# HEALTH IMPACT ASSESSMENT OF NIGHT TIME RAILWAY NOISE ON RESIDENTS OF DELHI CITY

A DISSERTATION

SUBMITTED IN THE PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE AWARD OF DEGREE OF

**MASTER OF TECHNOLOGY**

**IN**

**ENVIRONMENTAL ENGINEERING**


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## **CANDIDATE'S DECLARATION**

I, Anand Priy, Roll No. 2K21/ENE/04 student of M. Tech (Environmental Engineering), hereby declare that the project Dissertation titled "Health Impact Assessment of Night Time Railway Noise on Residents of Delhi City" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment 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 "Health Impact Assessment of Night Time Railway Noise on Residents of Delhi City" which is submitted by **Anand Priy, Roll No. 2K21/ENE/04**, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried 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.

Place: Delhi **DR. RAJEEV KUMAR MISHRA**

Date: **SUPERVISOR**

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# ABSTRACT

Noise is described as an obtrusive sound that could have a negative physiological and psychological effect on a person's health. Rail transport is one of the main sources of noise, with a particularly strong negative impact on environment, and on health of children and adults. Railway traffic noise is one of the most significant issues in urban and suburban areas especially in nearby areas of railway stations. According to this study, residential areas in vicinity of railroad tracks are highly affected. The adverse health effects of excessive noise include hearing loss, disturbances of sleep, spoken communication interference, cardiovascular issues, disturbed mental health, impaired work performance, negative social behaviour, and noise annoyance.

This study’s major goal is to assess the health impacts of night time rail noise and noise mapping for selected locations in New Delhi, India. The monitored noise data collected over a duration of 2 days at the selected locations, is converted into $L_{eq}$ values and compared with the CPCB standards and also the health impacts are predicted based on the NETHERLANDS HEALTH COUNCIL REPORT 1994. The monitored values varied from 63.8 dB (A) to 77.6 dB (A) for Sarai Rohilla railway station and from 56.7 dB (A) to 79.8 dB (A) for Sabzi Mandi railway station. The 8 hour equivalent continuous noise levels showed the occurrence of health effects such as disturbance of sleep and affected sleep quality. ArcGIS software is to be used for generation of noise contour maps. Questionnaire were prepared for Survey for the selected locations so as to know the actual effect of Noise Pollution on Human Health. For Analysis, Survey data set is further categorized in three parts, on the basis of Age, Gender and the respondents from which the data has been collected. The survey will help in analysing the adverse impact by taking responses of people towards the rail noise. Annoyance due to rail traffic noise is also taken into consideration by means of responses in the questionnaire.

**Keywords:** Rail Noise, Health Impact, ArcGIS, and Noise Mapping.

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# CHAPTER 1

# INTRODUCTION

## 1.1 GENERAL BACKGROUND OF STUDY

The term "noise pollution" refers to any unpleasant or grating sound that interferes with daily living and, as a result, degrades it. It has become one of the key elements of environmental degradation. The human ear adjusts to the level of ambient noise, and the gradual increases in ambient level are therefore ignored. As a result, noise continues to injure, quietly. "Noise should be perceived as the main threat to human happiness," the World Health Organisation states [1]. When anything vibrates, sound is produced and sent to the ears as a replacement for rarefactions.

Sound turns into noise when it exceeds the permitted threshold. The perception of sound and noise is highly individualised; one person's music may give another person a headache. The largest source of noise pollution in metropolitan areas has been transportation, including trains, planes, metros, cars, bikes, and heavy trucks. Social gatherings (such as weddings, funerals, and crowded marketplaces), domestic activities (such as music systems, televisions, and kitchen appliances), and commercial and industrial operations are other sources of noise. Numerous detrimental effects on our brain and body are hypothesised to result from noise pollution. According to WHO recommendations, the maximum level of sound that is permitted in any particular space should not be more than 45 decibels (dB). In an urban setting, the upper limit is violated far too frequently.

The widespread consensus is that air pollution includes noise pollution as a component. Noise cannot be defined solely in terms of physical boundaries of sound. Generally, noise is defined as inherently unpleasant sound, all other factors being equal. In contrast to other pollutants, noise does not leave behind waste or other indications of how unpleasant it is. This justification causes people to frequently ignore or misinterpret the issue of noise pollution. It is now crucial for the people to be educated about noise pollution on a global scale.

## 1.2 URBANIZATION AND POPULATION GROWTH

Development of transit stations is among urbanization's most important and long-lasting effects. From 1951 to 2019, India's motor vehicle population increased, as seen in Figure 1. The existing infrastructure and resources are put under further strain due to the growing population. Vehicle numbers and population growth are directly correlated throughout time. The transportation industry and population density are significant contributing causes to noise pollution. The population growth in India from 1901 to 2021 is shown in Figure 1.2.

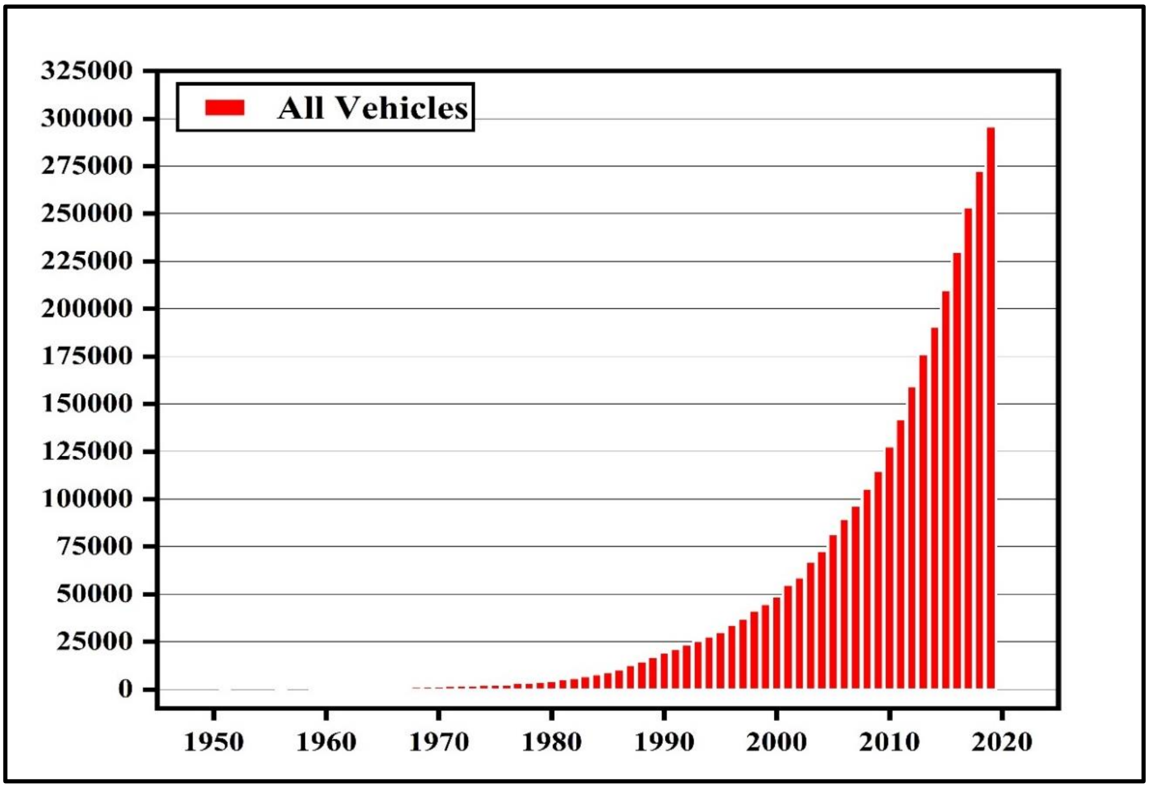


Figure 1.1. Number of motor vehicles registered in India (in thousands)

Source: [2]

