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I, Asif Iqbal, Roll No. 2K20/ENE/03 student of M. Tech (Environmental Engineering), hereby declare that the project Dissertation titled "A Comparative Study on Traffic Noise Prediction Models Applications and Associated Health Risks Analysis In Delhi" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "A Comparative Study on Traffic Noise Prediction Models Applications and Associated Health Risks Analysis In Delhi" which is submitted by **Asif Iqbal, Roll No. 2K20/ENE/03**, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work caried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Increased noise levels from traffic in few decades are a major cause of concern for urban residents' quality of life. It can be minimized to some extent by implementing mitigation measures such as noise barriers and proper traffic management. This can be accomplished via noise maps, which provide a visual depiction of a given area's noise level.

This study major aim is to observe the noise monitoring and mapping for selected locations in New Delhi, India. The monitored data are compared with different Noise Models such as Burgess, CSTB, CRTN and Griffith and Langdon Model so as to select the most accurate model for Delhi's Road traffic conditions. The accuracy of the model is calculated by comparing the traffic noise model with the monitored value using correlation test.

After Pearson Correlation test, the coefficient of correlation (r) comes maximum for the CSTB Traffic Model, which is r = 0.537. The result signifies a large positive relationship between Monitored value and CSTB Model.

The collected data are compared to the CPCB's acceptable limits and analyzed using ArcGIS' Spatial Interpolation technique. The Leq were estimated and analyzed for morning peak hours, off-peak hours and evening peak hours, and were used to create noise maps in ArcGIS for the city of Delhi. After analyzing the data set, it was observed that all the locations have exceeded the ambient noise standards. The ArcGIS noise contours developed can also be used for the noise prediction of other locations than that of the monitored locations.

During Morning Peak hours, the maximum noise level is monitored at Jangpura (South East, Delhi) which is ranging from 77 to 77.8 dB. The least noise monitored in the Dabri Gurgaon Road (South-West Delhi) and Lodhi (New Delhi) Road ranging from 70.1 to 70.9 dB.

For Off-Peak hours duration, the maximum noise level is monitored at Dharampura (North-East Delhi) and Jangpura Road (South-East Delhi) which is ranging from 76.07 to 76.9 dB. The least noise monitored in Lodhi Road (New Delhi) Road ranging from 69.5 to 70.3 dB.

For Evening Peak hours duration, the noise level has decreased by around 1-3%, the maximum and minimum noise monitoring station is same as that of Off-Peak Hours. The cumulative noise level for the day from Morning 8:00 to Evening 6:00 PM shows the value in the range of 70.1 to 77.9 dB which is quite high.

As Noise is often harmful and dangerous to one's health as it affects humans in a range of physical, physiological, and psychological ways. Questionnaire were prepared for Survey for the selected locations so as to know the effect of Noise Pollution on Human Health. For Analysis the Survey data set was further categorized in three parts. Firstly, on the basis of Age group. Second, on the basis of Gender and Finally on the basis of data collected from. The survey will help in analyzing the adverse impact by taking responses of people towards the road traffic noise.

After analysis it was observed that on the basis of Age group, the physiological effect is inversely proportional to psychological effects. As the age increases the age-related effects are increasing like Hearth Diseases, Hearing loss and Hypertension. The Younger generation are getting easily affected by the noise and develop annoyance and fatigue.

Based on the Gender data, it was observed that females are more getting affected than that of male. The Car/Bus and Truck drivers are the most affected by the traffic noise. This may be due to the rise in traffic congestion. When talking about the Physiological effects, like Cardiovascular issues and Insomnia, Shopkeepers and Traffic Wardens are mostly affected by it. As a conclusion, it is observed that majority of the group is affected by the road traffic noise.

Therefore, the noise related problem in Delhi is a matter of concern and needs a thoroughly examination by the Government authorities for the healthier environment.

Keywords: Traffic Noise Model, ArcGIS, Noise Mapping, Sound Level Meter.

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CHAPTER 1. INTRODUCTION

1.1. Introduction

Noise pollution is defined as any unwanted noise or irritating sound that interferes with daily activities and, as a result, lowers the quality of life. Chronic exposure to greater decibels of sound can cause a variety of health concerns. Higher blood pressure and cardiovascular disorders, which raise the chance of heart attacks, are examples of these health conditions. Long-term exposure to noise pollution may cause deep-seated physiological impacts, as implausible as it may appear.

In general, Noise pollution is defined as repeated exposure to high sound levels that can harm humans and other living beings. According to the WHO study, the sound intensity below 70 decibels do not harm living organisms, regardless of exposure time. Noise pollution is defined as an excessive amount of noise or an unpleasant sound that disrupts the natural balance for a short period of time. We have created an environment where noise is unavoidable. Our television, mixer grinder, and other electrical devices all produce noise. There are numerous causes and impacts of noise pollution. We must all do our part to protect the world and mankind from further harm.

Noise pollution is thought to have a number of negative consequences on our brain and body. The permissible upper limit of sound in any given location should not exceed 45 decibels (dB), according to WHO guidelines. This upper limit is far too frequently broken in a city atmosphere. Noise pollution is caused by a variety of sources, including all modes of transportation, industrial setup, and loud music.

1.2. Major Causes of Noise Pollution

Noise pollution manifests itself in a variety of ways. Some of the causes and sources are things we see and feel on a daily basis, but choose to ignore. Some of them are listed below:

i. Industrial Noise

Industrial noise is produced by high-intensity decibels produced by industrial equipment and other similar products. Mills, huge industrial machines, and even little exhaust fans that run for lengthy periods of time all contribute to the noise. Noise pollution from mechanical saws and pneumatic drills is intolerable, and it is the worst form of pollution for the public and the surrounding area.

ii. Road Traffic Noise

Noise from transportation is inevitable. The honking of the many vehicles in the crowd is nothing but a nuisance, and the traffic jams cause a significant quantity of vehicle noise. Whether on the road, rail, or on an aircraft, noise pollution is a significant factor. To be specified road traffic noise depends upon the rate of flow of traffic, vehicular speed, no. of heavy commercial vehicles and type or nature of road surface. Noise from the Rail traffic generally depends upon the type of engine, type of wagon and the roughness between rails and wheels. Aircraft noise are induced at the time of operations such as take-off and landing which are known to produce extreme noise which includes vibrations and rattle.

iii. Construction Noise

Certain amount of Noise is produced by mining, the construction of flyovers, and even ordinary house repairs. Drilling is a popular activity. The building machinery is too loud and difficult to bear. All of this has a negative impact on our quality of life and causes a lot of conflict in our area. Some of the factors, such as the sound of the mixer or grinder, cannot be eliminated, so we assume the other sources are also natural.

iv. Domestic Noise

This type of noise is found in residential areas due to sounds from ventilation system, music from parties, lawn movers, grinders, mixers and vacuum cleaners. Peculiar social behavior has always been a well-acknowledged problem of noise in multifamily dwellings. Also, various leisure activities contribute significantly to high noise levels in the residential area.

v. Poor Urban Planning

Noise pollution can also occur by poor urban planning. Noise can enter our environment in a variety of ways, including traffic jams and continual honking, congested places, competition for basic services, and large families sharing small quarters.

1.3. Effects of Noise Pollution on Humans health

Noise is generally harmful and poses a significant health risk. Noise is more than just a nuisance. Noise-induced hearing loss that can occur at specific levels and durations of exposure, causing physical damage to the eardrum and sensitive hair cells of the inner ear and resulting in temporary or permanent hearing loss. Noise pollution has a broad range of health risk in terms of physical, physiological and psychological effects.

i. Physical Effects

The impacts of the noise pollution on hearing ability are a physical manifestation of noise pollution. Depending on the level of noise during the exposure and repeat exposure to noise can cause a temporary or permanent shift in a person's hearing threshold.

The most common and immediate consequence of higher noise exposure is hearing loss or in severe cases resulting in total deafness. The sensory cells found in human ears are very sensitive and if they are in exposure of constant high noise level it results in permanent damage of ears.

ii. Physiological Effects

The following are the physiological effects of noise pollution;

(a) Headache caused by dilation of the brain's blood vessels.

(b) An increase in the rate at which the heart beats.

(c) Atherosclerosis (narrowing of arteries).

(d) Changes in arterial blood pressure caused by an increase in cholesterol levels in the blood.

(e) A reduction in cardiac output.

(f) Aches and pains in the heart.

(g) Digestive spasms caused by anxiety and dilution of the pupil, resulting in eye strain.

(h) Night vision impairment.

(i) A decrease in the rate at which people perceive color.

(j) A decrease in concentration and its impact on memory.

(k) Nervous breakdown and muscular strain.

iii. Psychological Effects:

Noise pollution has the following psychological effects:

(a) depression and exhaustion, which significantly diminish a person's efficiency.

(b) Insomnia due to a lack of restful and rejuvenating sleep.

(c) Straining of the senses and discomfort caused by gradual but constant noise from road traffic, alarm clocks, telephone rings, and other sources.

(d) The effect of a sudden loud sound on psychomotor performance.

(e) Disturbance of emotions.

1.4. Noise Standards

The unit for measurement of noise is decibels (dB). The measurement of noise helps us to determine the detrimental sound levels and which needs to be controlled with the help of noise reduction. The time weighted average of the sound level in decibels on the scale "A" that is comparable to human hearing is denoted by dB(A) Leq.

A “decibel” is a measurement unit for noise. The letter "A" in dB(A). Leq stands for frequency weighting in noise measurements, which correlates to the human ear's (about 40 dB(A) frequency response characteristics. Leq is the noise level's energy mean over a given time period. Figure 1.1. shows the decibel scale for showing the normal sound level generated from different activities.

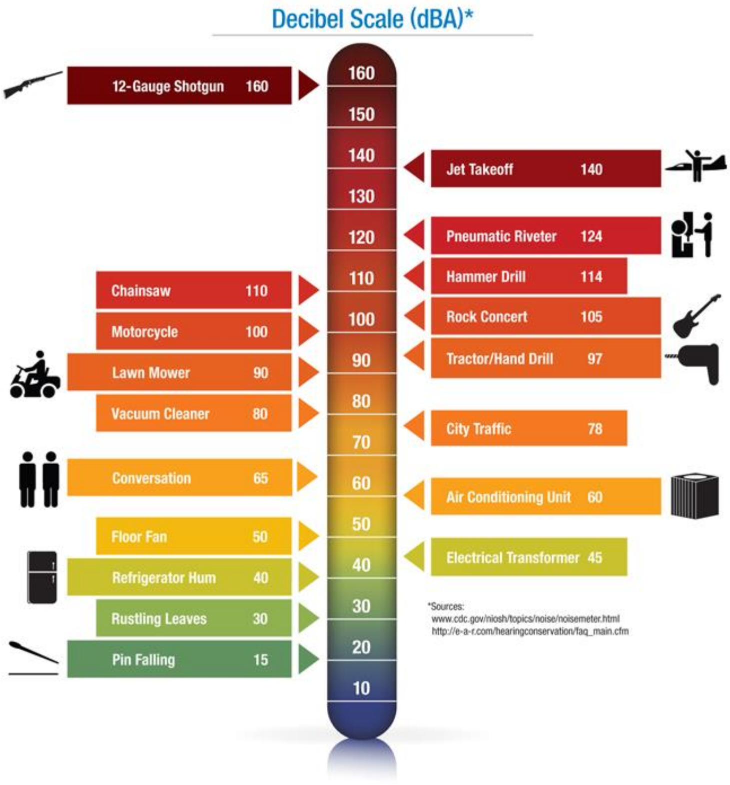


Figure 1. 1. dB(A) scale showing the levels of sounds

Source: Google image

The Table 1.1. shows the Ambient Air Quality standards for Noise Level as laid by CPCB. The area are classified in three four category and noise limit is given for both Day and Night time.

Table 1. 1. Ambient Air Quality Standards in respect of Noise

Area Code	Category of Area/Zone	Limits in dB(A) Leq *	
		Day Time	**Night Time**
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence Zone	50	40

Source: Standards of Noise levels under EPA (1986), Noise Pollution (Regulation and Control) Rules, 2000

Note:

1. The Day time is referring to the hours between 6:00 AM to 10:00 PM.
2. The Night time is referring to the period between 10:00 PM to 6:00 AM.
3. A silence zone is defined as a 100-meter radius surrounding hospitals, educational institutions, and courts. Silence zones are areas designated as such by the appropriate authority.
4. The competent authority may declare mixed categories of regions as one of the four categories described above.

1.5. Application of GIS in Noise Mapping

The sound levels of a geographical unit are graphically represented for a specific time span on a noise map. They're great for determining compatibility, defining land use, acoustic urban planning, and assessing environmental effect of any activity's evaluation. A centralized spatial database management system with suitable geographic information is required to facilitate noise effect investigations. With the use of GIS, this is created and maintained. When GIS is integrated with mathematical modelling and geographical data analysis, the quality of noise maps improves.

This is accomplished through altering the data used, data simplification, calculating algorithms, and interpolation techniques, among other things, to increase the precision of the results. As a result, GIS is becoming increasingly important in the analysis of the potential impact of noise pollution. GIS facilitates the graphical representation of noise effects and serves as an additional tool for analyzing the results. The GIS structure is shown in the Figure 1.2 for creating Noise maps.

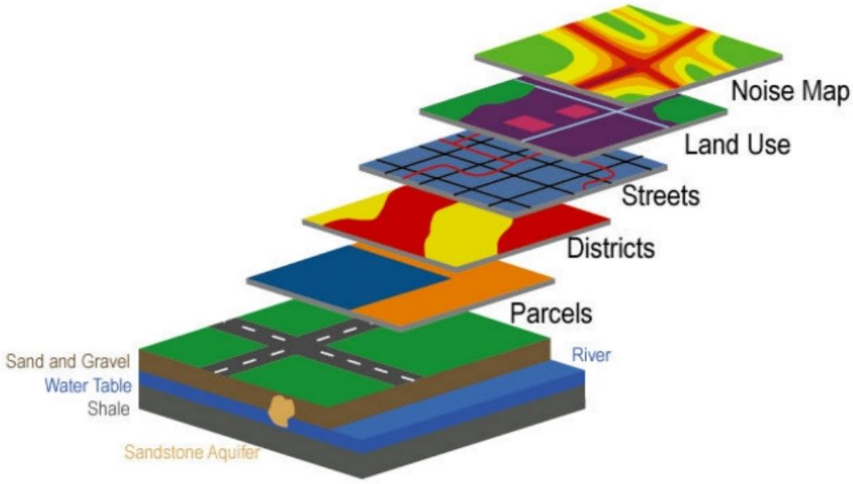


Figure 1. 2. GIS based structure for Nosie Mapping

Source: European Commission Working Group, 2006

The integration of GIS and noise models will help in the automatic generation of noise data models from supporting digital geographic information. The noise data is collected, stored, managed, and governed using a GIS database management system.

Noise contours are created using a variety of GIS interpolation algorithms. It is possible to create a continuous spatial model of noise levels using GIS. GIS is a significant tool in geographical analysis and modelling, in addition to being a management system and a computer-aided design system.

The scale, as well as the characteristics of the input data used, determine the quality and validity of noise mapping. When it comes to noise mapping, if the precision of the data is great, an accurate result is attained, especially when the noise levels shift rapidly. The type of input data that is used has an impact on the outcome of noise mapping. GIS is renowned for controlling and administering the type of outcome by considering the nature of the input data.

1.6. Objectives of the study

The objectives of the present study are as follows,

1. To monitor the traffic noise at various selected locations in Delhi.
2. To predict the Noise level at selected location using different Traffic Noise Model.
3. To compare the monitored and predicted noise level using with Ambient Noise standards in India.
4. To understand the impact of noise in the vicinity of selected locations by creating noise maps using ArcGIS.
5. To compare the noise levels with the permissible Noise levels standards.
6. To study the Noise induced health risks among people through Questionnaire bases Survey Analysis.

CHAPTER 2.
LITERATURE REVIEW

2.1. International Study

Noise measurements and sound observation surveys, either alone or in combination, can aid in comprehending the complicated problem of noise pollution in urban and educational settings, and so increase municipal administration's ability to cope with this type of pollution (Zannin et al., 2013).

