the study area during October 2022 – Jan. 2023.

Figure 2 Schematic Plan of Ashok Rajpath, Patna along with vicinity areas.

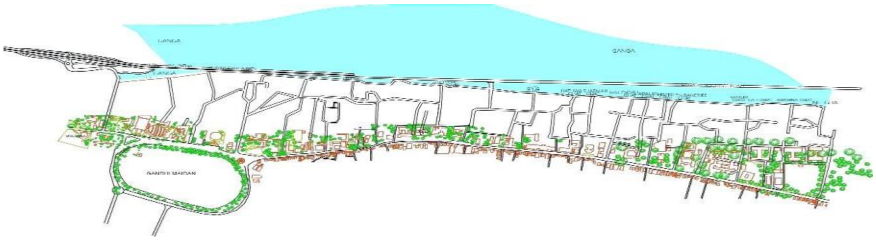


Table 5 Details of Ashok Rajpath 2-Lane Double Decker Flyover

Name of Project	**Construction of Elevated Corridor from Kargil Chowk, Gandhi Maidan to Science College via PMCH, Ashok Raj Path, Patna, Bihar (2-Lane Double Decker)**
daeH/tcirtsiD	antaP
Description of Project	(i) Type of Structure-RCC/PSC / Steel Composite, (ii) Length of elevated corridor-2.2 km, Length of Tier-1 is 1.5 km and Tier-2 is 2.2 km (iii) Carriage way-2 x 2-lane Double Decker (Tier-1 two lane + Tier-2 two lane)
lavorppA evitartsinimdA	Rs.422.00 Crore {RCD, Lt No.-5566 (S) dated-24.09.2020}
Agreement Amount	Rs.324.0049 Crore (Agreement no.-16/2021-22).
Date of Start	15.01.2022
Schedule Date of Completion	14.01.2025
Contractor	Gawar Construction Limited, DSS- 378, Sector: 16-17, Hisar 125 005 (Haryana)

ssergorP lacisyhP					Remarks
Foundation	Sub-Structure	Super-Structure	Approach	Expenditure (Rs. in Cr.)	Work In Progress
20%	15%	15%	-	5.40	

For a flyover construction the site is dynamic. Actual construction site keeps changing as the work progresses. The process involves the digging of pile pit, putting reinforcement in the pit, and finally casting of pile up (Huang, Wang, & Dong, 2020)to ground level. The second stage is casting of pier up to desired height and thirdstage is putting horizontal girder. Piling and subsequent casting work takes time of 10-12 days for a single pier.

2. METHODOLOGY

A double decker flyover is being constructed over this road and the traffic is diverted close to the property line on both the side. Two heavy equipment namely 280 kN. m Torque Piling Rig (TPR) and a backhoewas in operation on 21 Dec 2022 (Wednesday) at the site close to Khuda Baksh Library. Two readings were taken simultaneously, one at a non-construction site and the other one at the construction site. Readings were taken from 6 AM in the morning to 8 PM in the evening. Both the sites were separated by a distance of 300 m.Reading was taken from android based cell phone and validated with hand held sound meter placed at a distance of 12 meter from construction site (1.5 m above the ground level) and it was recorded for at least 15 minutes at an hourly interval.

2.1 Data Collection

Noise emitted by all sources (including vehicular and heavy construction equipment) were measured using android mobile app ‘Noisecapture’. The mobile app was calibrated using sound level meter as per standardprocedure laid in the manual of the app. It was verified using sound meter as per code(IS Code 3098, 1980). Allreadings were taken on working days under suitable weather condition. The breeze was gentle (less than 5 m/s,which was interpreted through general observation) and there was no rain. Beufort scale was used to interpret the wind velocity.(WMO, 1970)

Table 6 Beufort Scale for wind speed

Wind force number	Explanatory notes	Specification of Beaufort scale for use on land	Mean wind speed m/s
0	Calm	Calm, smoke rises vertically	Less than 0.5
1	Light Air	Direction of wind indicated by smoke drift, but not by wind vanes	0.5 – 1.5
2	Slight Breeze	Wind felt on face, leaves rustle, ordinary vane moved by wind	1.5 – 3
3	Gentle Breeze	Leaves and small twigs in constant motion; wind extends light flag	3 - 5
4	Moderate Breeze	Raises dust and loose paper; small branches moved	5 - 8
5	Fresh Breeze	Small trees in leaf begin to sway; wavelets from the inland waters	8 - 11
6	Strong Breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	11 – 14

Sound level instrument used for calibration was METRAVI *SL-4010 (IEC 651 TYPE II).* It was set to slow mode (response time of one second) for measuring environmental sound. Android phone was placed on a tripodwhich was unaffected by the traffic. Care was taken not to talk within the vicinity of the sound mater and the researcher was at least a meter away to avoid body reflection of sound. Reflection from hard surface was minimised by choosing the site at least 3.5 m away from hard surface. All the data collected was tabulated below.The reading was taken for several working days and it was tabulated. The data collected was min (dBA), Avg (dBA), LA90, LA50, LA10, and Max (dBA). The reading was also taken for road along Gandhi Maidan (famouslandmark of Patna) to compare the noise level from Ashok Rajpath.