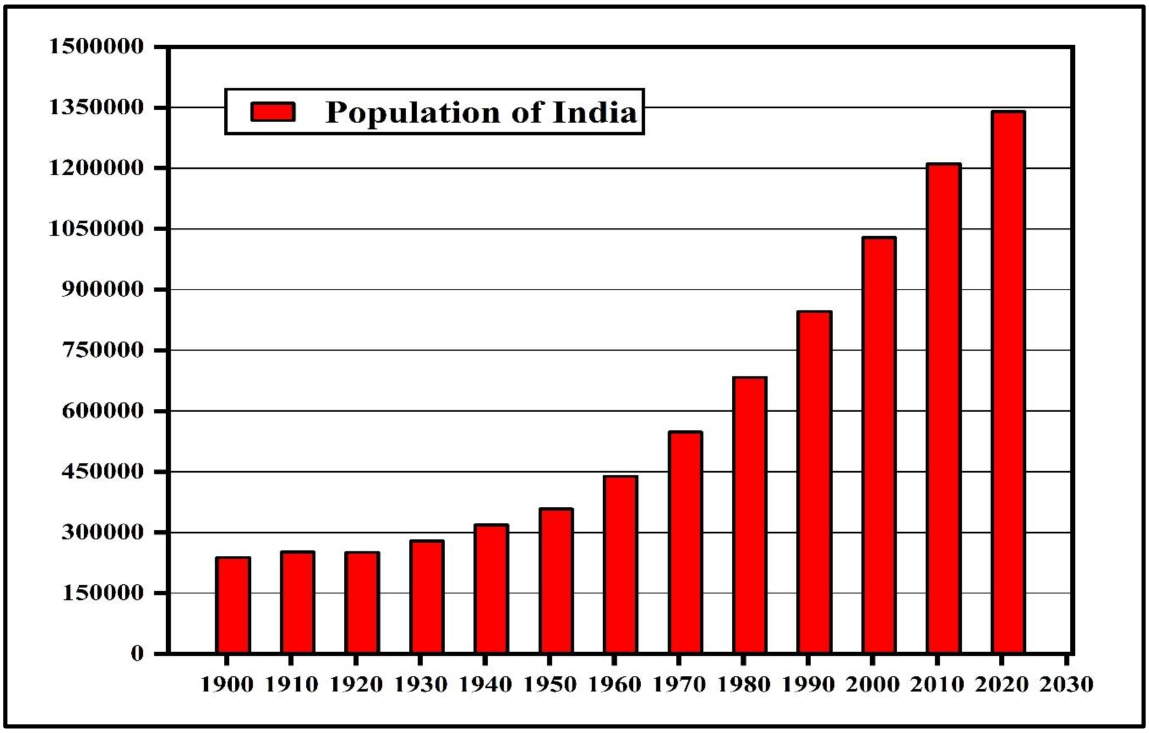


Figure 1.2. Population of India (in thousands)

Source: [3]

## 1.3 MAJOR SOURCES OF NOISE POLLUTION

There are numerous ways in which noise pollution might appear. Some of the causes and sources are things we notice and feel every day but choose to disregard. Listed below are a few of them:

### 1.3.1 Industrial Noise:

In today's environment, the use of tools and equipment is essential for productive labour. Industrial noise exacerbates the already problematic problem of noise contamination. The noise is primarily caused by mills, large industrial machines, and even little exhaust fans that run continuously.

### 1.3.2 Transportation Noise:

The most difficult source of noise to avoid in public spaces today is traffic noise. Noise due to traffic is the largest source of measured sound levels and also the biggest cause of annoyance, according to a noise survey research conducted globally [4]. Noise pollution is a significant factor whether travelling by car, train, or aeroplane. Engine type, waggon type, and degree of roughness between rails and wheels all affect the rail traffic noise.

### 1.3.3 Construction Noise:

Even routine home maintenance, flyover building, and mining all generate some amount of noise. All of this lowers our quality of life and increases conflict in our neighbourhood. It is the responsibility of those participating in such exercises to ensure that they cause as little difficulty as possible to others.

### 1.3.4 Domestic Noise:

Due to noises from ventilation systems, party music, lawn mowers, grinders, mixers, and vacuum cleaners, this kind of noise is common in residential settings. Unusual social behaviour has long been recognised as a source of noise in multifamily homes. Additionally, a variety of recreational activities greatly increase the already high noise levels in the neighbourhood.

### 1.3.5 Poor Urban Planning:

Poor urban planning can also contribute to noise pollution. Numerous factors, such as heavy traffic, constant honking, crowded areas, rivalry for basic services, and large families living in close quarters, can cause noise to permeate our surroundings.

## 1.4 EFFECTS OF NOISE POLLUTION ON HUMAN HEALTH

The WHO has identified the major risks posed by noise pollution to people's health, including hearing loss, aggressive behaviour, communication difficulties, mental illness, sleep disturbances, hormonal changes, and cardiovascular consequences [1][5]. Numerous investigations have demonstrated that several acute and abnormal medical conditions are caused by noise pollution [6]. There are numerous physical, physiological, and psychological health risks associated with noise pollution.

### 1.4.1 Physical Effects:

A person's hearing threshold may alter temporarily or permanently depending on the noise intensity present during the exposure and whether it happens more than once. Increased noise exposure's most frequent and immediate side effect is hearing loss, which in extreme situations can lead to utter deafness. Since the sensory cells in the ears are extremely sensitive, prolonged exposure to loud noise might permanently harm the ears.

### 1.4.2 Physiological Effects:

The physiological impacts of noise pollution include the following:

a) A headache brought on by dilated blood vessels in the brain.

b) Rise in the heartbeat’s frequency.
c) Development of atherosclerosis.
d) Variations in arterial blood pressure brought on by an increase in blood cholesterol levels.
e) A decrease in cardiac output
f) Heartaches and discomfort.
g) Anxiety-related digestive spasms that dilate the pupil and induce eye strain.
h) Impairment of night vision.
i) A slowing down of how quickly humans perceive colour.
j) A decline in attention span and how it affects memory.
k) Muscular strain and nervous collapse.

### 1.4.3 Psychological Effects:

The following are the psychological impacts of noise pollution:

a) Depression and exhaustion.
b) Insomnia.
c) The gradual but continual noise from alarm clocks, telephone ringing, and other sources that strains the senses and causes discomfort.
d) Psychomotor performance also gets affected.
e) Emotional disturbance.

Figure 1.4. and Figure 1.3.**,** exemplify how noise pollution affects human health.

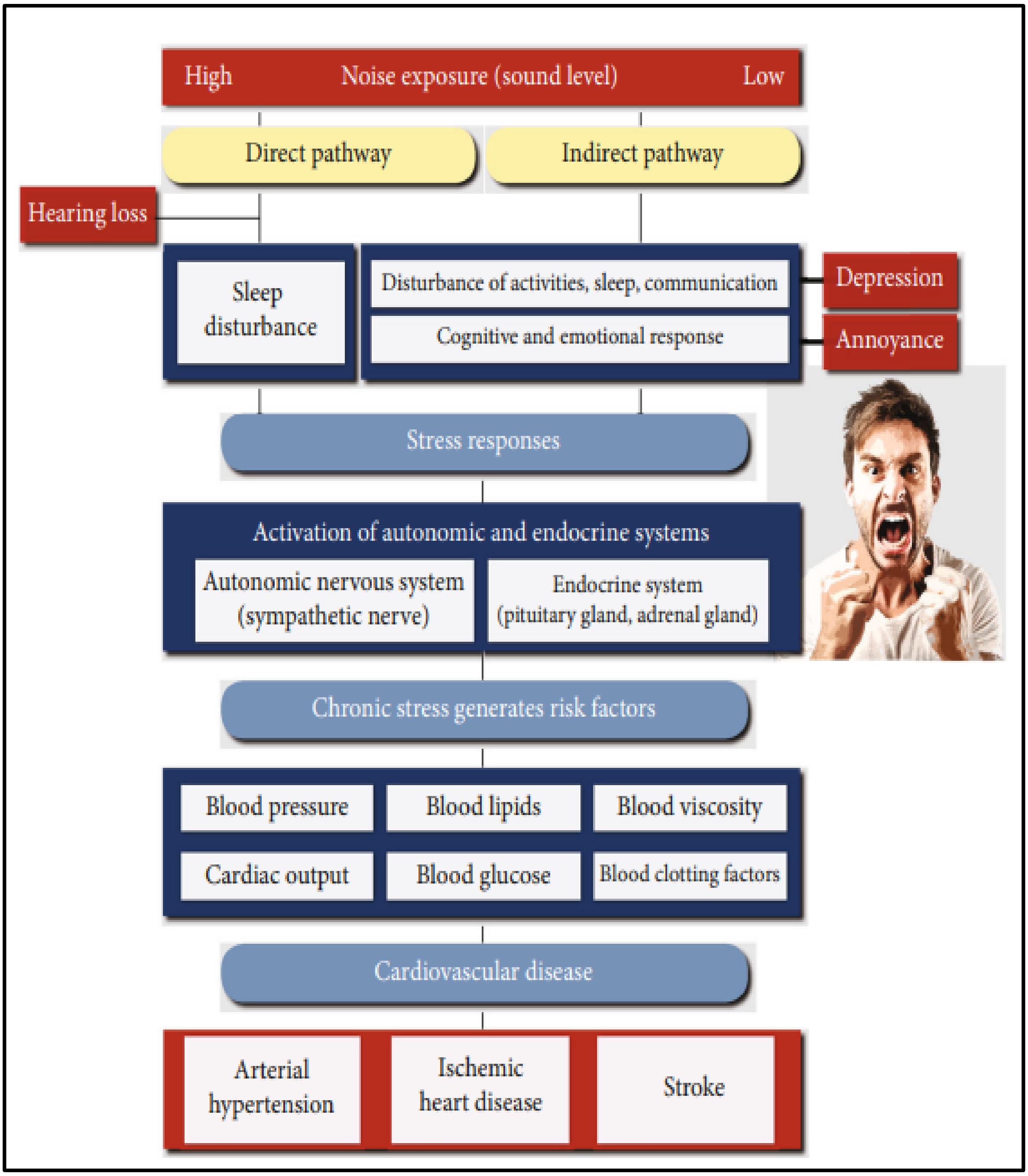


Figure 1.3. Adverse health effects of noise pollution

Source: [7]