Only if the density of monitoring stations is high enough can an accurate and full picture of the noise situation in the vicinity of the noise source be obtained. The transportation sector, which includes road traffic, rail traffic, and air traffic, is the primary source of environmental noise pollution in urban areas (Fiedler & Zannin, 2015).

Larger and heavier vehicles, on average, produce more noise than smaller and lighter vehicles. The sound pressure level generated by traffic can be estimated based on the traffic flow rate, vehicle speeds, the fraction of heavy vehicles, and the road surface type. From GPS data gathered from floating cars, the speed-density relationship was also used to estimate traffic volume (Cai et al., 2015).

In metropolitan areas, road traffic is one of the most significant sources of noise pollution. Local governments should implement action plans based on strategic noise maps to mitigate the impact of traffic noise (Covaciu et al., 2015).

A noise map is a visual representation of the sound level distribution in a specific area over a specified time period. Calculations that account all, or the most significant, noise sources impacting a community have been used to create noise mapping across a vast area (Stoter et al., 2008).

Noise mapping is a tool that estimates the intensity of noise pollution in specific areas to measure the impact of ambient noise in cities. Governmental agencies can use this topographical data to create environmental management plans aimed at mitigating relevant noise sources and ensuring healthy acoustic environments.

Traffic noise prediction models are very crucial in implementation for highway and non-highway road planning plans, as well as in assessing current traffic conditions and noise levels. Different traffic models have been used in past to forecast the traffic noise maps of a city. Different terms related to road traffic conditions like traffic density, road width, average speed and class of vehicles are required for the computation of the Model.

Furthermore, noise mapping can be utilized as a tool for territorial planning, assisting with land use decisions. Nowadays, two noise mapping approaches are commonly used. The first is based on measuring the Equivalent Noise Level (Leq) in the area of interest using a geographically distributed grid. The measured data are used as input for an interpolation procedure to estimate the noise curves (Alesheikh & Omidvari, 2006; Tsai et al., 2009). The second way involves using one or more calculation methods to anticipate noise levels based on the kind of sources and the surrounding environment (Diniz & Zannin, 2005; Murphy & King, 2011).

In Sydney, Metropolitan Area, National Physical Laboratory (NPL) developed a method for predicting the road traffic noise levels and it was compared with the measured values of road traffic noise. Multiple regression analysis was carried out using the NPL formula's basic structure and the cars' average speed was omitted for more accurate comparison. This new formula allows for a straightforward graphical representation of L_{10} for the urban traffic. Similarly, L_{eq} was also evaluated by the help of formula and graph (Burgess, 1977).

In London, a study consisting of acoustic measurements was performed at fourteen sites and around 1200 interviews dealing with the consequences of the noise conditions occurring at each of these sites was carried out. Residents' dissatisfaction with the noise conditions was related to sound levels in such a way that the median level of dissatisfaction at each site could be predicted by measure that took into account the mean sound levels exceeded for 90 and 10% of the sampling periods throughout a day, which is proposed to be called the Traffic Noise Index (T.N.I.). The mean sound level was more accurate than that of 90 and 10% of sound level (Griffiths & Langdon, 1968).

The French Centre Scientifique et Technique du Batiment (CSTB) suggested a model in which the equivalent emission level is determined using a formula based on the average L_{50}. Two different equations were given in CSTB model for urban road and highway on the basis of vehicular flows lower [13].

In 2003, a statistical model CALIXTO was created for road traffic noise monitoring based upon urban context that is based on the assumption that the percentage of heavy vehicles has a significant impact in road traffic noise emission (Calixto et al., 2003).

The Calculation of Road Traffic Noise (CRTN) model is one of the world's first traffic noise prediction models, and it's been widely used in many Western countries. Its performance in a motorbike metropolis, however, has not been properly evaluated. The CRTN model is evaluated for its ability to forecast both roadside and vertical distributions of traffic noise levels (*Calculation of Road Traffic Noise 1988*, n.d.).

In Europe, a study related to predicting the accuracy of a Traffic Noise Model (TNM) for the future infrastructure planning by evaluation the risk related to the design of road networks (Bulucea & WSEAS (Organization), 2009).

In Ghana, Noise levels were monitored at 50 monitoring sites, and a land-use regression model was developed using the Multiple linear regression (MLR) approach for intraurban noise prediction. The measured and anticipated noise levels were compared by using a standard noise model, Lyons empirical model. When compared to the Lyons Empirical model, the results from the constructed MLR model showed no significant variations in patterns. The generated maps revealed a heterogenous distribution of noise pollution level. This demonstrates the method's utility in determining the spatial pattern of noise pollution. As a result, it can further be used for urban planning and epidemiological studies (Baffoe & And Duker, 2018).

In Italy, a study proposed a systematic framework for the quantitative investigation of traffic noise in metropolitan settings. The analysis of acoustic data collected in the city of Villa S. Giovanni, Italy which included noise level measurements as well as vehicle flow and composition. General Regression Neural Network (GRNN), CoRTN model and Burgess model were used for the analysis purpose for evaluating the equivalent noise level. The results demonstrate how the neural network approach outperforms the traditional statistical analysis-based alternative. The GRNN network shows that how it can be used for higher variability for traffic patterns and also for the complex locations (Shigeru, 2012).

In Iran, two models were used for the prediction of noise level by the help of genetic algorithm and analyzed using MATLAB (Rahmani et al., 2011).

A study for the noise emitted from a steady statistically stationary traffic flow is investigated analytically using a stochastic acoustic model. In order to relate the noise field to the flow's details and the acoustic properties of the cars (Yeow, 1974).

According to the WHO (World Health Organization), the number of healthy life years lost due to traffic noise in European countries exceeds 1 million per year, with CVD (cardiovascular diseases) accounting for more than 61,000 years, sleep disturbance accounting for 9,03,000 years, and annoyance accounting for 6,54,000 years. The WHO has recommended that the noise level in the bed room should not exceed 45 dB and to be kept below 30 dB as average level. Higher sound level otherwise will be related to awakening and leads to bad sleeping quality (*Burden of Disease from Environmental Noise Burden of Disease from Environmental Noise Quantification of Healthy Life Years Lost in Europe*, 2011).

Noise pollution has a variety of effects, including disruption of interior peace, mental peace, hearing loss, and physiological effects. Noise pollution may have a negative impact on physiological and psychological wellbeing (Gümgüm, 2012). In recent times the effects of cardiovascular risk have been increasing over the years with respect to the traffic noise (Munzel et al., 2014). The long-term effects of exposure are not well recognized but Hypertension and heart disease are linked to long-term repercussions is recent studies (*FUTURE NOISE POLICY European Commission Green Paper*, n.d.).

Noise-induced hearing loss is caused by noise exposure and life events, and it can affect people of all ages. Early childhood exposure to various types of noise may have cumulative impacts on hearing damage in adulthood. Early social and biological variables may alter hearing in middle age, according to growing evidence (Russell Ecob, 2011).

According to recent research studies, the number of molecular processes involved in noise induced hair cell and nerve damage has expanded significantly. The evidence of ambient noise's non-auditory consequences on public health is rising (Basner et al., 2014).

The effect of health related from noise pollution were studied on traffic wardens with respect to the exposure duration. The resect shows the risks of psychological and physiological effect in them quite vulnerable (Tabraiz et al., 2015).

The absolute value of the Pearson correlation coefficient *r* of 0.1, 0.3 and 0.5 are classified as small, medium and large respectively for the relationship in between two variables (Cohen, 2013).

2.1. Indian Study

Unwanted sound is a primary source of environmental discomfort in urban residential environments. Noise pollution has an impact on the auditory system, neurological system, circulatory system, human physiology, and performance behavior in general. Recent studies have clearly demonstrated that road traffic is the most annoying source of aggravation; no other noise has a comparable impact. It's because of the enormous quantity of automobiles combined with other machines (Goswami, 2009).

In Delhi, different locations were selected on the basis of land-use pattern and noise were monitored and stored for generation of noise contours with the help of ArcGIS. The GIS map was also used to compare the difference in the noise monitored to predicted which comes-out to be less than 7%. It was observed that most of the results were violating the guidelines by the CPCB (R. K. Mishra et al., 2021).

A study for Delhi traffic conditions implies an inverse modelling technique which was employed to construct a traffic volume forecast model that may be used to scale emissions with traffic flow. The model was created using the Gaussian plume model. The model's hourly traffic volume can be used to limit vehicle's entry to a specific number of vehicles, for example, as a short-term control mechanism. The algorithm was used to anticipate hourly traffic volumes for a major traffic crossing in downtown Delhi, the income tax office (ITO) intersection. A high value of the index of agreement (d = 0.812) indicates that the model is giving satisfactory performance (Khare & Sharma, n.d.).

In Dehradun Haridwar highway for Dehradun city, India the noise level was analyzed at various points. The produced model's projected noise level is compared to the monitored noise level and t-test is then used for statistical analysis of the city and it is shown to be highly significant at the 5% level and 95 percent confidence level. The proposed road traffic noise model can further be used as a decision-supporting tool for road traffic noise prediction in Indian circumstances (Rawat & Katiyar, n.d.).

A study related to the exposure of traffic noise has been performed. The noise locations having noise level greater than 60 dB(A) were considered in this evaluation. The results have shown that people are getting affect by the coronary artery disease when are in exposure to noise level greater than 60 dB(A) (Gilani & Mir, 2021).

In Roorkee 2008, a survey was carried-out towards the noise pollution generating from the loudspeakers and automobiles. The survey classifies the group on age and gender category. The result shows that females are more affected than on male. The major problems irrupted from the survey results shows how the noise is causing sleep disturbance and interference the communication (R. K. , R. S. , P. M. Mishra, 2008).

Many studies have been happened over the years on the study of Psychological and Physiological effects on human beings. The survey helps in analyzing the cause of concern of people towards the traffic noise as well as to give an idea of the mental and physical heath of the community.

When we are discussing about public heath, it includes the risk generated from the air and noise pollution. In recent times, due to urbanization the level of air and noise related problems are emerging at a very high rate. In a study, the air and noise level of three mega city were analyzed from the duration 2006-11. The monitored value was compared to the CPCB guidelines. The equivalent sound level was found to be higher than the standard limits for three of the cities. (Kumar et al., 2018)

In the years 1991–1992, Rao & Rao conducted a noise pollution studies and community surveys in Visakhapatnam. Noise levels and subjective assessments were recorded in several locations, and a correlation between annoyance and 198 traffic noise was explored and forecasts made using the mean dissatisfaction score (MDS). The recorded Leq and Ldn values were associated with the subjective response to noise exposure measured on a 7-point scale of dissatisfaction. The conclusion was that the values predicted by the regression equations were significantly more dependable than those obtained from prior investigations.

In New Delhi, Mohan et al. investigated traffic noise and community response among residents living near an arterial route. According to the study, those who live up to 30 meters from the road are irritated by traffic. Residents on all floors of multistory apartments were also irritated to varying degrees. Approximately 70% of those surveyed people were willing to move their homes away from the road, regardless of current amenities.

In Jalgaon city of Maharashtra, the audiometric study revealed that the people of the city both exposed and unexposed population had minor hearing impairment. In compared to those who were not exposed, 81 percent of those questioned were affected by traffic noise (61 percent). It was determined that the population's hearing ability had been harmed as a result of increased noise levels.

In a study in Ahmedabad, the attitudes of traffic personnel about vehicle noise. This study did not include any traffic noise monitoring. The police officers were asked about their hearing abilities, past and present exposure to loud noise, and the use of personal protective gear such as earplugs and earmuffs in the questionnaire. 11.6 percent of those polled had regular tinnitus, whereas 62.8 percent had work-related tinnitus that only occurred during working hours (Tripathi & Tiwari, 2006).

CHAPTER 3. MATERIALS AND METHODOLOGY

3.1. Study Area

The study area for this research work is the city of Delhi, formally the National Capital Territory (NCT) of Delhi, is an Indian city and union territory that includes New Delhi, the country's capital. Delhi shares its borders with the state of Uttar Pradesh in the east and the state of Haryana in the remaining directions, since it straddles the Yamuna River, predominantly on its western or right bank. The National Capital Territory is around 1,484 square kilometers in land area size. Based on the 2011 census, the population of Delhi's city was over 11 million, while the population of the NCT was above 16.8 million. Since due to Industrialization and exponential growth in population, development and construction of industrial areas, automobiles and other manmade activities resulted in the consequences of noise related problems more adversely and frequently.

Traffic congestion in New Delhi: According to the New Delhi Traffic Index 2021, there has been a slight increase in the congestion levels and the data suggested that there has been an increase in the average time travel by 1 minutes per day. The traffic congestion has reduced from the base period of 2019 due to the Covid-19 breakdown which have led to sudden lockdown over the country for long time span. But still the congestion in traffic doesn't get much affected if taken account of the whole year. From Figure 3.1, the difference in congestion was around 56%, 47% and 48% in FY2019, FY2020 and 2021 respectively.

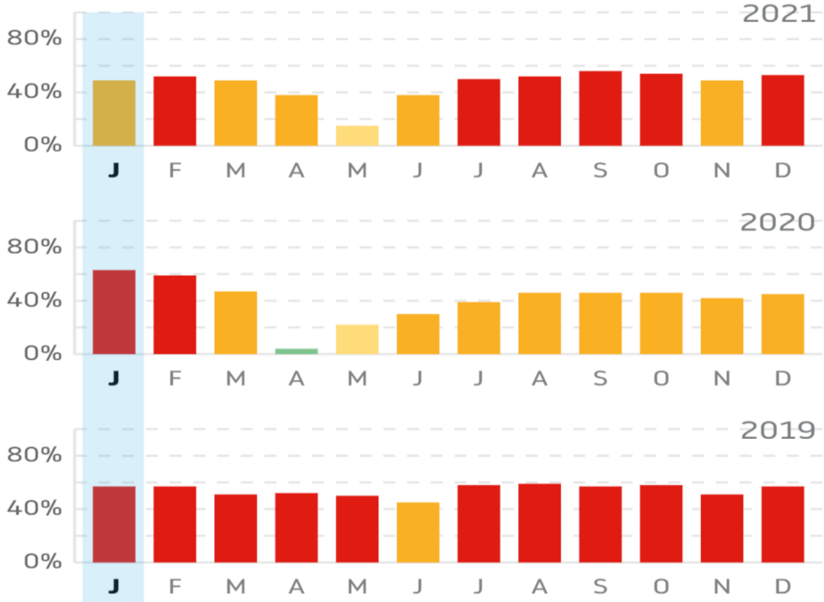


Figure 3. 1. Congestion Flow of Delhi since 2019-2021

Source: www.tomtom.com

As Delhi comes under urban area, so majority of the locations have a densely-populated and diverse development, with a combination of elements such as major trades, commercial operations, and residential properties. In this paper different locations are studied and they are classified on their Noise zone which includes the combination of Mixed, Commercial, Residential and Silent Zones within the city of Delhi.

A total of 14 site location has been shortlisted for the monitoring of Noise level on the basis of Delhi’s 11 Districts for study as shown in the Figure 3.2. Each location has its own distinct characteristics, such as road width or Carriageway, their land use pattern, and barriers on each side of the round, traffic flow patterns, and other socio-cultural activities. The vehicles used to evaluate the noise in any traffic situation were chosen at random, with no regard for the incidences of domination of any type of vehicle.