Table 7 Noise Level measured dB (A) at a non-construction site at Ashok Rajpath, Patna

Time (Hrs.)	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Min. dB(A)	60.8	59.9	61.3	70.7	71.1	64.4	69.1	71.1	72.6	73.1	68.2	68.1	72.0	70.2	68.6
Avg. dB(A)	**77.2**	**81.1**	**82.5**	**88.0**	**86.4**	**80.8**	**85.3**	**86.7**	**84.5**	**86**	**87**	**83.6**	**85.5**	**84.1**	**82.9**
LA90	64.8	68.5	67.8	78.1	77.6	72.3	74.4	76.2	76.6	77.9	74.5	76.7	77.6	73.8	72.4
LA50	71.1	76.5	77.0	83.1	82.4	74.9	79.7	81.4	80.6	82	81.3	80.2	81.9	79.6	78.4
LA10	80.2	84.7	84.8	91.2	90.0	84.6	86.6	90.4	87	87.9	91	86	88.8	86.6	86.4
Max dB(A)	90.6	95.4	97.1	99.2	97.2	95.3	101.1	99.3	98.90	100.6	99.5	95.1	95.8	96.7	94.5

Figure 3 Temporal noise level variation at footpath level

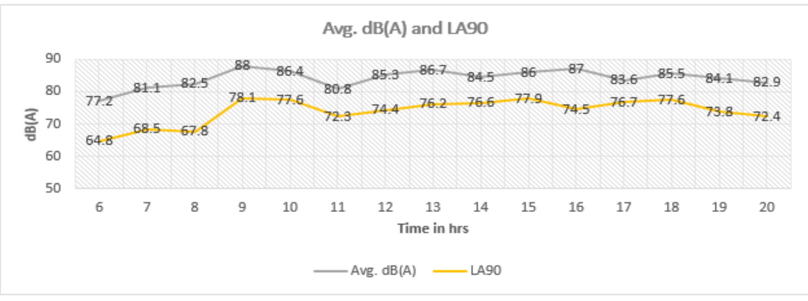


Table 8 Noise Level measured dB(A) at construction site at Patna Univ. Ashok Rajpath, Patna

Time (Hrs)	**12.08***
Min. dB(A)	71.8
Avg. dB(A)	**86.7**
LA90	76.6
LA50	81.5
LA10	88.4
Max. dB(A)	100.1

* Construction work going on

Calculating effective noise pressure dB at pedestrian position due to operating heavy equipment

$$L_{\Sigma} = 10\ log_{10}[\ 10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}}\ +\ldots\ldots]$$ *(here $L1$ is traffic noise and $L2$ is noise from heavy equipment)*

$$86.7\ \text{dB} = 10\ log_{10}[\ 10^{\frac{85.3}{10}} + 10^{\frac{L_2}{10}}\ ]$$

Calculating 86.7 dB to equivalent intensity (watt/m^2)

$$86.7\ \text{dB} = 10\ log_{10}(\frac{I}{10^{-12}\ watt/m^2})$$

$$\frac{86.7}{10} = log_{10}(\frac{I}{10^{-12}\ watt/m^2})$$

$$\frac{I}{10^{-12}\ watt/m^2} = 10^{8.67}$$

$$\text{I} = 10^{8.67} \times 10^{-12}\ watt/m^2$$

I = $10^{-3.33}$ $watt/m^2$ (total power at receiver end from all sources) (1)

Now calculating power generated by traffic noise

$$85.3\ \text{dB} = 10\ log_{10}(\frac{I}{10^{-12}\ watt/m^2})$$

$$\frac{85.3}{10} = log_{10}(\frac{I}{10^{-12}\ watt/m^2})$$

$$\frac{I}{10^{-12}\ watt/m^2} = 10^{8.53}$$

$$\text{I} = 10^{8.53} \times 10^{-12}\ watt/m^2$$

I = $10^{-3.47}$ $watt/m^2$ (power at receiver end from traffic sources) (2)

Sound power at receiver end from heavy equipment= Equation (1) – Equation (2)