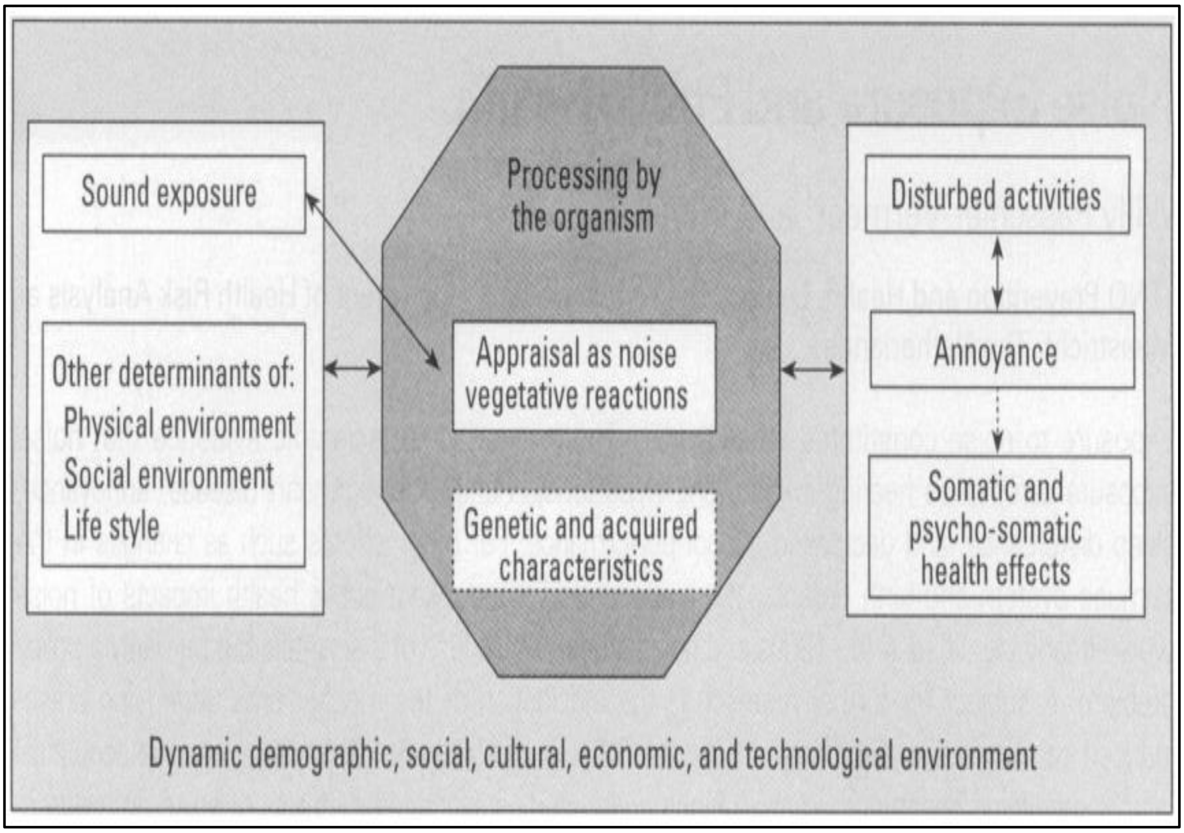


Figure 1.4. Mechanisms of noise-induced health effects

Source: [8]

### 1.5 NOISE STANDARDS

"Decibels (dB)" is the unit used to measure noise. Noise measurement enables us to identify the harmful sound levels that must be reduced in order to avoid health problems. "dB (A)" stands for time-weighted average of sound pressure level in decibels on scale "A", comparable to human hearing. Equivalent continuous sound level ($L_{eq}$), is defined as energy mean of noise level during a specified interval of time. Decibel scale for displaying the typical sound level produced by various activities is shown in Figure 1.5.

The Table 1.1 lists the CPCB-established Ambient Air Quality Standards for Noise Level. Table 1.2 displays community noise guidelines from World Health Organisation (WHO).

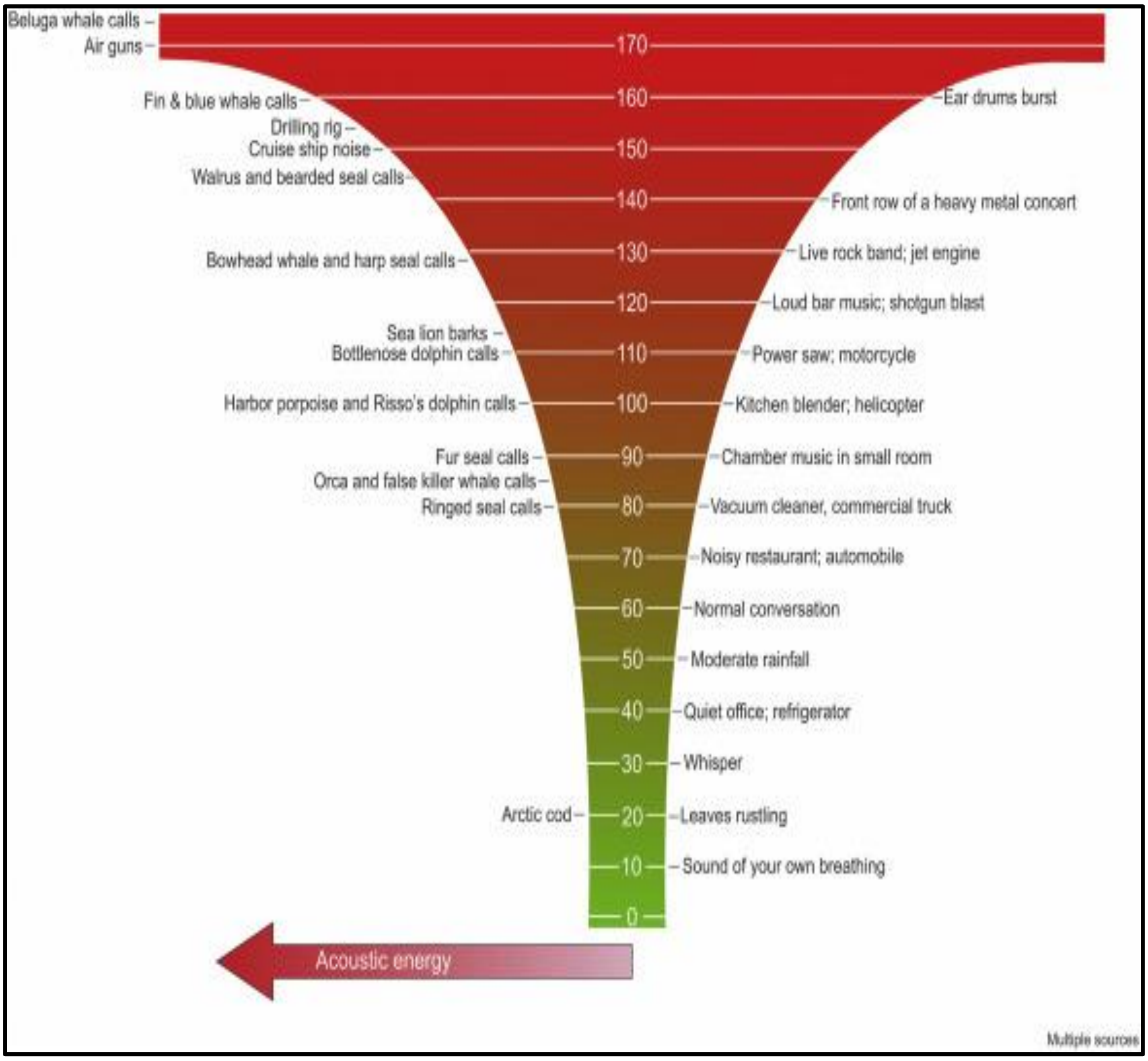


Figure 1.5. Decibel (dB (A)) scale with examples

Source: [9]

Table 1.1. Ambient noise quality standards

| AREA CODE | CATEGORY OF AREA/ZONE | LIMITS IN dB(A) IN $L_{eq}$ | |
|---|---|---|---|
| | | 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: [10]

**Note:**

a) Daytime = 06:00 am to 10:00 pm.
b) Night time = 10:00 pm to 6:00 am.
c) Silence zone is a 100-meter area around medical facilities, schools, and courthouses. The authorised authorities designates certain regions as silence zones.
d) Regions of mixed type may be designated as one of four aforementioned categories by governing authorities.