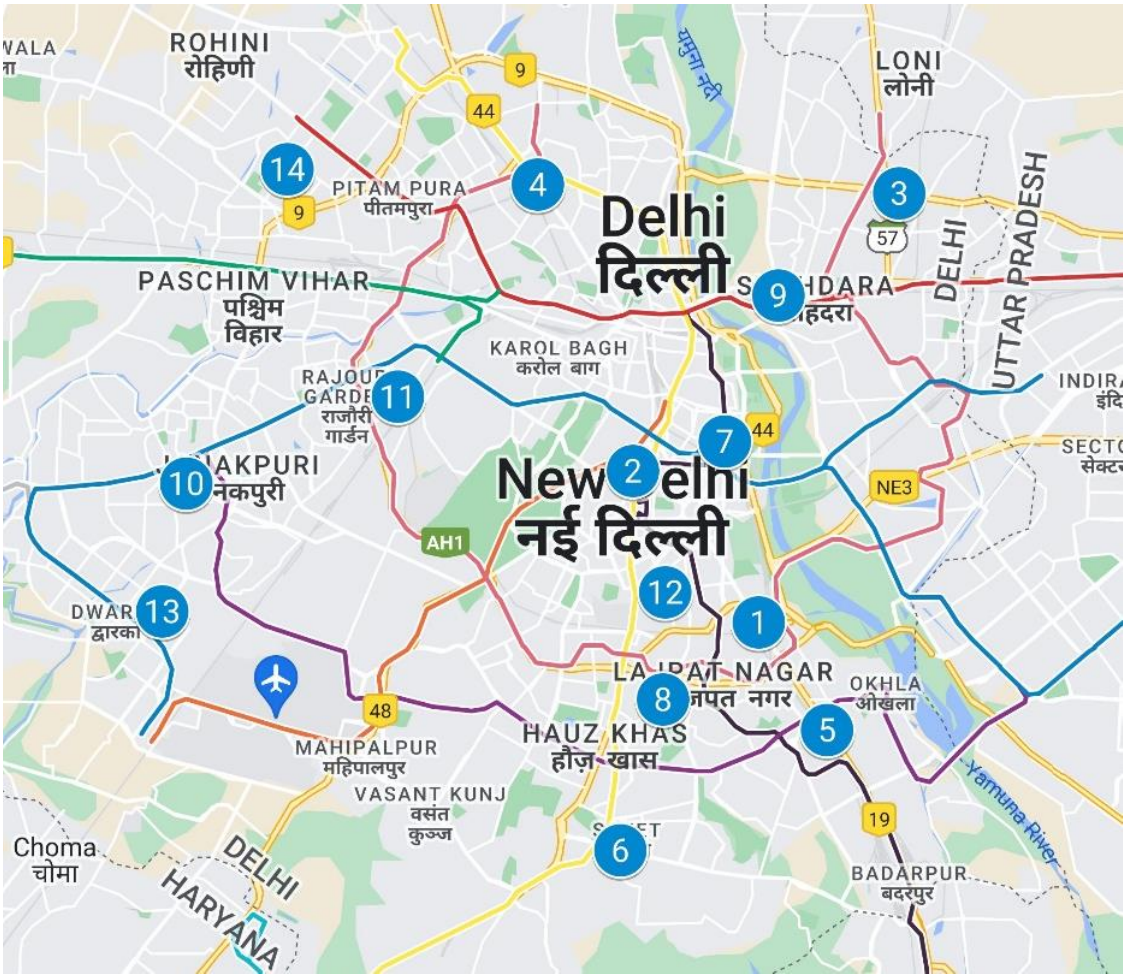


Figure 3. 2. Location of the Study Area

The entire list of selected locations along with land use pattern are presented in Table 3.1.

Table 3. 1. Site locations selected in Delhi

S. No.	Location	District	Category of Area/Zone	One Side	Other Side
1	Jangpura	South East	Mixed	Building	Building
2	Ashoka Road	New Delhi		Building	Building
3	Wazirabad Road	North East		Building	Building
4	GT Karnal Road	North		Building	Building
5	Mathura Road	South East	Commercial	Building	Open
6	Mehrauli Badarpur Road	South		Building	Open
7	Bahadur Shah Zafar Marg	Central		Building	Building
8	August Kranti Marg	South	Residential	Building	Open
9	Dharampura	North East		Building	Open
10	Pankha Road	South West		Building	Building
11	Satguru Ram Singh Marg	West		Building	Building
12	Lodhi Road	New Delhi	Silent	Building	Building
13	Dabri Gurgaon Road	South West		Building	Building
14	Sir Chotu Ram Marg	North West		Building	Building

3.2. Tools and Techniques

3.2.1. Sound Level Meter

The sound pressure level (SPL) was measured using the CESVA SC 260 sound level meter shown in Figure 3.3. The SC260 is a class 2 integrated sound level meter that is very user friendly. The International Standards (IEC 60942:2017) are used to assess sound level meters: Class 1- precision grade with a 0.5 dB tolerance for laboratory and field use and Class 2- general purpose grade with a 1.0 dB tolerance for field application. The class 2 filters in the SC260 can be used as a sound level meter or a real-time spectral analyzer with 1/1 or 1/3-octave bands which is widely used in noise pollution studies for the assessment of various types of sound levels, particularly for environmental, industrial, and commercial applications.

All functions are measured simultaneously, with all frequency-weightings. All of the functions required to construct the basic indices for acoustic evaluations in most countries are included like: S, F, and I function, equivalent continuous levels, percentiles, impulsiveness indices, peak levels, sound exposure levels, short functions, etc.

Figure 3. 3. A Pictorial view of Sound Level Meter

3.2.2. Arc GIS

The noise maps were created using ArcGIS version 10.5, a cutting-edge GIS program, at all of the detected locations. The combination of GIS with noise models allows for the automatic generation of noise data models from digital geographic data. The noise data is collected, stored, managed, and controlled using a GIS database management system.

After creating the shape file of the Delhi location, the coordinates are allotted to the selected site locations. Then interpolation techniques available in GIS are used to create noise contours.

3.3. Traffic Noise Models

The Noise Model are basically used for the designing and construction of new road infrastructure, for the evaluation of the acoustical impact and avoid costly post-construction mitigation measures. Noise models can also be used for an existing road network so as to reduce the assessment campaign and use it solely for tuning the model.

Some of the most commonly used Traffic Noise model particularly those involved in the comparison, are briefly described in this section. A total of four Traffic Noise Prediction Model i.e., Burgess Model, CSTB Model, CRTN Model and Griffith and Langdon Model are used in this study.

3.3.1. Burgess Model

$$Leq = 55.5 + 10.2 Log\, Q + 0.3P - 19.3 Log(d) \qquad Eq.\ (3.1)$$

where;

Leq = Equivalent Noise Level in dBA

Q = total traffic flow rate per hour

P = percentage of heavy vehicles

d = distance of source-to-receiver in meter.

3.3.2. CSTB Model

$$Leq = 0.65L50 + 28.8 \qquad Eq.(3.2)$$

The value of L50 is calculated taking into account only the equivalent vehicular flows, and is given by:

$$L50 = 11.9 Log\, Q + 31.4 \qquad Eq.(3.3)$$

for urban road and highway with vehicular flows lower than 1000 vehicles/hour;

$$L50 = 15.5 Log\, Q - 10 Log L + 36 \qquad Eq.(3.4)$$

for urban roads with elevated buildings near the carriageway edge, with L the width (in metres) of the road near the measurement point.

where;

Q = vehicular flow per hour

L = width of the road in meters

L50 = Sound level in dBA that exceeded for 50% of the time

Leq = Equivalent Sound Level in dBA.

3.3.3. CRTN model

$$Leq = 10 \log Q + 33 \log (V + 40 + 500 / V) + 10 \log (1 + 5P / V) - 26.6 \qquad Eq.(3.5)$$

Where:

Leq = Equivalent Noise Level

Q = Traffic flow rate per hour

V = Average speed of the vehicle in km/hrs

P = Percentage of heavy vehicle

V = Average speed of vehicles.

3.3.4. Griffith and Langdon Model

$$Leq = L50 + 0.018(L10 - L90)^2 \qquad Eq.(3.6)$$

Where the statistical percentile indicator is evaluated with the following formulas:

$$L10 = 61 + 8.4 Log\ Q + 0.15P - 11.5 log(d) \qquad Eq.(3.7)$$

$$L50 = 44.8 + 10.8 Log\ Q + 0.12P - 9.6 log(d) \qquad Eq.(3.8)$$

$$L90 = 39.1 + 10.5 Log\ Q + 0.06P - 9.3 log(d) \qquad Eq.(3.9)$$

where;

Q = Traffic flow rate per hour

P = Percentage of heavy vehicle

d = distance of source-to-receiver in meter

Leq = Equivalent Noise Level

L10 = sound level in dBA that exceeds 10% of the time

L50 = sound level in dBA that exceeds 10% of the time

L90 = sound level in dBA that exceeds 10% of the time

For every Traffic Noise Model, it is observed that they have a certain weightage percentage in their equations towards traffic flow, width of road, average speed of vehicle, percentage of heavy vehicles, etc. And a combination of all these terms is used to form the final equation for predicting the noise level.

3.4. Noise Monitoring at different locations

3.4.1. Jangpura Road

Jangpura Road is about 0.6 kilometer stretch of road in New Delhi's Defence Colony sub-district of the district South East Delhi. It connects the Jangpura district. The nearest railway station is Delhi Hazrat Nizamuddin which is around 0.5 km distance apart. Mathura Road and Hospital Road are the two connected major road for Jangpura Road. The commercial overview of the Jangpura Road is that it does have a variety of Offices & Industries, Residential buildings, Hospital, Home goods and electronic stores. The land use patter of Jangpura Road is Mixed type.

Figure 3. 4. Noise monitoring at Jangpura Road

3.4.2. Ashoka Road

Ashoka Road is about 1.54 kms stretch of road in New Delhi in the sub-district of Parliament Street. It connects the Sansad Marg Road, Connaught Place and Windsor Palace. The nearest railway station is Shivaji Bridge which is around 1.47 km distance apart. The major connected roads with the intersection of Ashoka Road are Minto Road Terminal, Badarpur Boarder, Raisina Road and Jantar Mantar Road. The Commercial overview of the Ashoka Road is that it does have Local Govt. Offices, Residential Buildings, Offices and Industries and Pharmacy, Electric Stores etc as shown in Figure 3.5. The land use pattern of Ashoka Road is Mixed type.

Figure 3. 5. Noise monitoring at Ashoka Road

3.4.3. Wazirabad Road

Wazirabad Road is about 6.44 kms stretch of road in North East Delhi in the sub-district of Seelampur. It connects Mukherjee Nagar, Shahdara, Wazirabad, Sonia Vihar areas. The nearest railway station is Old Delhi railway station which is around 4.5 km distance apart. The major connected roads with the intersection of Wazirabad Road are Outer Ring Road, Asian Highway AH1 & AH2 and Doctor KB Hedgewar Marg. The Commercial overview of the Wazirabad road is that it does have offices & Industries, Local Govt. Offices, Schools, Banks, Residential Buildings, Auto Repair and Hardware stores as shown in Figure 3.6. The land use pattern of Wazirabad Road is Mixed type.

Figure 3. 6. Noise monitoring at Wazirabad Road

3.4.4. GT Karnal Road

GT Karnal Road is about 4.67 kms stretch of road in North Delhi. The nearest railway station is Delhi Azadpur Railway station which is around 1 km distance apart. The major connected roads with the intersection of GT Karnal Road are Loni Road, Babarpur Road, Asian Highway AH2, and Mandoll Road. The Commercial overview of the Wazirabad road is that it does have Offices & Industries, University, Gas Station, Residential Buildings, Grocery shops, electronic stores and Restaurants as shown in Figure 3.7. The land use pattern of GT Karnal Road is Mixed type.

Figure 3. 7. *Noise monitoring at GT Karnal Road*

3.4.5. Mathura Road

Mathura Road is about 1 kms stretch of road in the district of South East Delhi's Kalkaji sub-district. The major connected roads with the intersection of Mathura Road are Badarpur Boarder and Haryana National Highway. The nearest railway station is Tuglakabad Railway station which is around 2 km distance apart. The Commercial overview of the Mathura Road is that it does have majorly Offices, Educational Centres and Research Laboratories, Grocery and Electronic stores as shown in Figure 3.8. The land use pattern of Mathura Road is Commercial type.

Figure 3. 8. *Noise monitoring at Mathura Road*

3.4.6. Mehrauli Badarpur Road

Mehrauli Badarpur Road is about 4.2 kms stretch of road in the district of South Delhi's Hauz Khas sub-district. It connects Lado Sarai, Pushp Vihar, Madangir, Mehrauli and Saket areas. The major connected roads with the intersection of Mehrauli Badarpur Road are Lado Sarai Terminal, Anuvart Marg, Lal Bahadur Shastri Marg, Minto Road and Hamdard Nagar Terminal. The nearest railway station is Lodhi Colony Railway station which is around 5.6 kms distance apart. The Commercial overview of the Mehrauli Badarpur Road are Offices and Industries, Restaurants, Coaching centres, Home Goods and Hardware stores as shown in Figure 3.9. The land use pattern of Mehrauli Badarpur Road is Commercial type.

Figure 3. 9. Noise monitoring at Mehrauli Badarpur Road

3.4.7. Bahadur Shah Zafar Marg

Bahadur Shah Zafar Marg is about 1.6 kms stretch of road in the district of Central Delhi's Hauz Khas sub-district. It connects Pragati Maidan, Mandi House, IP Estate and Maulana Azad College Campus area. The major connected roads with the intersection of Bahadur Shah Zafar Mar are Indraprastha Marg, Kotla Road, Deen Dayal Upadhyay Road and Maharao Krishna Road Marg. The nearest railway station is Tilak Bridge Railway station which is around 0.5 kms distance apart. The Commercial overview of the Bahadur Shah Zafar Marg are majorly Govt. Offices and markets for Grocery, Electronic store and Auto Repair, Restaurants and etc as shown in Figure 3.10. The land use pattern for Bahadur Shah Zafar Marg is Commercial type.

Figure 3. 10. Noise monitoring at Bahadur Shah Zafar Marg

3.4.8. August Kranti Marg

August Kranti Marg is about 3.7 kms stretch of road in the district of South Delhi's Hauz Khas sub-district. It connects South Extension II, Hauz Khas, Andrews Ganj, Siri Fort, Sadiq Nagar, Panchsheel Park areas. The major connected roads with the intersection of August Kranti Marg are Ring Road, South Extension Flyover, Delhi Outer Ring Road and Badarpur Boarder. The nearest railway station is Lodi Colony Railway station which is around 2.2 kms distance apart. The Commercial overview of the August Kranti Marg are majorly Residential Houses, Gym, Hotels, Grocery and Electronic stores as shown in Figure 3.11. The land use pattern of August Kranti Marg is Residential type.

Figure 3. 11. Noise monitoring at August Kranti Marg

3.4.9. Dharampura

Dharampura comes under the district of North East Delhi's Shahdara district. It connects Shastri Park, Shahdara, Valmiki Colony, Seelampur areas. The major connected roads with the intersection of Dharampura are Ansari Road, Grand Trunk Road. The nearest railway station is Delhi Shahdara Railway station which is around 2.6 kms distance apart. The Commercial overview of the Dharampura is that it includes majorly Residential Flats and Grocery shops and electronic repair stores as shown in Figure 3.12. The land use pattern of Dharampura is Residential type.

Figure 3. 12. Noise monitoring at Dharampura

3.4.10. Pankha Road

Pankha Road comes under the district of South West Delhi's Bindapur sub-district region. It connects Rani Bagh, Uttam Nagar, Aslatpur Village areas. The major connected roads with the intersection of Pankha Road are Major Deep Tyagi Marg, Aslatpur Road, Nala Road and Major P Srikumar Marg. The nearest railway station is Palam Railway Station which is around 3.6 kms distance apart. The Commercial overview of the Pankha Road is that it majorly includes Residential Flats and Pharmacy, Hardware and Electronic Stores and Grocery as shown in Figure 3.13. The land use patter of Pankha Road is Residential type.

Figure 3. 13. Noise monitoring at Pankha Road

3.4.11. Satguru Ram Singh Marg

Satguru Ram Singh Marg is about 3.3 kms stretch of road in the district of West Delhi's Patel Nagar sub-district. It connects Ramesh Nagar, Mansarovar Garden, Najafgarh, Kirti Nagar, Rajouri garden areas. The major connected roads with the intersection of Satguru Ram Singh Marg are Ring Road, Mayapuri Road, Mahatma Gandhi Marg and Patel Road. The nearest railway station is Kirti Nagar Railway Station which is around 0.4 kms distance apart. The Commercial overview of the Satguru Ram Singh is that it is majorly covered with Residential Areas, Hotels, Restaurants, Auto Repairs and Electric stores as shown in Figure 3.14. The land use pattern of Satguru Ram Singh Marg is Residential type.