= $10^{-3.33}$ $watt/m^2$ - $10^{-3.47}$ $watt/m^2$

$= 10^{-3.47}(10^{0.14} - 1)$

$= 10^{-3.47}(1.38 - 1)$

$= 0.38 \times 10^{-3.47}\ watt/m^2$ (3)

Now calculating decibel equivalent of Equation (3)

$$dB = 10\ log_{10}\left(\frac{0.38 \times 10^{-3.47}\ watt/m^2}{10^{-12}\ watt/m^2}\right)$$

$$= 10\ log_{10}(0.38 \times 10^{8.53})$$

$$= 10\ \{log_{10} 0.38 + log_{10}(10^{8.53})\}$$

$$= 10\ \{-0.42 + 8.53\}$$

$$= 10\ \{8.11\}$$

= 81.1 dB (noise at receiver end from heavy equipment)

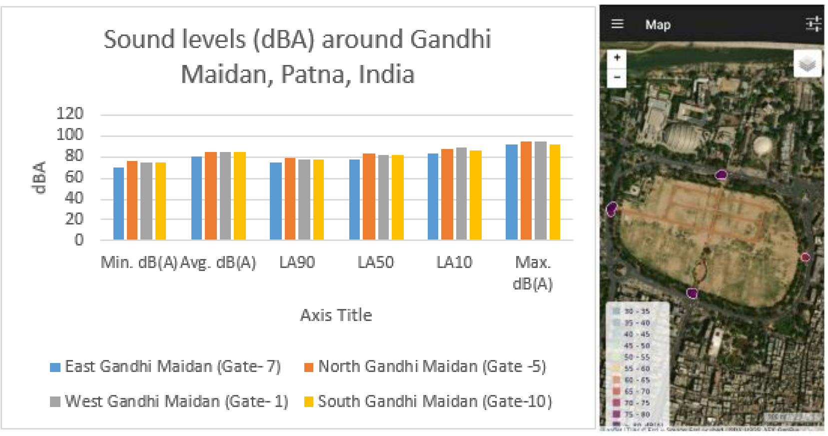
Note: All the calculations are done on A weighted scale (dBA)

Sound level was measured at a prominent land mark of Patna (Gandhi Maidan) and tabulated below. It was recorded from 4.30 pm to 5.45 pm on Jan 21, 2023.

Table 9 Sound level around Gandhi Maidan on Jan 21, 2023

Hrs	16.30-16.45	16.50- 17.05	17.10-17.25	17.30-17.45
Site	East Gandhi Maidan (Gate- 7)	North Gandhi Maidan (Gate -5)	West Gandhi Maidan (Gate- 1)	South Gandhi Maidan (Gate-10)
Min. dB(A)	70.6	76.4	73.9	74.5
Avg. dB(A)	**80.4**	**85.0**	**84.8**	**83.9**
LA90	74.3	79.4	76.9	77.3
LA50	78	82.5	81.0	81.4
LA10	83.0	87.8	88.2	86.7
Max. dB(A)	91.1	95.2	95.2	92.3

Figure 2 Noise Level around Gandhi Maidan (Patna)



3. RESULTS AND DISCUSSION

Average sound level at all the sites are at risk level much above the recommended level (65 dBA) by CPCB. Average sound level and LA90 was highest (85.0 dBA) at North Gandhi Maidan (GATE No. 5) for several reasons. It’s a site for Metro station and the construction work is in progress. Secondly it’s the auto stand for the para transit passengers. Day time noise at Ashok Rajpath both the construction and non-construction site isunder moderate risk (76 dBA- 81 dBA) around Gandhi Maidan. In traffic noise 3.15 kHz frequency was prominent. Morning trips are mostly to Railway stations and bus terminals along with children on school buses(81.1 dBA at 7 am). At the arterial road of Ashok Rajpath (at Patna College site) peak traffic noise was reportedat 9 AM (avg. 88dBA). At this time the office goers move towards the destination and it’s the peak time for institutions too. It was observed that at traffic bottlenecks the traffic noise was high because of horn (honking).It was higher at those spots where the road was in bad condition and traffic used to move slowly. People lose patience and express anger through pressure horn. Heavy equipment raised the noise pollution by additionally 1.4 dBA at the pedestrian position when the heavy equipment were at 10 meters away from the pathway. The noise calculated from heavy equipment at pedestrian position (10 m away from equipment) was 81.1 dB.

4. CONCLUSION

The commercial area around Gandhi Maidan is under moderate risk of sound pollution. The people working around these areas are exposed to health risk. At construction site there is additional increment in noise pollution,but psychologically it is camouflaged with traffic noise. Constant exposure may cause physiological damage toear. Since the projects are time bound and construction work is prohibited at night, all measures are adopted tocomplete the task in stipulated time, and residents are in a moderate risk of sound pollution in day time and traffic noise is still above prescribed limit at night time. The noise from equipment is at par with the traffic noise,so it blends together. Since the traffic noise is reduced at night time, the construction activity should not be allowed in residential areas during night (8 pm to 6 am).