Table 1.2. WHO Guidelines regarding Community Noise

| Specific environment | Critical health effect(s) | $L_{Aeq}$ [dB(A)] | Time base [hours] |
|---|---|---|---|
| Outdoor living area | Serious annoyance, daytime and evening | 55 | 16 |
| | Moderate annoyance, daytime and evening | 50 | 16 |
| Dwelling, indoors | Speech intelligibility & moderate annoyance, daytime & evening | 35 | 16 |
| Inside bedrooms | Sleep disturbance, night-time | 30 | 8 |
| Outside bedrooms | Sleep disturbance, window open (outdoor values) | 45 | 8 |
| School, playground outdoor | Annoyance (external source) | 55 | during play |
| Hospital ward rooms, indoors | Sleep disturbance, night-time | 30 | 8 |
| | Sleep disturbance, daytime and evenings | 30 | 16 |
| Hospital treatment rooms, indoors | Interference with rest and recovery | #1 | |
| Industrial, commercial shopping and traffic areas, indoors, outdoors | Hearing impairment | 70 | 24 |
| Public addresses, indoors, outdoors | Hearing impairment | 85 | 1 |

| | | | |
|---|---|---|---|
| Music and other sounds through headphones/ earphones | Hearing impairment (free-field value) | 85 #4 | 1 |
| Impulse sounds from toys, fireworks and firearms | Hearing impairment (adults)<br><br>Hearing impairment (children) | -<br><br>- | -<br><br>- |
| Outdoors in parkland and conservations areas | Disruption of tranquillity | #3 | |

Source: [11]

#1: Lowest possible.

#3: Quiet outdoor spaces should be safeguarded, and intrusive noise volume should be kept at a minimum.

#4: Adapted to free-field values while wearing headphones.

## 1.6 RAILWAY TRANSPORTATION

Transportation by train is one of the best options for moving people and goods on wheels along fixed rail tracks. Typically, force is provided by a train pulling a series of unpowered wagons/coaches that can transport people or goods. The trackside framework can provide electricity, steam, or diesel to power the locomotive. The 6 km (3.7 m) Diolkos wagon way, used to transport boats across Greece’s Corinth isthmus in the sixth century B.C., served as the first evidence of a railway. Although there is no denying that railway transport can move and ship things to some extents, when compared to street transit, it has a higher capital concentration.

### 1.6.1 World Scenario:

When it comes to the size of its railway network, the United States of America comes in first [12]. Indian railway is one of the least expensive and safest ways of transportation. It has 1,26,366 kilometres of route, and it transports 23 million people daily [13].

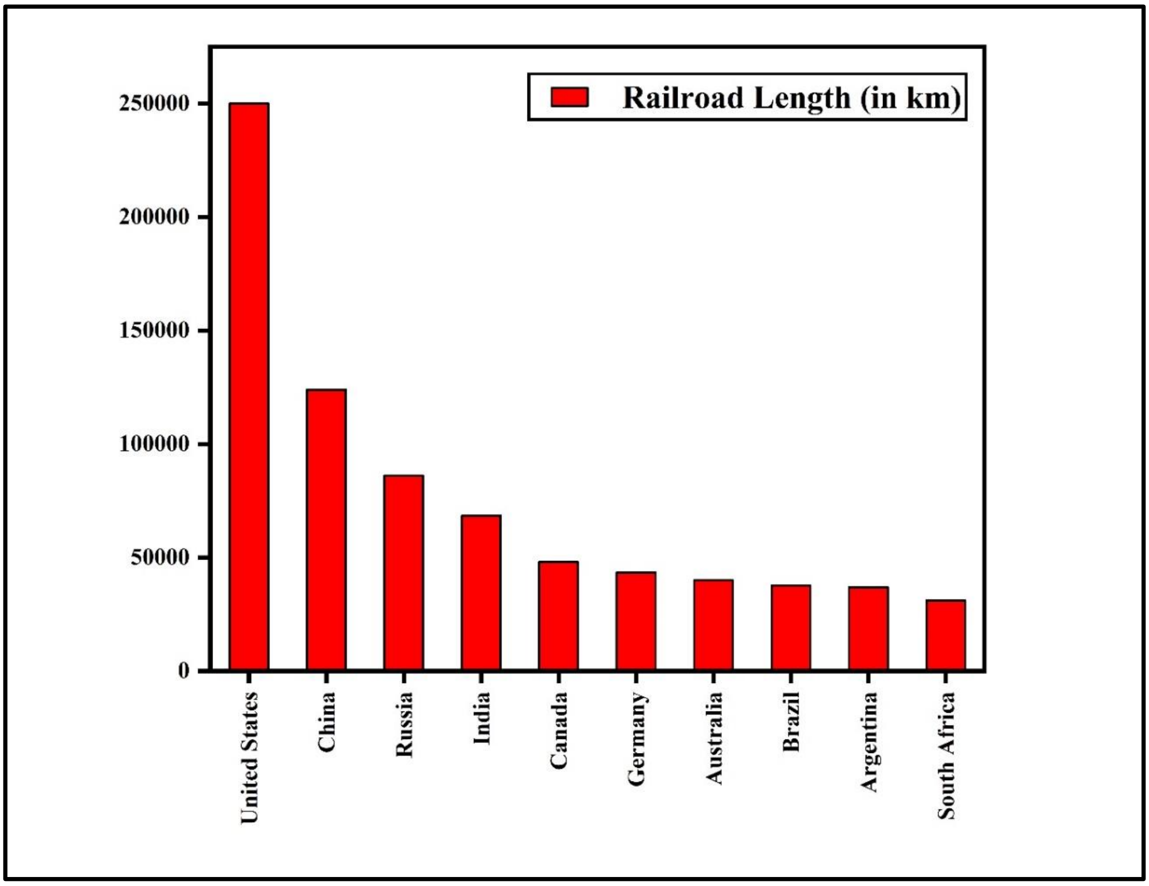


Figure 1.6. World Scenario of rail route

Source: [14]

### 1.6.2 Indian Scenario:

The first passenger railway travelled 34 kilometres from Bombay to Thane on April 16, 1853. With 13,523 passenger trains and 9,146 goods trains, Indian Railways has built 7,349 stations along 68,000 miles of track. Every day, more than 23 million passengers and 1.225 billion tonnes of goods are transported by Indian Railway. The route length of the railway in India is depicted in Figure 1.7. India's railway system is split up into zones and then into divisions. The zones and divisions of Indian Railways are depicted in Figure 1.8.


Figure 1.7. Indian railway map

Source: [15]