Figure 3. 14. Noise monitoring at Satguru Ram Singh Marg

3.4.12. Lodhi Road

Lodhi Road is about 6.9 kms stretch of road in the district of New Delhi's Defence Colony sub-district. It connects Nizamuddin West, Jor Bagh, Sundar Nagar, Pragati Vihar and Lodhi Colony areas. The major connected roads with the intersection of Lodhi Road are Minto Road, Lala Lajpat Rai Path and Badarpur Boarder. The nearest railway station is Sewa Nagar Railway Station which is around 1.2 kms distance apart. The commercial overview of the Lodhi Road is that it includes India Meteorological Department, Mausam Bhawan, Indian Islamic Culture Centre and UNICEF office nearby as shown in Figure 3.15. The land use pattern of Lodhi Road is Silent type.

Figure 3. 15.Noise monitoring at Lodhi Road

3.4.13. Dabri Gurgaon Road

Dabri Gurgaon Road comes under the district of South West Delhi's Dwarka sub-district. It connects Mall Marg, Palam Extension and Dwarka Sector6,7, 9 and 10 areas. The major connected roads with the intersection of Dabri Gurgaon Road are Mall Road, Road No. 201, Road No. 224 and Palam Vihar Road. The nearest railway station is Nasipur Halt Railway Station which is around 1.7 kms distance apart. The Commercial overview of the Dabri Gurgaon road is that it includes majorly DDA Flats and Health Care centres as shown in Figure 3.16. The land use pattern of Dabri Gurgaon Road is Silent type.

Figure 3. 16. Noise monitoring at Dabri Gurgaon Road

3.4.14. Sir Chotu Ram Marg

Sir Chotu Ram Marg comes under the district of North West Delhi's Rohini sub-district. It connects Vishram Chowk, Rithala More, Avantika Chowk, Sai Baba Marg and Mahadev Chowk areas. The major connected roads with the intersection of Sir Chotu Ram Marg are Maharaja Agrasen Marg, Shiva Road, Avantika Road and Bhagwan Mahavir Marg. The nearest railway station is Mangolpuri Railway Station which is around 2.8 kms distance apart. The Commercial overview of the Sir Chotu Ram Marg is that it majorly includes schools like Mother Divian Senior School and St. Giri Senior Secondary School as shown in Figure 3.17. The land use pattern of Sir Chotu Ram Marg is Silent type.

Figure 3. 17. Noise monitoring at Sir Chotu Ram Marg

3.5. Noise Survey

The Noise survey will help to study and evaluate about the situation of Human health towards the Road Traffic in Delhi region. This survey questionnaire is from the perspective of Physiological and Physiological effect on the human beings. The criteria adopted for the survey includes:

a) Study about the population is well defined i.e., Age and Gender have been asked.
b) Classifying the population in terms of usage of road: Pedestrian, Shopkeepers/Workers, Traffic wardens, Rickshaw/Cycle/ Bike Drivers and Car/Bus and Truck Drivers.
c) Physiological and Physiological effects including fatigue, Concentration loss, Headache, Behaviour Effects, Public Conflict, Hypertension, Insomnia, Hearing Impairment and Cardiovascular Issues.

3.6. Framework Methodology

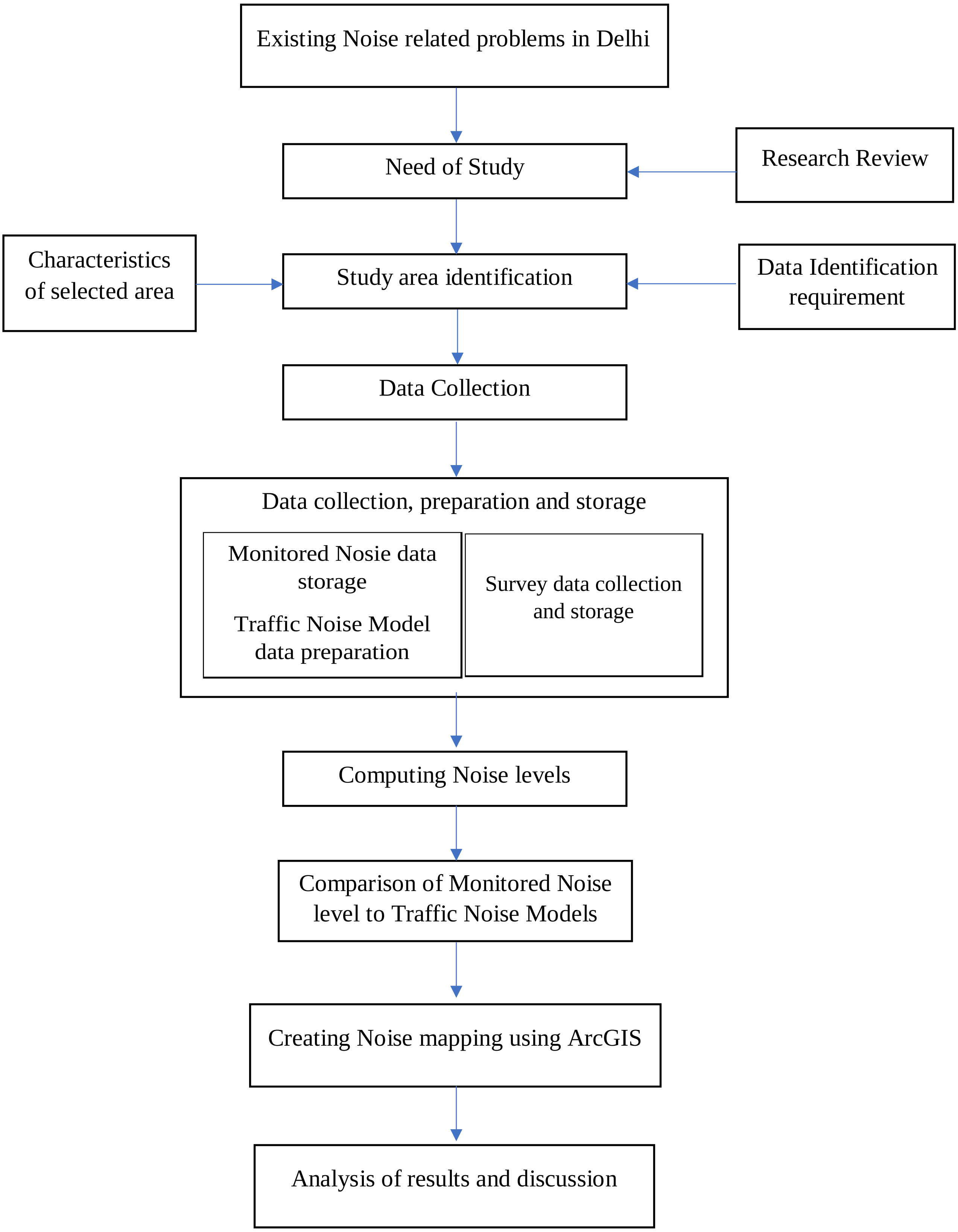


Figure 3. 18. Framework Methodology

3.7. Collection of Data

There are two different ways to measure the Nosie level i.e., Static and Ear level noise measurement. In Static noise measurement, the sound level mounted on the tripod which is nearly around 1.2 meters above ground level and records the environment's SPL over time. In Ear level noise measurement, the SLM is held roughly around 0.1-0.2 meter from the worker's ear can entrance. In this study Static Noise measurement is selected for the study.

The traffic noise level was measured at a distance of 1 m from the road's edge, with the sound level meter at a height of 1.5 m. The typical height of a human ear is measured in millimeters. Readings were taken at an interval of 15 minutes. The traffic details are taken from the IIT Delhi annual report for Traffic congestion in Delhi (Malik et al., 2020).

With this setup procedure, the noise was monitored for all the selected locations. The data for noise levels were collected from 8:00 AM to 6:00 PM on weekdays.

For noise survey data, a total of 30+ data are collected from each site location. The data collection was random and any data with no information were further removed from the study.

3.8. Calculation

In general, there are two approaches for determining traffic noise levels. The first approach involves using a sound level meter to measure noise levels, whereas the second method involves utilizing standard models to simulate noise levels. In this study, both approaches are selected for the analysis purposes.

The research approach includes selecting or identifying the study area, measuring noise levels, creating noise maps, and projecting them using a geographic information system (GIS). In the city of Delhi, 14 study locations were evaluated based on various land use patterns. A sound level meter was used to measure noise levels at various locations for 15 minutes during morning and evening peak hours, as well as off-peak hours. The noise levels measured with the sound level meter were reported as Leq, which stands for equivalent continuous sound level and represents the exposure to sound levels over time.

$$Total\ Leq = 10\log\left(10^{(Leq_1/10)} + 10^{(Leq_2/10)} + \ldots 10^{(Leq_n/10)}\right) \qquad Eq.(3.10)$$

where,

Leq is the equivalent continuous linear weighted sound pressure level, determined over a measured time interval Tm.

Obtained Leq at each 15-min time interval were then averaged to obtain the total Leq for the entire time period, i.e., for morning peak hours, evening peak hours and off-peak hours, respectively, using the following equation.

The Prediction of Noise is done with the help of different Noise Model which is stated earlier in the research paper. After this Root Mean Square Evaluation (RMSE) is done to know about the degree of error occurring between the Monitored and Noise Models. The least error Model is selected for the Traffic Flow of Delhi region.

The collected data then are compared to the CPCB's acceptable limits and analyzed using ArcGIS' spatial interpolation technique-inverse distance-weighted (IDW) technique. The results were then used to create noise maps in ArcGIS for the city of Delhi.

The Pearson correlation coefficient, generally known as the Pearson R statistical test, measures the strength of correlations between variables. It is one of the most common methods for determining the correlation among the variables.

$$r = \frac{n\,(\sum XY) - (\sum X)\,(\sum Y)}{\sqrt{[n\sum X^2 - (\sum X)^2] * [n\,\sum Y^2 - (\sum Y)^2]}} \qquad \textit{Eq. 3.11}$$

where;

n is the size of the sample.

X and *Y* are the sample points for analyzing the correlation

r is the Pearson correlation coefficient and its value is in the range of The Pearson correlation coefficient, r, can be anything between +1 and -1. A value of 0 implies that the two variables have no relationship.

To determine whether the correlation coefficient is statically significant we can perform t-test which includes calculation to find the t-score and p-value.

The formula to calculate the t-score is;

$$t = \frac{r}{\sqrt{(1-r^2)/(N-2)}} \qquad \textit{Eq. 3.12}$$

where;

t = t-score value

r = Pearson correlation coefficient

N = size of the sample

Covariance is the expected value i.e., mean of the product deviations from their expected values.

$$\sigma_{XY} \equiv cov(X,Y) = E[(X-E[X])(Y-E[Y])] \qquad \text{Eq. 3.13}$$

where;

X and Y are the variables.

The Pearson correlation value will be used for the selection Traffic Models and its significancy will also be test by the p-value and t-value.

CHAPTER 4. RESULTS AND DISCUSSION

4.1. Temporal distribution of Noise at selected location

4.1.1. Temporal distribution of Noise at Jangpura Road

At Jangpura Road, the average noise level has varied from 76.6 to 79 dB and 75.2 to 76.2 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 76.2 to 76.9 dB as shown in Figure 4.1. The maximum noise level was 79 dB during early morning 9 to 10 AM.

The monitored noise level is 15.7-21.5 % higher than the CPCB limit for the day time which is 65 dB for the selected location.

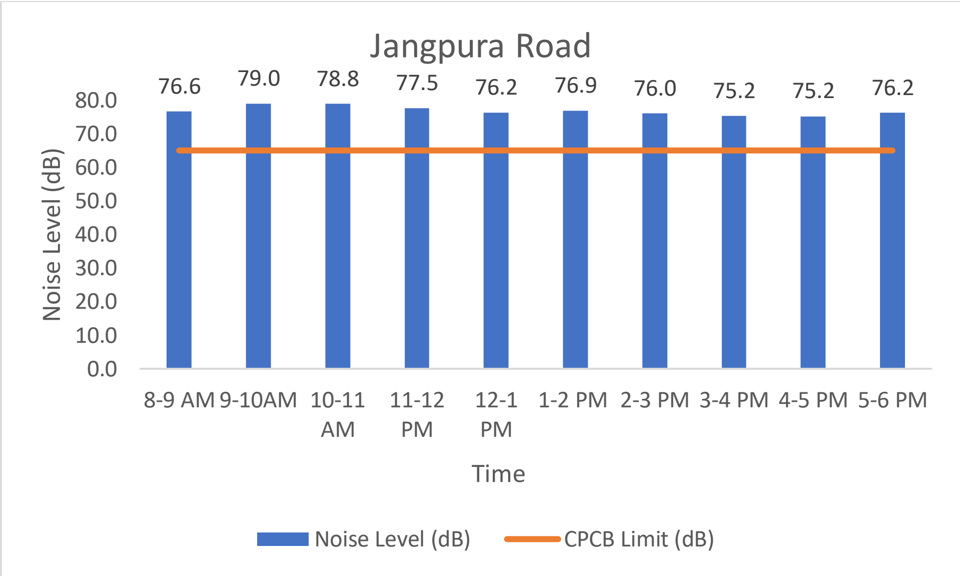


Figure 4. 1. Noise monitoring variation at Jangpura Road

4.1.2. Temporal distribution of Noise at Ashoka Road

At Ashoka Road, the average noise level has varied from 75.2 to 77 dB and 74.3 to 75.1 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 75.2 to 75.4 dB. The maximum noise level was 77 dB during 9 to 10 AM as shown in Figure 4.2.

The monitored noise level is 12.9-18.4 % higher than the CPCB limit for the day time which is 65 dB for the selected location.

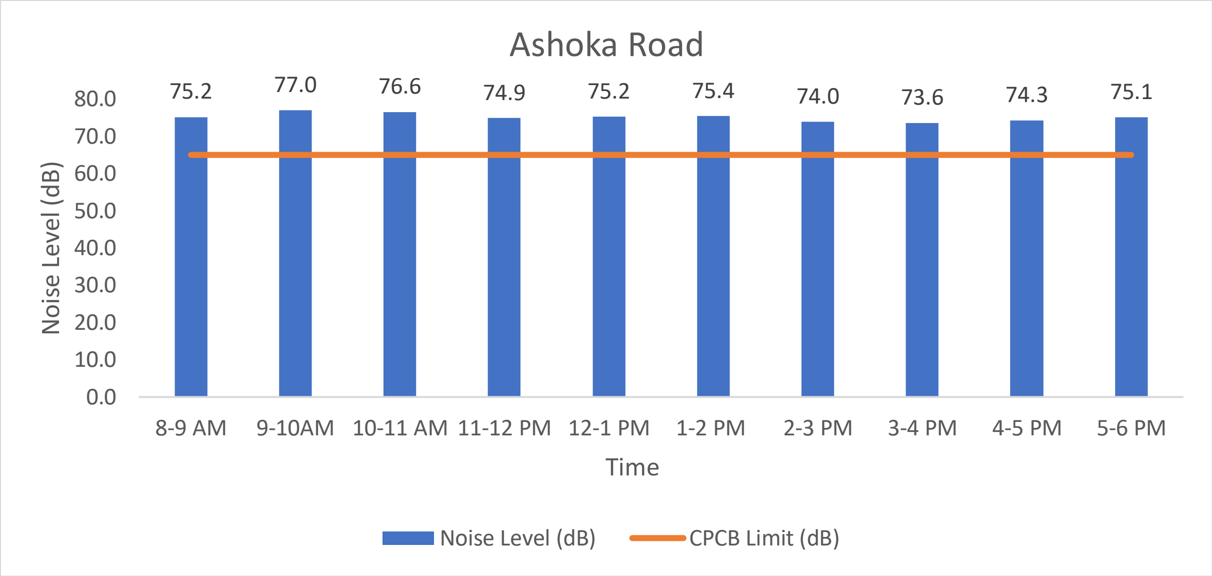


Figure 4. 2. Noise monitoring variation at Ashoka Road

4.1.3. Temporal distribution of Noise at Wazirabad Road

At Wazirabad Road, the average noise level has varied from 75.9 to 76.2 dB and 72.7 to 73.8 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 72.4 to 73.1 dB. The maximum noise level was 76.2 dB during 9 to 10 AM as shown in Figure 4.4.