FUNDING:

There is no funding associated with this research from any source.Disclaimer: There is no conflict of interest associated with this paper.

ACKNOWLEDGEMENT:-

We acknowledge Bihar *Rajya Pul Nirman Nigam* Limited (BRPNNL) for providingvaluable data for the research project.

REFERENCES

1. Berglund, B., Lindvall, T., & Schwela, D. (1995). Guidelines for Community Noise. World Health Organization. In Noise& Vibration Worldwide (Vol. 31, Issue 4, pp. 1–141).

2. CPCB. (2020). National Ambient Air Quality (NAAQ) monitoring.

3. Freitas, E. F., Martins, F. F., Oliveira, A., Segundo, I. R., & Torres, H. (2018). Traffic noise and pavement distresses:

4. Modelling and assessment of input parameters influence through data mining techniques. Applied Acoustics,138(2017), 147–155. https://doi.org/10.1016/j.apacoust.2018.03.019

5. Huang, H.; Wang, J.; & Dong, R. (n.d.). Noise Pollution and Control Measures in Construction Site of Shallow Warehousein Port. Journal of Coastal Research, 586–589.

6. ISCode 3098. (1980). The noise pollution (regulation and control) rules (Vol. 2000, Issue

1).http://cpcbenvis.nic.in/noisepollution/noise_rules_2000.pdf

7. Ising, H., & Kruppa, B. (2004). Health effects caused by Noise: Evidence in the Literature from the past 25 years. Noiseand Health,

6(22), 5–13.

8. Jamrah, A., Al-Omari, A., & Sharabi, R. (2006). Evaluation of traffic noise pollution in Amman, Jordan. EnvironmentalMonitoring and Assessment, 120(1–3), 499–525. https://doi.org/10.1007/s10661-005-9077-5

9. Jariawala, H. S. (2017). Noise Pollution & Human Health: A Review. Noise Health, 15(64).

10. Kageyama TT, Yano S, Kuwano T, Sueoka S, T. H. (2016). Exposure-response relationship of wind turbine noise with self-reported symptoms of sleep and health problems: a nationwide socio-acoustic survey in Japan. Noise Health, 18(81), 53–61.

11. Kantova, R. (2017). Construction Machines as a Source of Construction noise. Procedia Engineering, 92–99.

12. Licitra, G., Teti, L., Cerchiai, M., & Bianco, F. (2017). The influence of tyres on the use of the CPX method for evaluatingthe effectiveness of a noise mitigation action based on low-noise road surfaces. Transportation Research Part D: Transport and Environment, 55, 217–226. https://doi.org/10.1016/j.trd.2017.07.002

13. Mishra, R. K., Parida, M., & Rangnekar, S. (2010). Evaluation and analysis of traffic noise along bus rapid transit systemcorridor. International Journal of Environmental Science and Technology, 7(4), 737–750. https://doi.org/10.1007/BF03326183

14. N, T. B., & Jem, M. (2013). Assessment and Mlr Modeling of Urban Traffic Noise At Major Arterial Roads of Surat, India.

15. J. Environ. Res. Develop. Journal of Environmental Research and Development, 7(4A).

16. Ranpise, R. B., Tandel, B. N., & Singh, V. A. (2021). Development of traffic noise prediction model for major arterial roads of tier-II city of India (Surat) using artificial neural network. Noise Mapping, 8(1), 172–184. https://doi.org/10.1515/noise-2021-0013

17. Sharifzadeh Mirshekarloo, M., Tan, C. Y., Yu, X., Zhang, L., Chen, S., Yao, K., Cui, F., Pandit, S. M., Chong, S. H., & Tan, S. T. (2018). Transparent piezoelectric film speakers for windows with active noise mitigation function. Applied Acoustics, 137(2017), 90–97. https://doi.org/10.1016/j.apacoust.2018.03.017

18. UN. (2018). World Urbanization Prospects: The 2018 Revision.Department of Economics and Social Affair, Population Division, United Nations.

19. WMO., W. M. O. C. for M. M. G. (1970). The Beaufort Scale of Wind Force : (Technical and Operational Aspects).

20. Zambon, G., Roman, H. E., Smiraglia, M., & Benocci, R. (2018). Monitoring and prediction of traffic noise in large urbanareas. Applied Sciences (Switzerland), 8(251), 2–17. https://doi.org/10.3390/app8020251