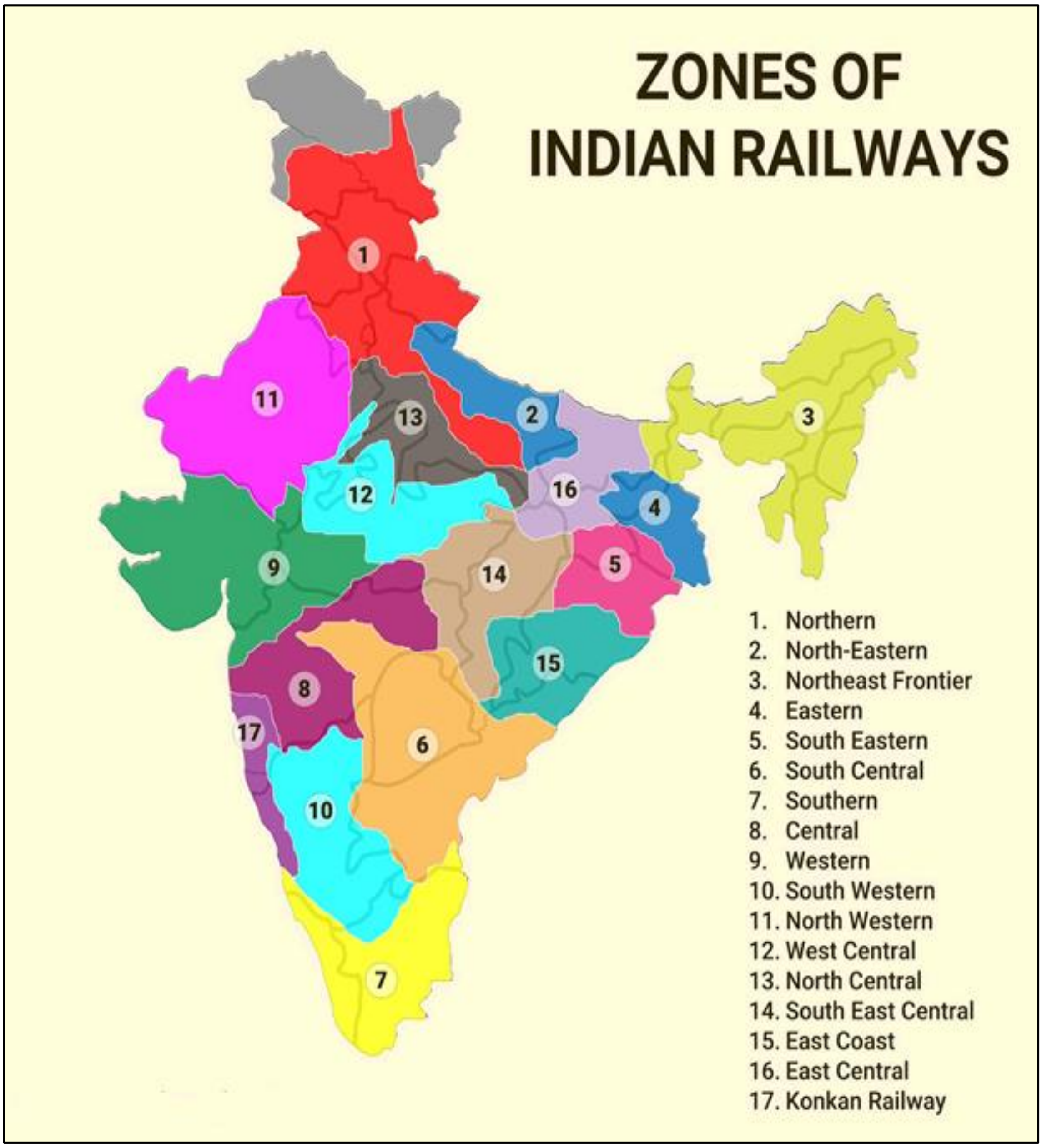


Figure 1.8. Zones of Indian railway

Source: [16]

### 1.6.3 Effects of Indian Railways' Expansion on Noise Pollution:

Most Indian cities now have severe noise pollution as a consequence of increased traffic, expansion of rail lines, and industry. The two railway-related disturbances that are most understood are train noise and vibration. The Indian railway route length has continuously increased since 1947. Figure 1.9 shows the route length of Indian railroads from financial year 2003 to 2022.

Railway noise can cause cardiovascular illness, disrupt sleep, and increase heart rate. People's mental effects are also factors, but they are difficult to quantify. These negative effects include a lack of focus, inefficiency, tension, and traffic accidents [1][17][18]. Traffic generated noise has been one of the fastest growing and most widespread type of environmental pollution, which contributes to the greatest environmental risk factors in mechanised areas.

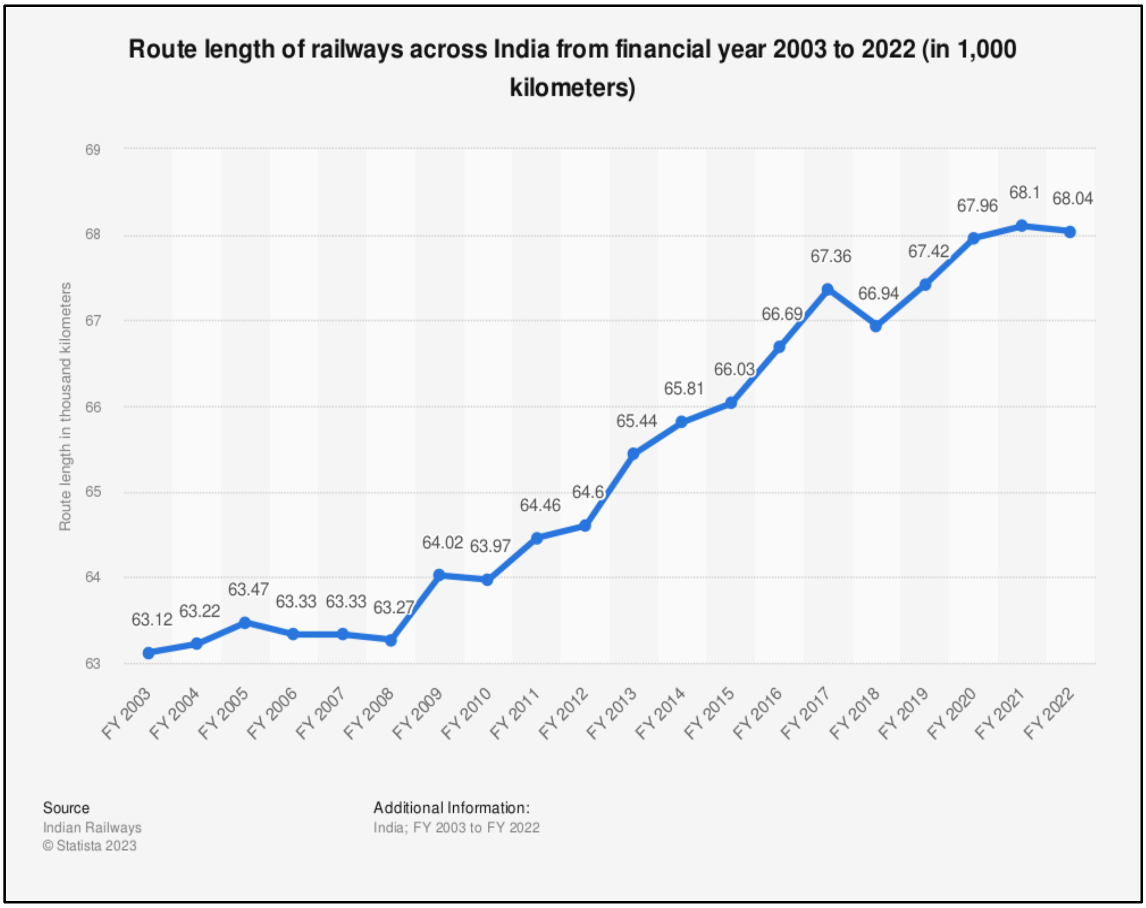


Figure 1.9. Route length expansion of Indian railway from 2003 to 2022

Source: [19]

## 1.7 OBJECTIVES OF THE STUDY

The research conducted for this thesis tries to quantify the railway noise pollution levels and their effects on public health in Delhi city. The study's objectives consist of the following:

- To assess the noise pollution in Delhi as a result of railway traffic.
- To develop noise maps for a better understanding of the noise pollution in areas near railway stations.
- To compare the obtained results with permissible standards of noise.
- To evaluate the noise exposure impact due to railway on the basis of measured noise levels and questionnaire survey.

One of the most cost-effective modes of transportation in India is railways. Noise pollution has developed into a serious problem as a consequence of the rapid expansion of railroads. Data has been collected at selected railway stations using sound level meter. To assess the effects of railway noise pollution on human health, a questionnaire-based survey was generated. The hotspots of noise pollution and its effects on the everyday life of people have been identified with the aid of data analysis from this survey.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTERNATIONAL STUDY

Nemec et al. [20] compared the predictive accuracy of two prediction methods of railway noise, "Schall 03" and "Methodical instructions for the calculation of sound pressure level from transport" (MPVHD), against measured noise levels in a residential area in Zvolen, Slovakia and found that the "Schall 03" method showed better agreement with the measured noise levels in comparison to the MPVHD method.

Tong et al. [21] conducted a comprehensive investigation of noise radiation mechanism and evaluated the situation based on national sound environment standards and measurement specifications. They also gathered data on noise pollution and its impact on residents of that area. Using acoustic environmental quality evaluation indices, they provided valuable data and references to enhance the sound environment of Binzhou railway bridge area and practical value for the related department of the Harbin City Hall.

Zea et al. [22] proposed a novel method for the bifurcation of contributions of rail and wheel noise in pass-by noise measurements of trains which employed sparse regularization of microphone array data to collectively estimate two noise contributions with few non-zero coefficients. Separation results were investigated with synthetic data and validated with experimental data against reference predictions for trains running at different speeds. The proposed method showed promising results and the potential for improvement of noise assessment accuracy of in railway environments.