The monitored noise level is 11.3-17.2 % higher than the CPCB limit for the day time which is 65 dB for the selected location.

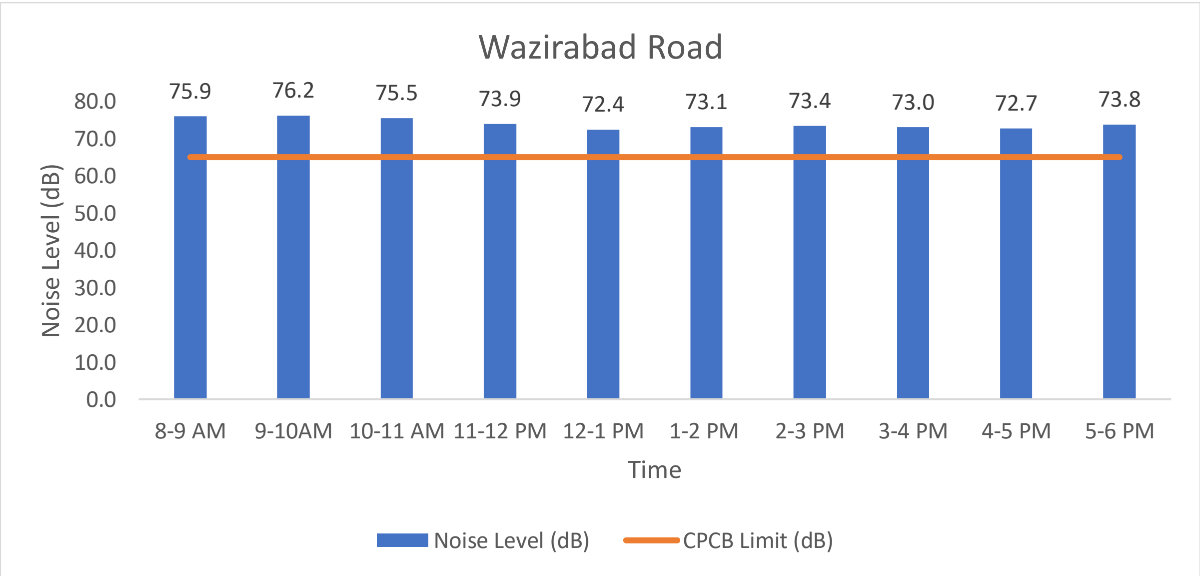


Figure 4. 3. Noise monitoring variation at Wazirabad Road

4.1.4. Temporal distribution of Noise at GT Karnal Road

At GT Karnal Road, the average noise level has varied from 72.1 to 73.9 dB and 74.3 to 75.1 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 76.2 to 76 dB. The maximum noise level was 76.2 dB during 12 to 1 PM as shown in Figure 4.4.

The monitored noise level is 10.9-17.2 % higher than the CPCB limit for the day time which is 65 dB for the selected location.

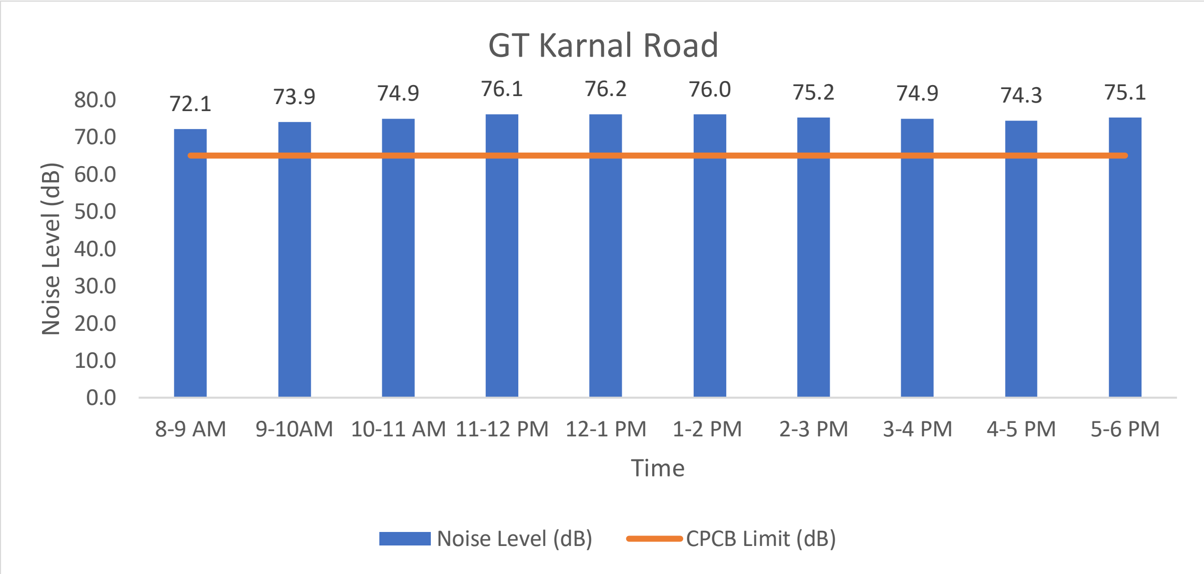


Figure 4. 4. Noise monitoring variation at GT Karnal Road

4.1.5. Temporal distribution of Noise at Mathura Road

At Mathura Road, the average noise level has varied from 76.8 to 76.2 dB and 74.9 to 75.5 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 74.8 to 75.5 dB. The maximum noise level was 76.8 dB during 8 to 9 AM as shown in Figure 4.5. In comparison to the CPCB limit for the day time for Commercial zone is 65 dB and the measured value is exceeding the desired limits.

The monitored noise level is 15-18.1 % higher than the CPCB limit for the day time which is 65 dB for the selected location.

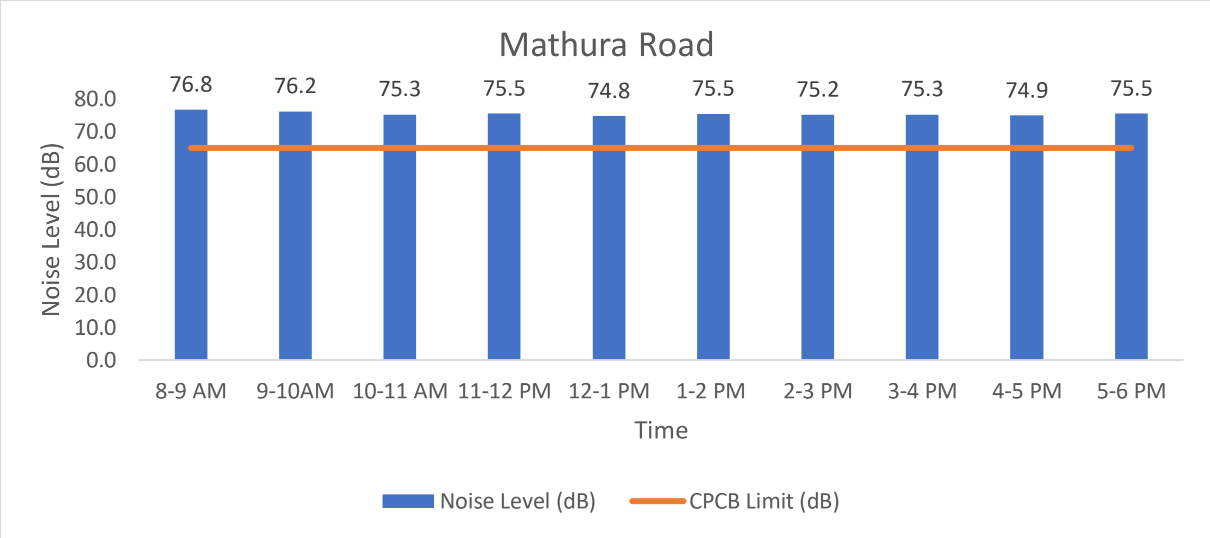


Figure 4. 5. Noise monitoring variation at Mathura Road

4.1.6. Temporal distribution of Noise at Mehrauli Badarpur Road

At Mehrauli Badarpur Road, the average noise level has varied from 74.6 to 76.5 dB and 73.6 to 74.5 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 75.6 to 75.7 dB. The maximum noise level was 76.7 dB during 10 to 11 AM as shown in Figure 4.6. In comparison to the CPCB limit for the day time for Commercial zone is 65 dB and the measured value is exceeding the desired limits.

The monitored noise level is 13.2-18 % higher than the CPCB limit for the day time which is 65 dB for the selected location.

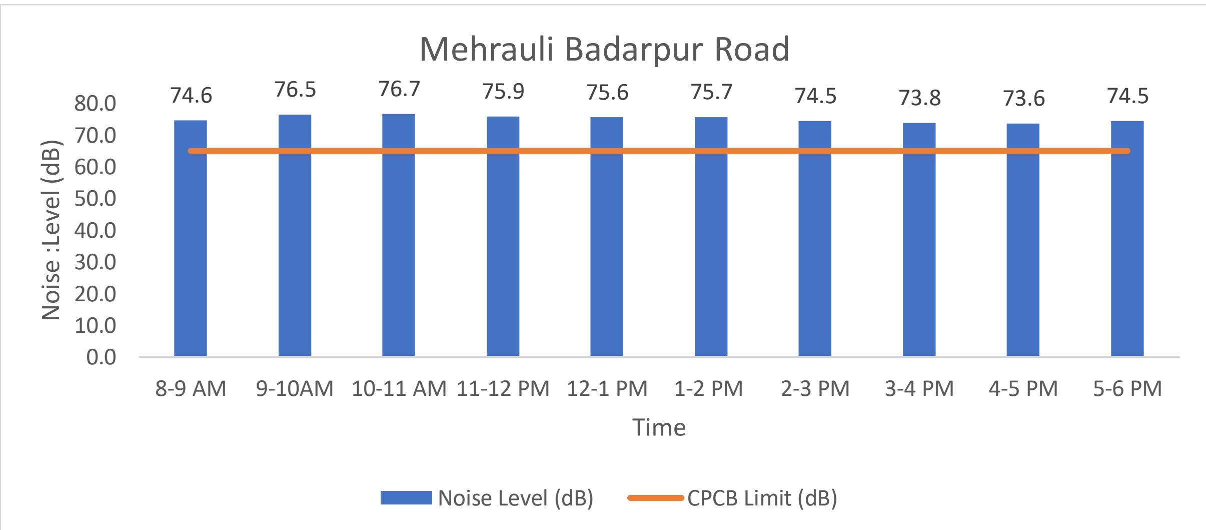


Figure 4. 6. Noise monitoring variation at Mehrauli Badarpur Road

4.1.7. Temporal distribution of Noise at Bahadur Shah Zafar Marg

At Bahadur Shah Zafar Marg, the average noise level has varied from 72.5 to 74.7 dB and 72.9 to 73.8 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 73.5 to 74.2 dB. The maximum noise level was 75.1 dB during 11 to 12 PM as shown in Figure 4.7. In comparison to the CPCB limit for the day time for Commercial zone is 65 dB and the measured value is exceeding the desired limits.

The monitored noise level is 10-15.5 % higher than the CPCB limit for the day time which is 65 dB for the selected location.

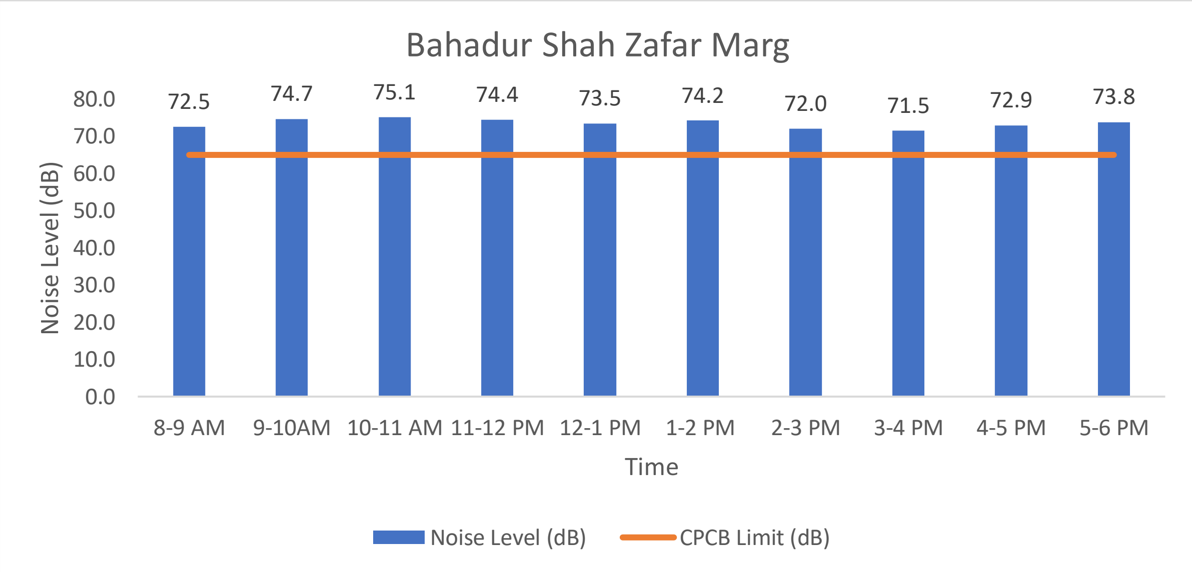


Figure 4. 7. **N**oise monitoring variation at Bahadur Shah Zafar Marg

4.1.8. Temporal distribution of Noise at August Kranti Marg

At August Kranti Marg, the average noise level has varied from 73.9 to 74.6 dB and 72.2 to 73.5 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 74.4 to 74 dB. The maximum noise level was 74.6 dB during 10 to 11 AM as shown in Figure 4.8. In comparison to the CPCB limit for the day time for Residential zone is 55 dB and the measured value is exceeding the desired limits.

The monitored noise level is 31.2-35.6 % higher than the CPCB limit for the day time which is 55 dB for the selected location.

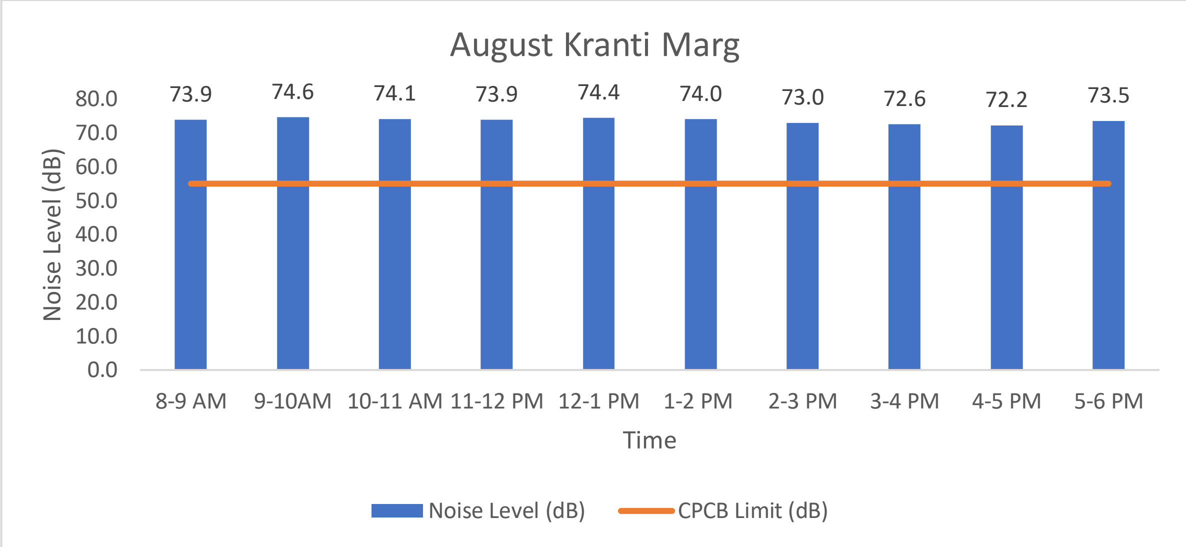


Figure 4. 8. Noise monitoring variation at August Kranti Marg

4.1.9. Temporal distribution of Noise at Dharampura

At Dharampura, the average noise level has varied from 76.3 to 77.7 dB and 75.3 to 76.4 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 77 to 76.9 dB. The maximum noise level was 77.7 dB during 9 to 10 AM as shown in Figure 4.9. In comparison to the CPCB limit for the day time for Residential zone is 55 dB and the measured value is exceeding the desired limits.