Zannin et al. [23] assessed the noise pollution caused due to railway traffic in a large city of Latin America which involved measuring the noise levels produced by passing trains in residential areas with and without blowing of horn. Also, noise maps were created to illustrate the extent of noise pollution caused by train traffic, and residents were interviewed to evaluate their annoyance level due to railway noise. The noise levels generated by trains with horn blowing exceeded the municipal laws' equivalent sound pressure level limits established for daytime and night-time periods. Residents reported being affected by the noise, experienced irritation, headaches, poor concentration, and insomnia. The majority of surveyed residents believed that train noise could devalue their property.

Wosniacki et al. [24] proposed a framework for managing railway noise exposure in Brazil, which has increased due to the growth of rail freight transport. They used Strategic Noise Mapping (SNM) to measure background noise levels caused by road traffic and train pass-by noise, and suggested that level crossings elimination and reducing the sounding of train horns is more cost-effective than installing noise barriers. They also suggested several strategies for the management of rail noise exposure in Brazil, such as repurposing non-built-up areas next to railways, establishing acoustic performance criteria for new buildings, level crossings reduction and creation of an emission database regarding noise control at source by federal government and railway operators.

Demir et al. [25] discussed how railway transportation contributes to ambient noise, creating an unpleasant environment for those living near railway lines. They explored the process of developing a noise action plan for railway lines in Turkey, using case studies from Istanbul including a questionnaire assessing the impact of noise on residents, noise reduction strategies, and cost-effective methods for designing noise barriers. The aim was to provide decision-makers and practitioners with a roadmap to manage urban railway noise.

Bunn et al. [26] examined the railway noise pollution issue in Curitiba caused by incompatible railway routes with the city's urban density and proposed potential solutions to reduce noise levels and assessed the effectiveness of three alternatives: elimination of train horns, acoustic barrier installation, and rail track removal from urban perimeter. They also measured noise levels near major hospitals, large educational institution and found that simulated noise mitigation measures can reduce noise level by 2-12 dB (A) near facades of hospitals and school.

Gołębiewski et al. [27] discussed the generation of noise maps for urban areas, which included various origin of noise such as road traffic, trams, aircraft, industrial activities, and railways. The European Union (EU) recommends specific calculation methods for each noise source, but member states can use their own methods if they produce compatible results. They compared two railway noise propagation methods, one given by EU and second developed at Adam Mickiewicz University, Poznań. Both methods produced similar results, suggesting that university-developed method is a suitable alternative for estimating railway noise levels in urban areas.

Environmental noise has been categorised as hazardous pollution by the WHO because it can interrupt sleep and have negative psychosocial and physiological consequences on people's health. Health effect studies of noise have been extensively done in Europe, but have lagged in the United States. Kim et al. [18] collected the data from 2009 to 2011, and data analysis was conducted from 2010 to 2011. They developed indicators of noise-impact for irritation, disturbance of sleep based on exposure-response model and predicted the population that would be affected using a sound-propagation model. It was found that 109,967 people in Fulton County, Georgia were at high risk of irritation, and 19,621 people were at high risk of sleep disturbance.

Alain Muzet [28] highlighted the significance of noise as a physical ambient factor affecting health and well-being of humans, especially for people living in large cities. Unlike other environmental factors, noise is sensed and evaluated by everyone through the auditory system. He emphasised that sleep is crucial for human recovery, but noise can disrupt it, leading to potential negative effects on health and quality of life.

Pirrera et al. [29] discussed the detrimental noise impacts from road traffic on sleep and daytime function and explored the processing of noise in relation to sleep and provided insights into methodological considerations for studying noise and sleep. They also highlighted need for better assessment of noise's impact on various sleep variables and distinguished between measured and reported complaints. The study emphasized on significance of mediating factors such as noise sensitivity.

A. Lex Brown [30] discussed the prevalence of transportation noise as a significant urban environmental pollutant and presented three works, in which he was involved, that collectively made a significant contribution to the development of sound policies for managing the health effects of this pollutant. One of the works was an analysis of exposure, response, and exposure-response to road traffic noise in a densely populated city in Asia. The other being a systematic review of current evidence on interventions' effectiveness at controlling environmental noise in terms of health effects.

Children's brains development and their general health can be damaged by environmental stressors. Stansfeld et al. [31] carried out a cross-sectional analysis of 2844 children 9-10 years of age from 89 schools of Netherlands, Spain, and UK. The schools were located in regions near major airports, and children were chosen based on their exposure to aircraft and road traffic noise at school. Cognitive, health outcomes were calculated through standard tests and questionnaires, and socioeconomic information was obtained from parents through a questionnaire. They found that long term exposure to aircraft noise could damage children's cognitive development, particularly reading, and that schools with high aircraft noise levels are not a healthy environment for education.

Alkheder et al. [32] did a study predicting impact of a new railway system on transportation noise in Kuwait. They used Netherlands national calculation method and Predictor 5.04 software to estimate overall emission and analyze the acoustic perspective of areas near the rail line. Several isophone alternatives were produced and compared based on their acoustic quality, as determined by their surface lengths. The goal was to control the noise emitted from railways to mitigate critical annoyance and sleep disturbance in people's lives.

Sayed Abas Ali [33] assessed the impact of railway noise in Assiut City, the largest city in Upper Egypt, which is divided by a railway line. He measured railway noise levels, proposed measures to reduce noise, and assessed attitudes of people to railway noise. Results showed that noise exceeded permissible levels according to Egyptian noise standards, with $L_{dn}$ values of 80 dB or higher. Attitude survey revealed 51.3% of residents heard railway noise, and of those, 67% felt highly annoyed concluding that railway noise in Assiut negatively impacts public health and welfare.

The main factor affecting geometrical spreading for downward ray bending is air turbulence. Variations in rolling stock and train speed also happen. As a result, equivalent continuous A-weighted sound pressure level of railroad noise, $L_{AeqT}$, as well as sound exposure level, $L_{AE}$, vary from each train and day. As a result, one of key aspects of ambient noise is the mean, $L_{AeqT}$ [34].

Batko et al. [35] aimed to explore the use of nonparametric density function estimators in estimating standard uncertainty of environmental noise indices, such as $L_{DEN}$ and $L_N$. They found that the standard deviation of the mean, which is commonly used assuming normal distribution, was not suitable for noise measurement results. Therefore, non-standard methods such as kernel estimators were necessary. For the study, they performed continuous monitoring of traffic noise in Kraków between 2004 and 2005 to describe the origin, advantages, and construction method of kernel estimators.

Zannin et al. [36] collected data to understand the response of residents of Curitiba, a Brazilian city with over 1.6 million residents, to background noise by distributing surveys randomly to city residents, and 860 (86%) of the 1,000 distributed surveys were returned and evaluated.

Motor vehicle traffic and neighbours were identified as the primary sources of disturbing noise. Every respondent mentioned at least one of following as a source of noise: close neighbours, animals, sirens, civil construction, places of worship, nightclubs, toys, and home electric appliances. The primary responses were irritation (58%), trouble concentrating (42%), sleep problems (20%) and headache (20%).

Germany has been implementing noise abatement planning for over a decade, with more than 500 towns having prepared noise maps for different sources, developed action plans, and implemented noise mitigation measures. C. Popp [37] provided an overview of progress made at the local, regional, and national levels in noise abatement planning, including common mapping tools, action planning, and noise mitigation measures. He also discussed Germany's plans to implementing EU Directive on Assessment of Environmental Noise into national legislation and provided information to be considered in noise mapping and action planning.

Madrid introduced the SADMAM system and automated calibration of noise maps on December 29, 2003 which aimed at producing quick and affordable noise maps that accurately represented short-term and long-term noise, while accounting for realistic sound propagation. It utilized mobile noise monitoring terminals to create noise maps for smaller areas and to update them to reflect changes in traffic or special events. Manvell et al. [38] discussed various aspects of the system, integrating GPS, measurement data, and GIS, incorporating measurements into calculations, calibrating multiple sources in complex environment, plans for future development.

Mohammed Taleb Obaidat [39] utilized both field data and an analytical approach to create spatial noise maps of high traffic volume signalized intersections in Amman, Jordan, using Geographic Information Systems (GIS). During three peak traffic periods, noise data were collected using a portable sound level meter at 29 signalized intersections and their surrounding neighbourhoods. The GIS maps showed noise levels at different time periods and locations, with some intersections exceeding the acceptable standard and proved to be useful for city planning and environmental management, including monitoring changes in noise levels over time, identifying the highest noise disturbance locations and their times and assessing the acoustic climate of urban areas.