The monitored noise level is 36.9-41.2 % higher than the CPCB limit for the day time which is 55 dB for the selected location.

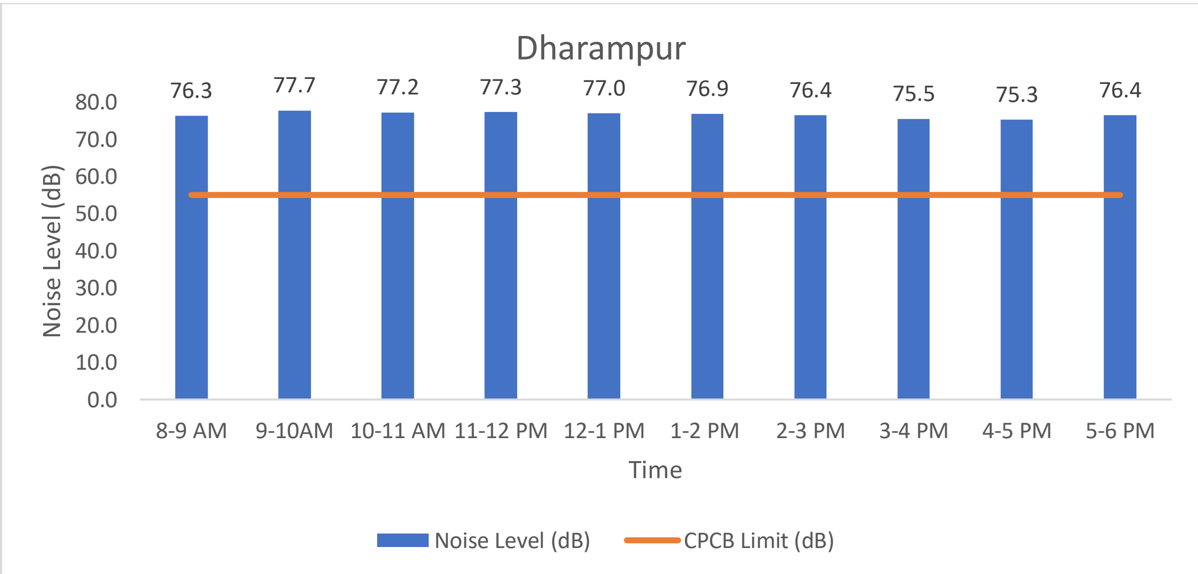


Figure 4. 9. Noise monitoring variation at Dharampura

4.1.10. Temporal distribution of Noise at Pankha Road

At Pankha Road, the average noise level has varied from 72.5 to 73.9 dB and 74.5 to 75.2 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 74.3 to 73.6 dB. The maximum noise level was 75.2 dB during 5 to 6 PM as shown in Figure 4.10. In comparison to the CPCB limit for the day time for Residential zone is 55 dB and the measured value is exceeding the desired limits.

The monitored noise level is 30.1-36.7 % higher than the CPCB limit for the day time which is 55 dB for the selected location.

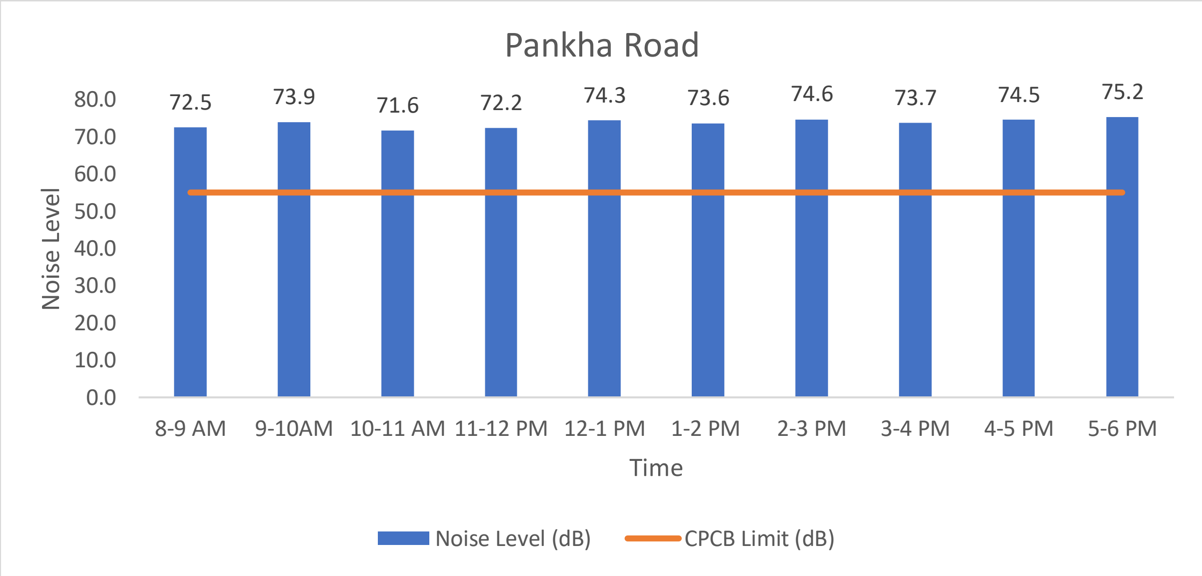


Figure 4. 10. Noise monitoring variation at Pankha Road

4.1.11. Temporal distribution of Noise at Satguru Ram Singh Marg

At Satguru Ram Singh Marg, the average noise level has varied from 71.4 to 72.7 dB and 72.2 to 73.3 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 72.3 to 73 dB. The maximum noise level was 73.6 dB during 11 to 12 PM as shown in Figure 4.11. In comparison to the CPCB limit for the day time for Residential zone is 55 dB and the measured value is exceeding the desired limits.

The monitored noise level is 29.2-33.8 % higher than the CPCB limit for the day time which is 55 dB for the selected location.

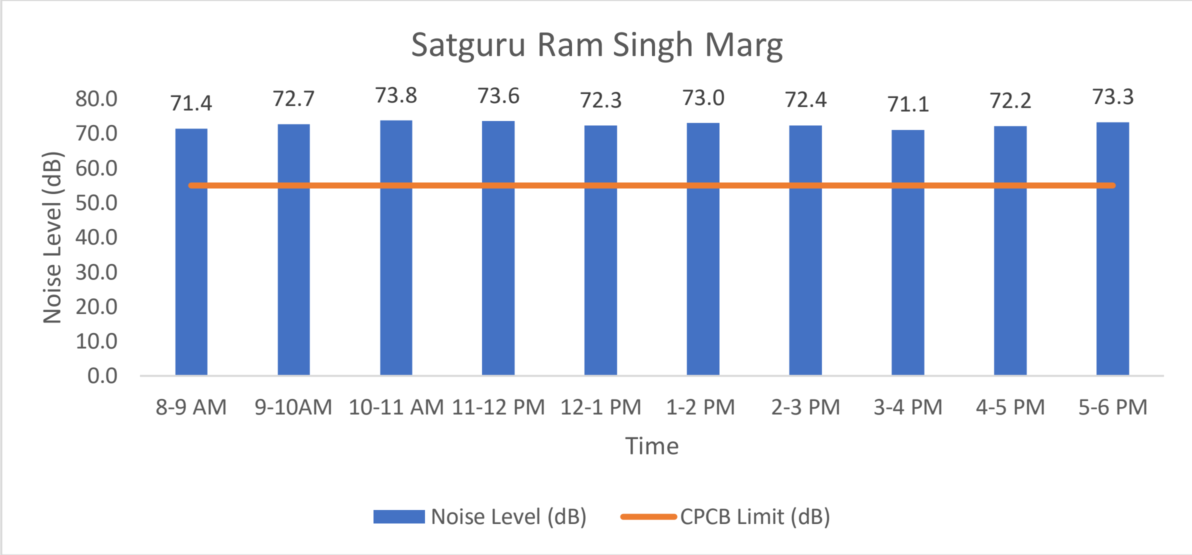


Figure 4. 11. Noise monitoring variation at Satguru Ram Singh Marg

4.1.12. Temporal distribution of Noise at Lodhi Road

At Lodhi Road, the average noise level has varied from 70.2 to 71.1 dB and 68.6 to 69.3 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 69.4 to 69.6 dB. The maximum noise level was 71.1 dB during 10 to 11 AM as shown in Figure 4.12. In comparison to the CPCB limit for the day time for Silent zone is 50 dB and the measured value is exceeding the desired limits.

The monitored noise level is 37.2-42.2 % higher than the CPCB limit for the day time which is 50 dB for the selected location.

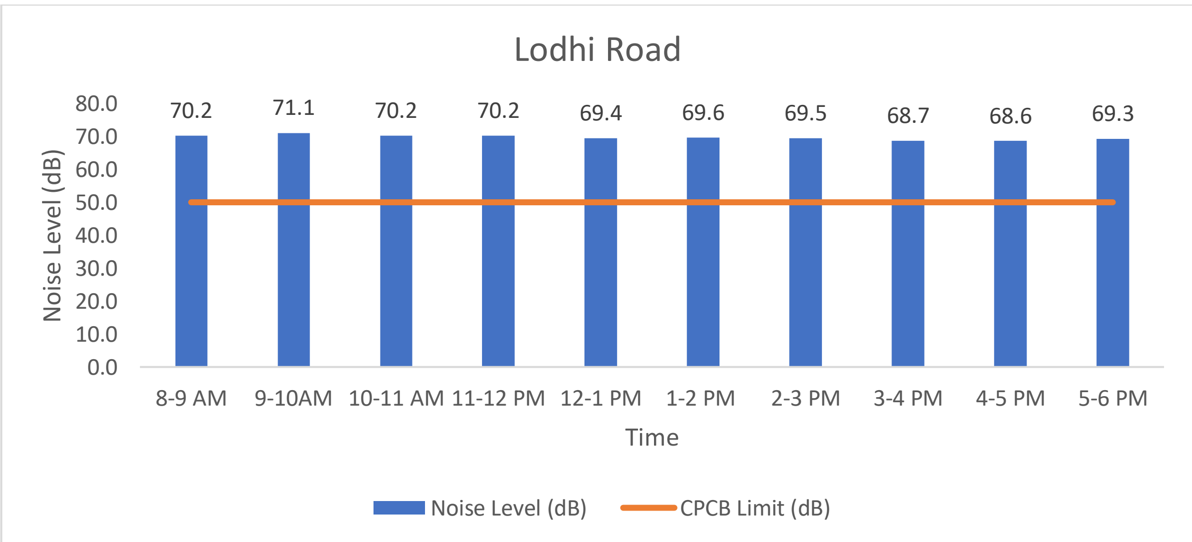


Figure 4. 12. Noise monitoring variation at Lodhi Road

4.1.13. Temporal distribution of Noise at Dabri Gurgaon Road

At Dabri Gurgaon Road, the average noise level has varied from 69.5 to 70.7 dB and 71.4 to 72.4 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 72.3 to 72.5 dB. The maximum noise level was 72.5 dB during 1 to 2 PM as shown in Figure 4.13. In comparison to the CPCB limit for the day time for Silent zone is 50 dB and the measured value is exceeding the desired limits.

The monitored noise level is 39-45 % higher than the CPCB limit for the day time which is 50 dB for the selected location.

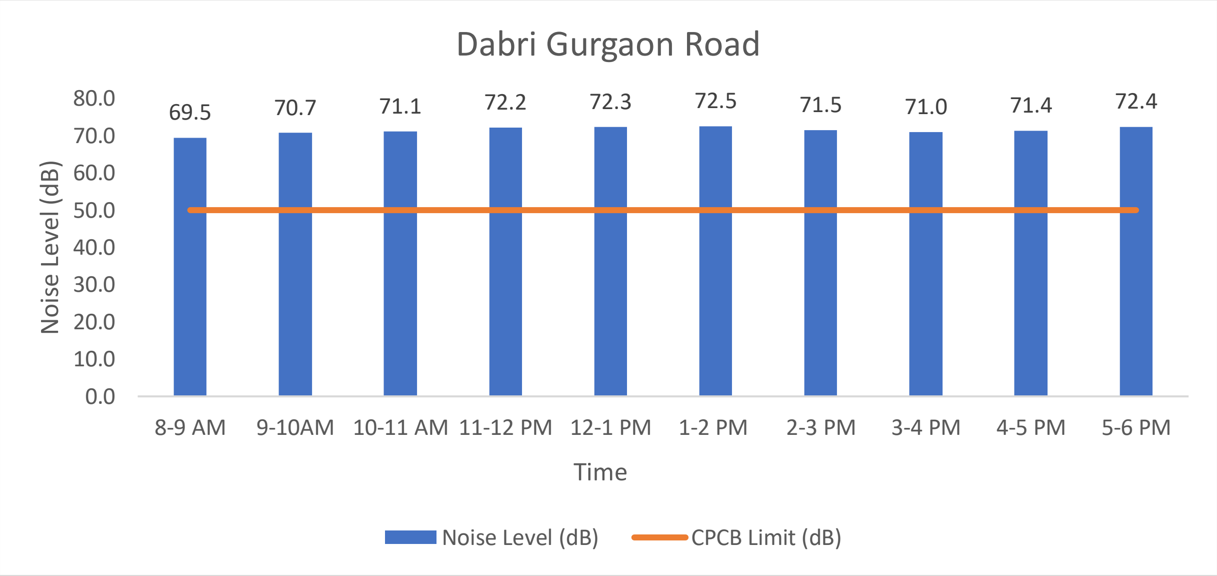


Figure 4. 13. Noise monitoring variation at Dabri Gurgaon Road

4.1.14. Temporal distribution of Noise at Sir Chotu Ram Marg

At Sir Chotu Ram Marg, the average noise level has varied from 72.6 to 73.7 dB and 73.4 to 74.5 dB during the morning and evening peak respectively and for the off-peak hour the noise level varies from 74.7 to 75 dB. The maximum noise level was 75 dB during 1 to 2 PM as shown in Figure 4.14. In comparison to the CPCB limit for the day time for Silent zone is 50 dB and the measured value is exceeding the desired limits.

The monitored noise level is 45.2-50 % higher than the CPCB limit for the day time which is 50 dB for the selected location.

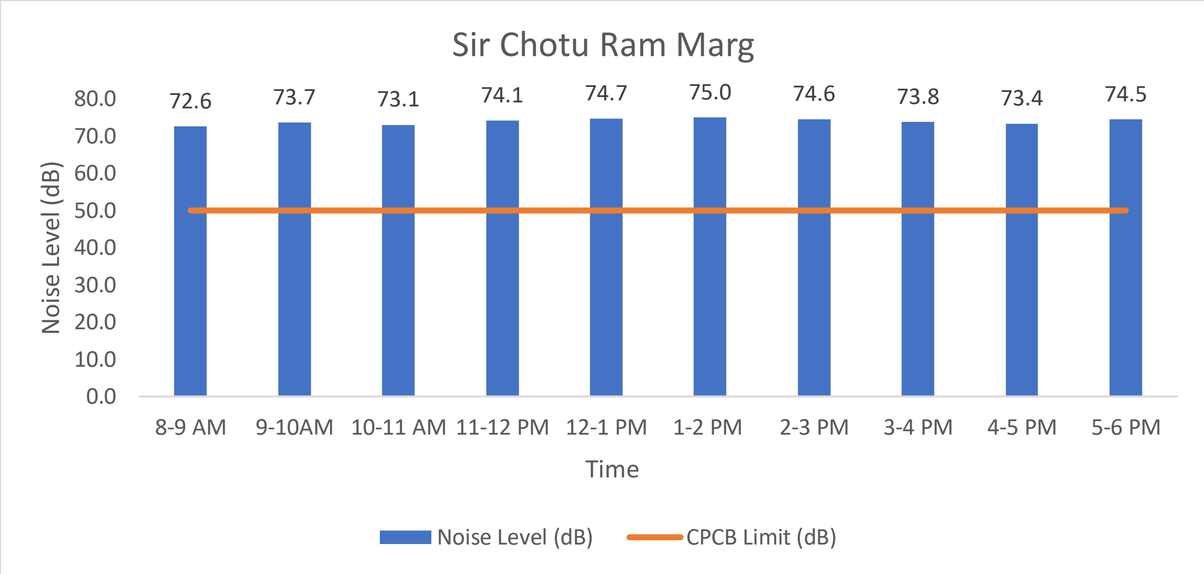


Figure 4. 14. Noise monitoring variation at Sir Chotu Ram Marg

4.2. Noise Mapping at selected location in Delhi

The Noise map for different peak and off- peak zone states the current scenario of noise level in Delhi. After analyzing the data from the map, it is showing no monitored location have shown that it is under the desirable standard level.

4.2.1. Noise Mapping for Morning Peak (8-10 AM)

Noise mapping for Morning Peak that is from 8:00 AM to 10:00 AM. The noise level extreme points for the morning peak duration for this ArcGIS Map is ranging from 70.1 to 77.8 dB. The Noise map shown in the Figure 4.15 says that the South, North and Central District region of Delhi is mostly affected by the Noise pollution. The noise level is similar to the cumulative noise map and have a mere difference of around 0.1 %.

The maximum noise level is monitored at Jangpura which is ranging from 77 to 77.8 dB. The least noise monitored in the Dabri Gurgaon Road (South-West Delhi) and Lodhi (New Delhi) Road ranging from 70.1 to 70.9 dB.

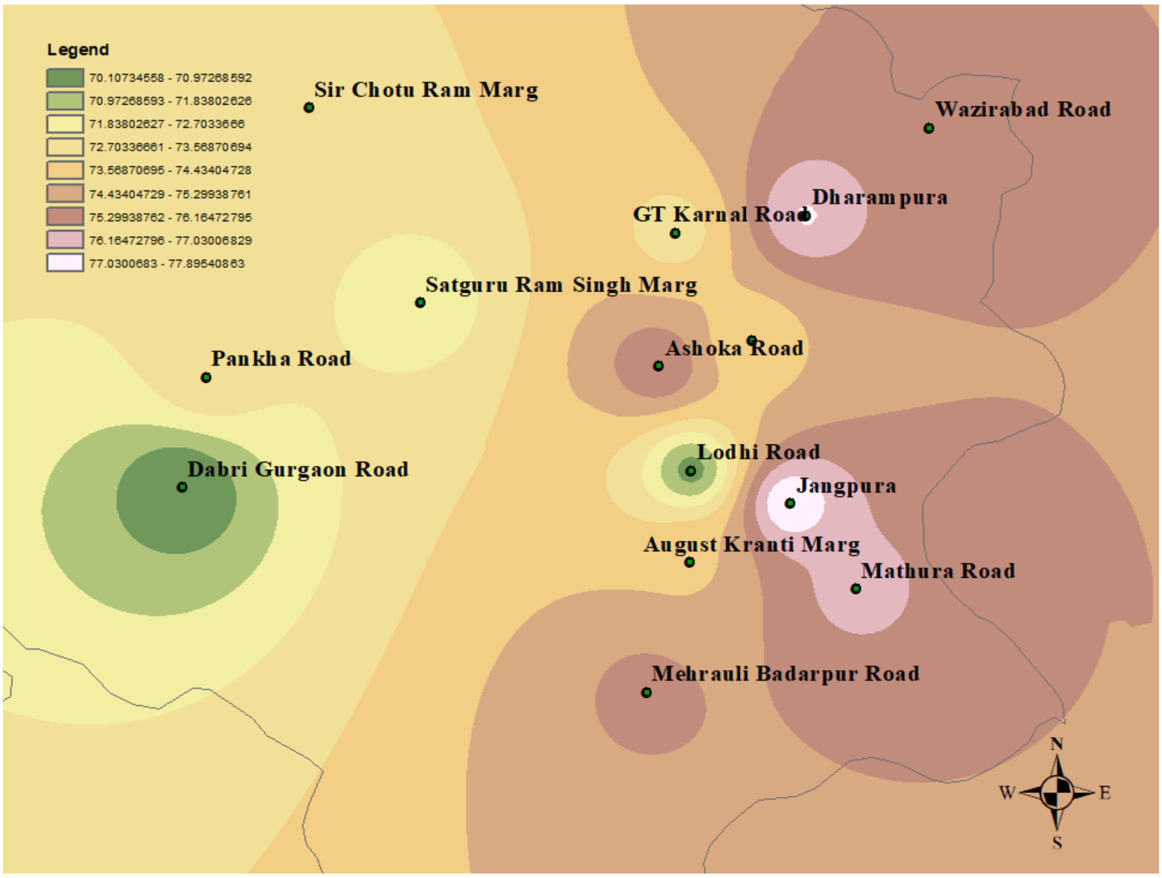


Figure 4. 15. Noise Mapping for Morning Peak (8-10 AM)

4.2.2. Noise Mapping for Off-Peak (12-2 PM)

Noise mapping for Off-Peak that is from 8:00 AM to 10:00 AM. The noise level varying for the off-peak duration for this ArcGIS Map is ranging from 69.5 to 76.9 dB. The noise level has reduced a bit for most of the locations. The reduction observed in the noise intensity level from the morning peak is around 2% and the reduction in the noise level compared to cumulative is around 1 %.

The maximum noise level is monitored at Dharampura and Jangpura Road which is ranging from 76.07 to 76.9 dB. The least noise monitored in Lodhi Road (New Delhi) Road ranging from 69.5 to 70.3 dB.

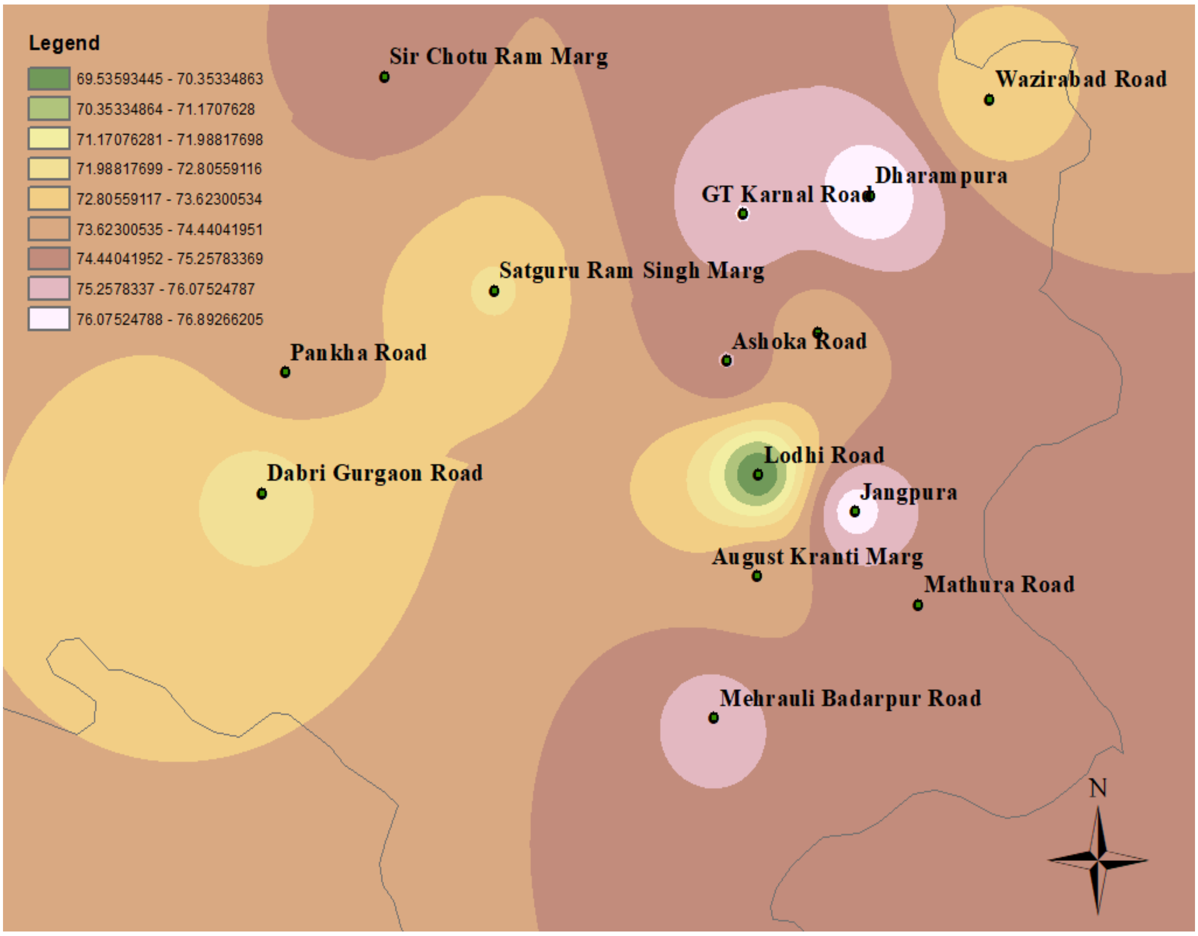


Figure 4. 16. Noise Mapping for Off-Peak (12-2 PM)

4.2.3. Noise Mapping for Evening Peak (4-6 PM)

Noise mapping for Evening peak that is from 4:00 PM to 6:00 PM. The noise level monitored for the evening peak duration for this ArcGIS Map is showing the noise intensity ranging from 69 to 75.9 dB.

The noise level has increased by 2.13% in comparison to the off-peak hours There has been a decrease in the noise level when compared to cumulative noise map which is merely 2%.

The maximum noise level is monitored at Dharampura and Jangpura Road which is ranging from 75.1 to 76.9 dB. The least noise monitored in Lodhi Road (New Delhi) Road ranging from 69 to 69.8 dB.

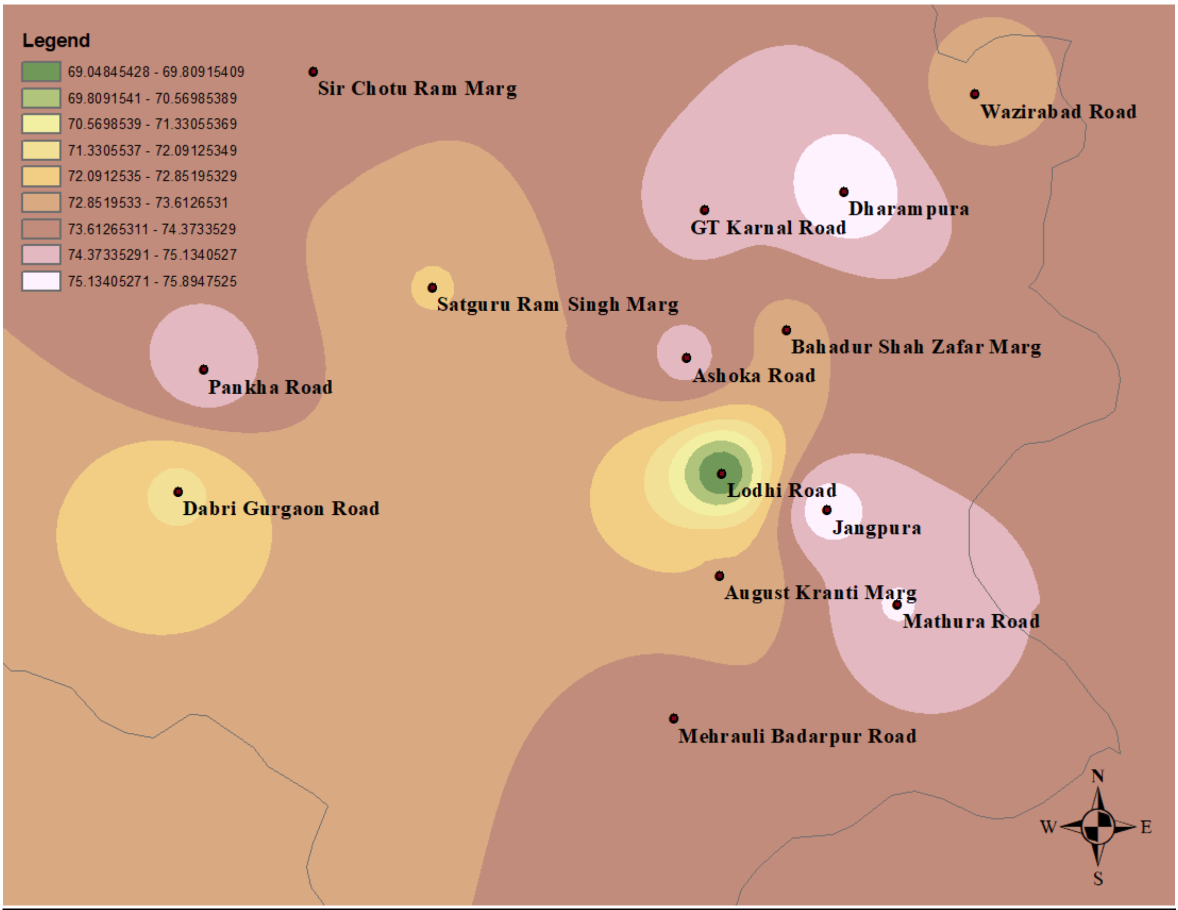


Figure 4. 17. Noise Mapping for Evening Peak (4-6 PM)

4.2.4. Cumulative Noise Mapping

Noise mapping for cumulative noise mapping that is from 8:00 AM to 6:00 PM. The noise level extreme points for the cumulative noise duration for this ArcGIS Map is ranging from 70.1 to 77.9 dB. The noise level has reduced a bit for most of the locations.

The maximum noise level is monitored same for the previous two location i.e., Dharampura and Jangpura Road which is ranging from 77 to 77.9 dB. The least noise monitored in Lodhi (New Delhi) Road ranging from 70.1 to 70.9 dB. When analyzed, it is observed that the noise level is having a marginal change in the noise intensity and the locations which were selected for the maximum and minimum noise level were almost the same.

For all the selected location, no values were there that were showing the monitored noise less than that of Standards by the CPCB for Ambient Noise Level.