Tsai et al. [40] utilized noise maps to assess the spatial characteristics of environmental noise in Tainan, Taiwan by collecting data from 345 monitoring stations at different intervals, and spatial distributions were analysed using geographic information systems. It was revealed that highest and lowest average noise levels occurred during summer mornings and winter evenings. Violations of noise standards were found to be as high as 23 dB(A), mainly during summer evening, and over 90% of the Tainan City population was exposed to unacceptable noise.

Law et al. [41] discussed the improvements made in road traffic noise assessments and data presentation in Hong Kong. While 2D and 3D noise mapping was feasible over large areas, 2D noise mapping was insufficient for accurately representing the noise environment in Hong Kong's high-rise landscape. Therefore, they explained development of advanced 3D GIS tools and information technologies that integrated noise modeling, GIS, and computer graphics along with highlighting the efforts to disseminate noise information to the community and recent advancements in making this information available in a user-friendly manner through the internet.

Zhao et al. [42] introduced 3D road traffic noise mapping that made it possible to realistically map the noise environment of building and road models due to the surface meshes' ability to represent objects with complex geometry. To determine the basic noise level, the method relied on established road emission noise levels from field measurements rather than data from traffic. Quadrilateral mesh model of road was created using vertices captured from the original triangular mesh and an angle-scanning algorithm was also developed to model 3D noise propagation, accounting for obstructions between virtual receiver and road segment sources, providing verification and validation involving high-rise buildings, as well as examples of 3D noise mapping.

Cai et al. [43] developed day and night road traffic noise maps using GIS and GPS. The traffic volume was estimated from GPS data collected from floating cars, road and building attributes were automatically extracted from GIS. A regional noise calculation model was formulated, combining a single vehicle emission model with noise propagation model that considered urban traffic noise attenuation and the accuracy was verified by conducting traffic noise monitoring in different districts of Guangzhou. It was found that the average error was less than 2.0 dB.

To comply with the Environmental Noise Directive, major cities were required to produce noise maps generated by using proprietary software and required significant input data related to buildings, land use, transportation networks, and traffic. Bocher et al. [44] presented an open-source noise mapping tool that was fully integrated into a GIS compliant with Open Geospatial Consortium standards which simplified the formatting and collection of noise model input data, cartographic rendering, and linkage of output data with population data. An application of this tool was demonstrated for a French city, where the impact of road traffic on population exposure to noise levels was estimated with respect to both threshold values and level classes.

Licitra et al. [45] surveyed 119 residents between 35 and 70 years who had lived in Pisa, Italy for more than five years and selected measuring points based on the railway infrastructure's characteristics and the distribution of receptors. They compared conventional noise modelling to measured noise levels that included unconventional noise and calculated dose-effect relationships between %HA and railway noise, which were compared to existing literature. They found that traditional noise mapping based solely on ordinary train transits is insufficient for railway epidemiological studies and highlighted the role of vibrations in increasing disturbance.

Uddin et al. [46] measured impact of rail noise on passengers and residents near railway stations in Dhaka, Mymensingh, and Sylhet regions of Bangladesh using a digital sound level meter , collected traffic volume and train frequency data, conducted a questionnaire survey, and carried out field observations. They found that the sound produced during train arrivals and departures exceeded the standard noise level of 60dB, reaching as high as (90-1) WdB. They also identified significant health impacts of noise on passengers, employees, and staff of the railway stations.

Griefahn et al. [47] compared effects of road, rail, aircraft noise on sleep quality and assessed applicability of equivalent noise in measuring sleep disturbances. 16 women and 16 men aged 19 to 28 slept in a laboratory for three weeks, with 8 sleeping in quiet and 24 exposed to noise with permuted changes. Most physiological variables showed similar reactions to all noise types, but rail noise had the most severe impact on sleep parameters. Equivalent noise level proved to be useful in predicting subjectively evaluated sleep quality but not sleep disturbances.

Rylander [48] investigated the relationship between exposure to external noise and physiological stress reaction on the basis of properties of the hearing system. It was found that environmental noises had the potential to cause stress reactions, which could have health impacts, including raised blood pressure. The results suggested that extended noise exposure in the workplace and environment caused stress reactions, and the level of irritation was related to stress.

Lim et al. [49] investigated relationship between railway noise levels and annoyance in 18 areas along railway line in Korea where railway noise was measured using portable sound-level meters, and social surveys administered to a total of 726 respondents between 18 to 70 years people within 50m of measurement sites. They assumed that annoyance caused by railway noise would be similar to those in Japan. It was found that the distance between railways and houses was the most important factor contributing to the difference in annoyance response between Korea and Europe.

Smith et al. [50] examined effects of ground-borne train noise on sleep physiology and quality in a laboratory setting where 23 healthy participants were subjected to noise exposure over five nights at maximum values of 35, 40, and 45 dB. The results showed that nights with 45 dB noise considerably disrupted sleep, with only minor effects whereas at 35 dB and above, noise with higher amplitude frequencies above 100 Hz increased heart rate and arousal probability. The study backed the adoption of the Swedish recommendation value of 35 dB maximum noise indoors to guard against poor sleep outcomes caused by ground-borne railway noise.

The NORAH research programme covered quality of life, irritation, and numerous health outcomes in its thorough investigation of the long-term impacts of transport noise in Europe. About 10,000 people in the Rhine-Main district were polled as part of the irritation module about the consequences of transport noise, such as aeroplane and noise from road, aircraft and railway. Wothge et al. [51] found that participants' assessments of overall noise annoyance were predominantly influenced by the source of noise they found to be more unpleasant (in this example, aircraft noise), with average sound pressure level of two sources also being significant but to a lesser degree.

A thorough daytime acoustic map of the city of Pamplona, Spain, was generated as an outcome of a two-year long intensive noise survey. This survey was used to examine the link between measured noise levels and community's level of noise displeasure [52].

The relationship between irritation and disruptions brought on by road noise and occurrence of ischemic heart disease was investigated by Babisch et al. [53], in a prospective cohort study involving 3950 middle-aged males. It was found that road traffic noise annoyance and disturbance are linked to a higher prevalence of IHD and a major effect modifier of relationship between noise irritation and health outcomes is disease prevalence.

De Kluizenaar et al. [54] determined whether exposure to residential traffic noise has any effect on the prevalence of hypertension. A large random sample of Groningen City residents (N=40,856) and subsample from Prevention of Renal and Vascular End-Stage Disease [PREVEND] study cohort (N=8592) were used for cross-sectional analysis. It was found that people between the ages of 45 and 55 may develop hypertension as a result of noise exposure from traffic and correlations seemed to be more potent at greater noise levels.

Murphy et al. [55] determined how much road traffic noise was being exposed to by locals and workers in central Dublin, Ireland. Calculating and estimating noise exposure levels required the use of a Geographical Information System (GIS) and the Harmonoise calculating method. They found that noise exposure in Dublin was high, particularly at night, and that traffic management strategies may potentially lower noise exposure levels, provided that the effects on residential populations were carefully considered.

Anne Vernez Moudon [56] emphasised the necessity to take into account the possible health consequences of environmental noise on people because continuous exposure to loud sounds may have a number of adverse impacts and increased automotive traffic and machinery use had caused ambient noise levels in inhabited places to steadily grow. It was observed that decreasing noise at the source might need revised road standards and lower permitted engine noise levels, and that policies and actions would require detailed data on real ambient noise levels.

Stansfeld et al. [57] assessed whether reduction in road traffic noise exposure, resulting from opening of a bypass, could lead to improvement in quality of life, reduction in annoyance, common mental disorder among residents aged 16 to 90 years in 3 small towns in North Wales, UK. The results indicated that the small reduction in noise exposure, ranging from 2-4 dB (A), was not associated with improvement in quality of life or reductions in common mental disorder. However, it was difficult to conclude whether a causal relationship existed between noise exposure and common mental disorder.

Seidler et al. [58] investigated the risk-exposure relationship between myocardial infarction and noise from aeroplanes, cars, and trains. Compared to 834,734 control people, the study group included 19,632 patients, diagnosed with myocardial infarction in Germany between 2006 and 2010. They found that there is a very little risk of myocardial infarction related with exposure to levels of traffic noise and emphasised how crucial it is to prevent traffic noise effectively to lower the risk of myocardial infarction.

Ko et al. [59] analyzed transportation noise in Youngdeungpo-gu area of Seoul Metropolitan City, Republic of Korea by noise prediction models. They estimated number of people exposed to transportation noise, including those vulnerable to serious annoyance, sleep disturbance and found that majority of the Youngdeungpo-gu area experienced nighttime transportation noise levels exceeding WHO recommendations, and up to 80% of the people in study area were exposed to transportation noise levels greater than 40 dB[A] during nighttime.