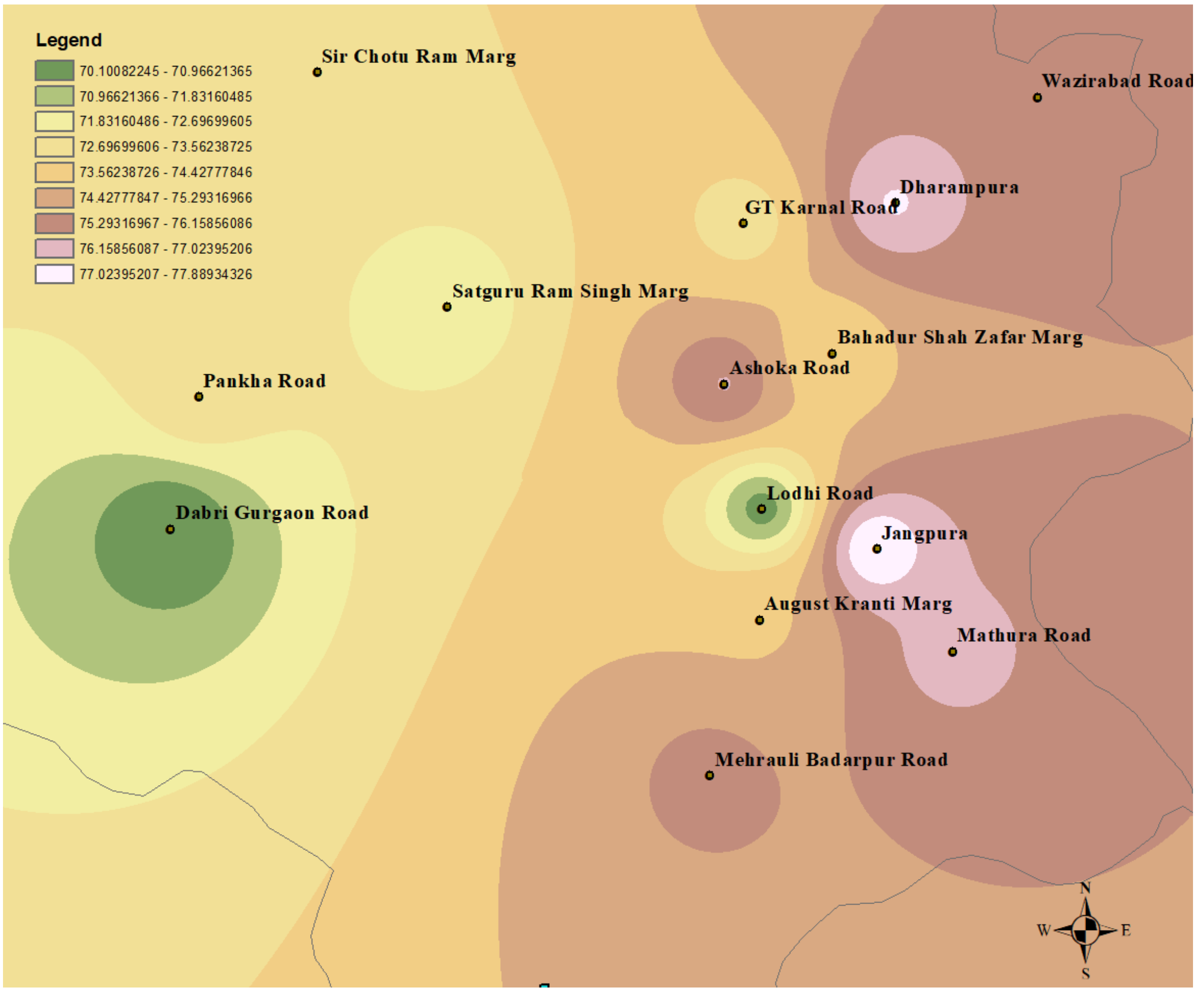


Figure 4. 18. Cumulative Noise Mapping

4.3. Pearson Correlation test for selected Noise Model

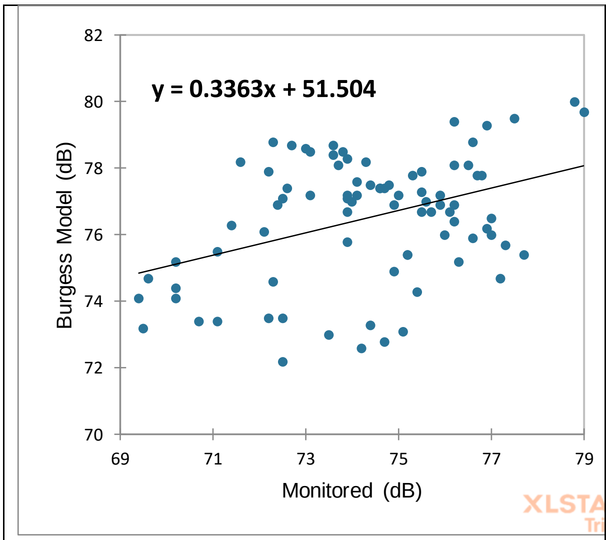
A correlation test is performed when we have to determine the link or relationship in between two variables. The Pearson's Correlation is one of the most frequently used for the regression analysis. The symbol "*r*" stands for the Pearson's correlation coefficient and is used for the calculation of correlation in two variables and its value lies in the range of +1 to -1.

The positive extreme values are generally said to give strong relationship in between the variables. If the value of correlation coefficient is 0 then it signifies that there is no certain relationship between the two variables. The Pearson correlation coefficient *r* more than 0.5 is classified strong relationship in between two variables

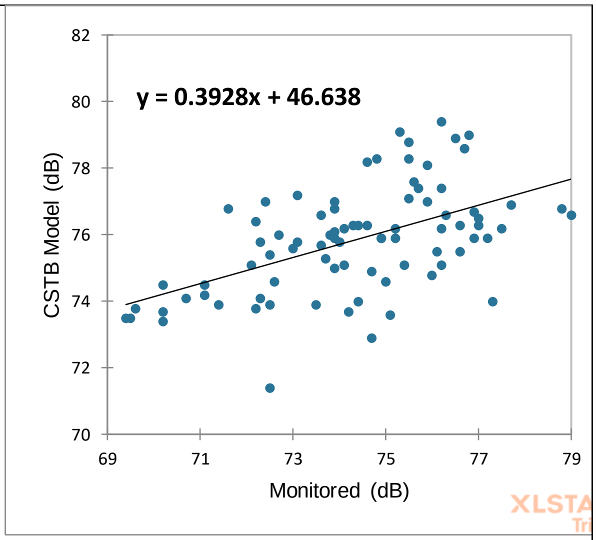
For determine the stability of the data set, the t-test and p-value is used to basically evaluated the as how easily the data are rejecting the null hypothesis. The null hypothesis says that there is no relationship between the two variables. p-value less than 0.01 signifies that the result is highly statistically significant and have rejected the null hypothesis condition.

The positive value of Pearson correlation coefficient value signifies that there is positive correlation between two variables. Positive correlation signifies that if a variable is increasing then the other variable is also increasing and vise-versa. The R^2 value i.e., Coefficient of Determination indicates that the amount of variance in between the two variables and it is just the square of the Correlation coefficient "*r*".

The scatter plot and regression equation from Figure 4.19 (a-d) can be used for further prediction of the noise level with the help of monitored sound level of the locations.



(a)



(b)

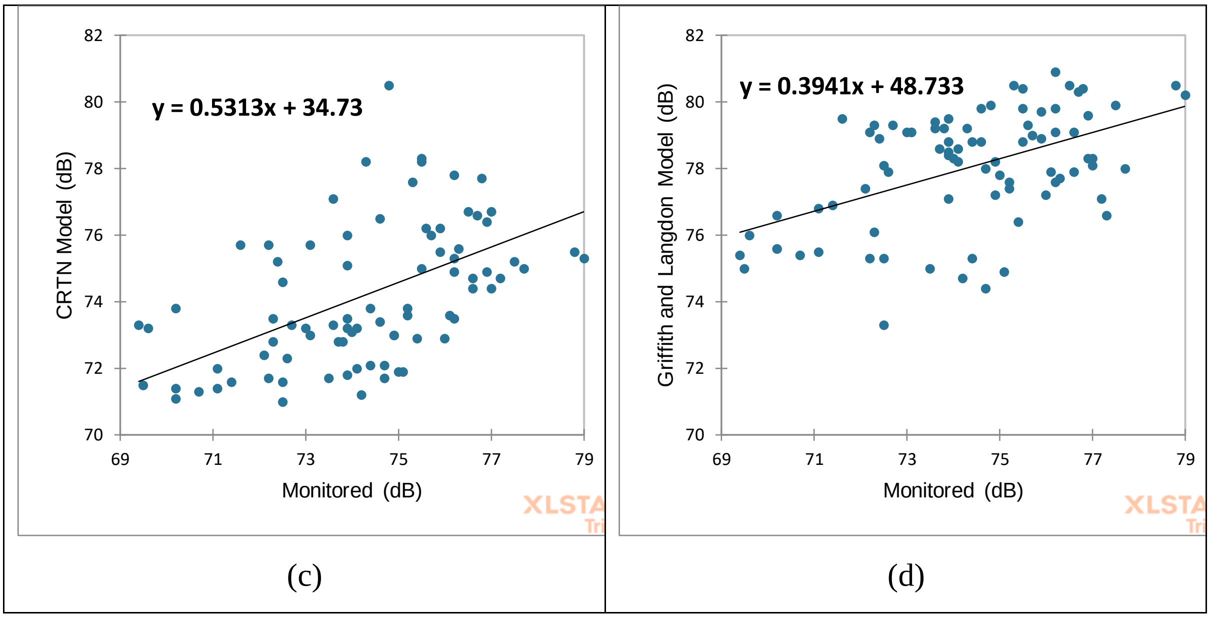


Figure 4. 19. Scatter Plot

All the four Noise models were analyzed for the Pearson correlation test by making Monitored value as an independent variable.

In Table 4.1, the Pearson correlation results are mentioned for all the traffic Noise Model:

Table 4. 1. *Pearson Correlation test result*

Statistic	Burgess Model	CSTB Model	CRTN Model	Griffith and Langdon Model
Mean	76.5	75.83333333	74.220238	78.02619048
Biased Variance	3.50642857	2.53531746	4.9947095	2.958123583
Biased Standard Deviation	1.87254601	1.592268024	2.2348847	1.719919644
Covariance	1.61289157	1.883815261	2.5481383	1.890149168
Correlation (*r*)	0.39096291	0.537013271	0.5175243	0.498827978
Determination (R^2)	0.15285199	0.288383253	0.2678314	0.248829351
t-Test	3.84647429	5.764595847	5.4768663	5.211808202
p-value (2 sided)	0.00023596	1.39E-07	4.63E-07	1.37E-06
p-value (1 sided)	0.00011798	6.96E-08	2.32E-07	6.85E-07

95% CI of Correlation	[0.192721769974451, 0.558540877872368]	[0.364595028432021, 0.673828516197434]	[0.340960279564746, 0.658820275232383]	[0.31849462072227, 0.644315944655395]

The highest value of Pearson correlation comes for the CSTB Model which is 0.537. This indicated that there is a significant large positive relationship between Monitored value and CSTB Model.

Based on the correlation test, CSTB is selected for the Road Traffic Noise Modelling for Delhi.

4.4. Noise Survey Analysis

A total of 542 data were collected over the 14 site locations in Delhi. A total of 542 survey forms have been submitted during the study period. The data have collection of different samples categorized on the basis of Gender, age and Data collected from.

Out of 542 data set the numbers of traffic wardens' data are 49, the number of shopkeepers/workers is 93, pedestrian is 219, Rickshaw/Cycle/Bike Driver is 102 and Car/Bus/Truck driver is 78. One other data set is there for the inspection of the data generated from the google form.

4.4.1. Survey Analysis on the basis of Age group

On the basis of Age group classification, we have found that the fatigue, behavioral effect is somewhat similar in all the age group as shown in Figure 4.2. We have seen high cases of vulnerability towards the concentration loss and Headache in youth (blow 30 years). There has been rise in the cases of public conflict involvement over the age from 5 to 38%. Sleeping disorder have been found most (23%) in the 18-30 age group. Cases of Hearing Impairment and Heart related issues are increasing as the age increases.

As a conclusion we can say that, on age-based analysis the physiological effect is inversely proportional to the psychological effect and vise-versa.

Table 4. 2. Survey Analysis on the basis of Age group

Effect	**Age (Years)**			
	Below 18	**18-30**	**30-45**	**Above 45**
Data Set (No.)	40	136	214	152
Fatigue (%)	53	57	46	45
Concentration Loss (%)	65	68	52	41
Headache (%)	80	66	55	45
Behavioural Effect (%)	53	61	59	57
Public Conflict (%)	5	23	26	38
Hypertension (%)	0	3	14	40
Insomnia (%)	0	23	21	17
Hearing Impairment (%)	0	13	11	38
Cardiovascular Issue (%)	0	2	9	34

4.4.2. Survey Analysis on the basis of Gender

Cases of fatigue, behavioral effect, hypertension and insomnia due to traffic noise is kind of similar for both male as well as female. There have been more cases of public conflict involvement in Male i.e., 32% as shown in Table 4.3. Females are developing more chances of headache from the traffic noise than male. The hearing loss is more found in male than that of female. Females are more prone to Cardiovascular issues like having high blood pressure and cholesterol level etc. Many people have said that they have developed snoring due to the uneven sleep pattern.

As a conclusion from the Gender based analysis of Heath effect, it is found that the females are more prone to the noise related risk.

Table 4. 3. Survey Analysis on the basis of Gender

Effect	**Gender**	
	Male	**Female**
Data Set (No.)	447	95

Fatigue (%)	46	62
Concentration Loss (%)	52	61
Headache (%)	51	85
Behavioural Effect (%)	58	60
Public Conflict (%)	32	4
Hypertension (%)	18	15
Insomnia (%)	18	21
Hearing Impairment (%)	21	6
Cardiovascular Issue (%)	13	18

4.4.3. Survey Analysis on the basis of Data set collected from

The Car/Bus and Truck drivers are the most affected by the noise pollution. It may be due to the traffic congestion. The cases of fatigue, insomnia and concentration loss are generally less for traffic officers and Shopkeepers than that of Pedestrian, Rickshaw/Cycle and Bike Drivers, Car/Bus and Truck drivers. Due to the constant exposure to noise the hearing loss has been seen in traffic officers and Shopkeepers/Workers.

Table 4. 4. Survey Analysis on the basis of Data Set collected from

Effect	**Data Collected From**				
	Traffic Officers	**Shopkeepers/ Workers**	**Pedestrian**	**Rickshaw, Cycle and Bike Driver**	**Car, Bus and Truck Drivers**
Data Set (No.)	49	93	219	102	78
Fatigue (%)	31	35	54	40	72
Concentration Loss (%)	27	46	58	51	71
Headache (%)	37	42	72	44	62
Behavioural Effect (%)	65	40	58	62	74
Public Conflict (%)	29	18	12	39	62

Hypertension (%)	24	23	8	22	28
Insomnia (%)	10	13	17	25	26
Hearing Impairment (%)	27	23	12	20	22
Cardiovascular Issue (%)	20	19	9	12	19

During survey, it was observed from the result that the shopkeeper, workers and traffic warden are less affected by the Traffic noise aa they have developed the tolerance level in them. Heavy Vehicles drivers are more prone to the noise and cases of Heart related and Hearing loss are shown in Traffic wardens and Shopkeepers.

CHAPTER 5. CONCLUSION

In Delhi or elsewhere, the road traffic noise is distinct from other pollutants unlike air or water pollution. Noise pollution leaves no leftover evidence to act as a reminder of its displeasure. Noise Pollution is generally given the lowest priority for regulation and management, despite the fact that its impacts are usually as severe as any other pollution. Although road traffic is an important aspect of the urban environment, it is also the primary cause of urban noise pollution.

On the basis of Pearson Correlation test, the noise model for the traffic conditions in Delhi is favoring to the CSTB Traffic Noise Model. As the number of vehicles on the roads are growing over the years, so does unrestricted noise pollution and its related health effects, which can create both short-term and long-term psychological and physiological problems. The CSTB model is basically dependent on two factors first one is Road traffic Volume and width of the road so managing these two parameters can help in reduction of Noise pollution.

Burgess Traffic Noise Model Griffith and Langdon Traffic Noise Model have shown the least correlation to that of Monitored noise value. hence it can be said that the Percentage of heavy vehicles isn’t affecting the overall traffic noise level.

Most of the location have shown an alarming call about the conditions of Noise pollution in Delhi. The most affected noise level was reported for Dharampur (North-East Delhi) and Jangpura Road (South-East Delhi) which is seen for every ArcGIS mapping. The lowest noise level monitored is from Lodhi Road (New Delhi).

The Noise Map created can also be used for predicting the Noise level for the nearby area of the pre-selected monitoring locations. From the Noise Map, it was observed that the highest change in the noise level was shown for Off-Peak to Evening Peak hours that is 2.14%. After creating the cumulative Noise map for Delhi in ArcGIS it showing that no value is in the safe zone of ambient noise standards.

The survey data have suggested that peoples are getting easily affected by the road noise and are showing discomfort and health related issues. The younger people have developed annoyance towards the road traffic noise and the elderly people are getting affected by the old age problems like High Blood Pressure and Heart related issues from the traffic noise.

On Age based study, it was observed that Male and Female have somewhat similar responses towards behavioral effect and fatigue lessness. Female are easily affected by the noise and cases are higher for the Headache and Cardiovascular issues. As generally Male are more in exposure of traffic noise from the road so the data have shown that they are involved in more public conflict than that of Female also Male have developed more cases of hearing related problems.

On the basis of Data collected from it is observed that Car, Bus and Truck drivers are affected mostly from the road traffic noise, this has developed in number of health-related problems in them. The shopkeeper and traffic warden shows lesser impact from the traffic noise as over the years they have developed the tolerance less in them. High cases of Hearing issues have shown in the Traffic warden due to constant exposure to the road traffic noise and further this results in emerging the cases of hypertension and heart related problems in them.

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