The EU Environmental Noise Directive (END) has been implemented throughout Member States, and Murphy et al. [60], examined the methodological issues and policy implications which are centred on two important thematic concerns related to Directive: (1) computation method, (2) mapping method. Regarding (1), they focused in particular on how various calculation techniques affected the outcomes of noise prediction and value of the EU noise indicator $L_{den}$ and its implications for comparability of noise data across EU nations and for (2), the focus was on identifying the problems that affected noise mapping, measuring exposure, planning noise action, disseminating findings of noise mapping to broader public.

Sakhvidi et al. [61] conducted systematic review and meta-analysis of available data on relationship between chronic exposure to noise from transport and workplaces and diabetes mellitus. Following MOOSE recommendations, relevant databases were looked up for evidence up until September 13th, 2017 and Newcastle-Ottawa Scale was used to rate the studies' quality, and random effects meta-analysis was also conducted to come up with combined estimates of the prevalence of diabetes mellitus/5 dB increase in noise exposure. Cochran's Q test to assess heterogeneity, I2 statistic to quantify it and for finding the causes of heterogeneity, meta-regressions were used. It was found that exposure to air and road traffic noise may raise the chance of developing type 2 diabetes.

More and more people are becoming aware of how noise affects health as well as its role as an environmental problem. Beyond its impact on the auditory system, noise annoyed people, interrupted their sleep, and decreased their cognitive function and it was also linked to an elevated risk of arterial hypertension, myocardial infarction, and stroke, according to findings from epidemiologic studies. Münzel et al. [62] found that that nighttime noise, in particular, disrupted sleep patterns, increased levels of stress hormones and oxidative stress, as well as vegetative arousals (such as elevated blood pressure and heart rates), which lead to endothelial dysfunction and arterial hypertension.

Basner at al. [63] examined the molecular processes that caused hair cells and nerve damage brought on by noise, and made the optimistic prediction that both preventative and therapeutic medications may soon be made available. The detrimental noise effect on sleep, cognition, hypertension, and cardiovascular disease was also discussed which highlighted the significance of efficient noise control and mitigation measures for health of public.

Considerable effects of background noise and air pollution as environmental risk factors for chronic non-communicable diseases, including cardio-metabolic disease, were underlined by Münzel et al. [64]. They discussed the pathophysiological pathways for noise and air pollution-mediated consequences including low-grade inflammation, oxidative stress, vascular dysfunction, unbalanced autonomic nervous system.

To find observational epidemiological studies that looked at relationship between noise and risk of hypertension, Fu et al. [65] searched the literature from the time the databases first existed until December 2016 and combined the studies using a random effects model. They also performed a dose-response meta-analysis to look into any possible dose-response relationships. It was found that there is strong dose-response relationship between noise exposures, hypertension and integrated epidemiological evidence supports this theory.

Roswall et al. [66] investigated the link between residential traffic noise and the occurrence of colorectal cancer by estimating the residential addresses' exposure to traffic noise of 51,283 Danes in Diet, Cancer, and Health Cohort from 1987-2012. They examined the relationship between residential traffic noise and incidence of all types of colorectal cancer as well as its subtypes using Cox proportional hazard models and computed Crude hazard ratios (HRs) and found that prolonged exposure to the noise of residential traffic may raise your chance of developing colon cancer, particularly distal colon cancer.

Oftedal et al. [67] examined the associations between obesity markers and noise from traffic and also the moderating effects of noise sensitivity, noise irritation, and sleep disruptions. Among extremely noise sensitive women in an adult urban Scandinavian population, road traffic noise was strongly correlated with obesity markers. Men who had bedrooms facing a street exhibited stronger connections, corresponding to a population with more precisely assigned exposure.

## 2.2 INDIAN STUDY

According to Ali et al. [68], rolling noise, aerodynamic noise, traction noise, and warning signal noise are main sources of rail noise, which is second biggest source of noise pollution. At Bolpur station, Prantik station, and outside the station, where the train passed at full speed at distances of 10m and 20m, they measured the noise levels produced by railway activity and found that railway activities generated a lot of noise, particularly when a train was passing and express trains and other high-speed trains made greater noise than passenger trains.

To determine the degree of station noise, Kanakasabai et al. [69] conducted a research at the Southern Railway junctions in Tiruchirapalli, Villupuram, and Chennai Central. SVAN 943A (Poland make) device was used to record observations at vantage points and it was revealed that the equivalent continuous sound level ($L_{eq}$) near the waiting room ranged from 52 to 56 dB (A) on several days. The CPCB's residential zone noise level category was exceeded by average sound pressure level ($L_p$) of 52 to 57 dB (A) in important platforms and drivers' lavatory.

Kolhapur city's continuous noise monitoring was done by Mangalekar et al. [6] in December 2011 where 6 locations were selected and divided into four zones: the silent zone, the business zone, and the industrial zone and the average noise levels were determined to be 74.28, 65.52, 58.88 and 50.02 dB (A) in industrial, commercial, residential, and silent sectors, respectively. They observed that when the number of vehicles and transport infrastructure increased, there was an increased pressure of noise at all places surpassing the CPCB established standards at all sites.

Noise pollution has a well-known negative influence on a variety of functions, including sleep, communication, annoyance, hearing loss, cardiovascular issues, and task performance and in order to regulate and control sources that generate and produce noise, the Indian government put into effect "The Noise Pollution (Regulation and Control) Rules, 2000". Kolhapur city's noise had increased as a result of the increased traffic and population. Therefore, Patil et al. [70] performed a study for determining the noise levels in Kolhapur at various locations, times, and environmental factors.

Rapid urbanisation and population increase have caused major environmental problems, such as noise pollution, in Amravati region of Vidarbha. Using a digital sound metre and information on traffic volume, Tiwari et al. [71] conducted a research to track the noise pollution brought on by railway and vehicle traffic at the significant crossroads of Rajapeth. They examined the fluctuation in noise levels during peak times and graphically displayed the findings.

The influence of ground-borne vibration on people was discussed by Shiva et al. [72], in relation to railway bridge structures where rough contact area between wheel and rail was identified as primary source of noise, vibration emissions from railways, with an estimated contribution to ambient noise from rails of roughly 1.7%. While admitting the limited knowledge on noise emission from bridges, they provided recent results on sources and reduction of noise and vibration in rail bridges.

Muralidharan et al. [73] examined how Mumbai kids were affected by train noise pollution in terms of their ability to sleep and function academically where based on how close they lived to the train station, 20 volunteers were chosen and split into control and experimental groups. It was found that the experimental group had an irregular sleep pattern, which may have stressed them out and harmed their ability to work and succeed in school.

Das et al. [74] examined the sources, spatial mapping, and diurnal cycle of noise in the meso-level town of English Bazar Municipality (EBM) in order to determine the town's most noise-sensitive areas, calculate the degree of noise irritation experienced by various groups, and identify the most vulnerable group. They found that the main sources of noise were traffic and construction activities, with office hours being the noisiest. The most sensitive location to noise exposure was identified as a particular region that made up 9.94% of the entire study area.

Using a Sound Level Metre (SLM), Joshi et al. [75] mapped the various noise levels in Mumbai and compared them to the optimal noise levels recommended by guidelines and the findings, which were displayed in cartographic maps, showed that the noise levels, which ranged from 70 to 80 dB on average across the city, were higher.

Garg et al. [76] did a thorough analysis of the noise mapping technique, exploring the advantages of noise mapping and notes the difficulties in creating noise maps for large metropolitan areas in India. They also discussed the problems during production of strategic noise maps, along with input parameter, methodology, sampling and interpolation techniques used along with suggesting national policy framework for noise mapping and control in India.

In developing nations like India, where traffic noise characteristics fluctuate due to heterogeneous traffic composition, road geometrical features, honking conditions, and building density, Kalaiselvi and Ramachandraiah [77] conducted a study on traffic noise mapping where the propagation and dispersion of traffic noise were examined using field measurements of $L_{10}$, $L_{50}$, $L_{90}$, and $L_{eq}$ and noise mapping parameters such as $L_d$, $L_N$, and $L_{den}$. They analysed the limited application of current prediction models for heterogeneity and offered a different multiple regression model for noise mapping under heterogeneous traffic situations.

Wazir Alam [78] used a Sound Level Metre (SLM) to measure the noise level and Geographic Information System to map noise pollution at several places throughout the city of Guwahati. He found that the noise level in Guwahati was rising and becoming harmful in a number of areas, exceeding the CPCB and BIS limits with highest noise levels seen in commercial places (80–90 dB (A)), compared to residential regions and quiet zones (65–75 dB (A)).

For comprehending the noise pollution issue in metropolitan areas brought on by road traffic, Akhtar et al. [79] mapped and monitored several previously chosen places in New Delhi city, India. $L_{eq}$, noise climate, and noise pollution levels were calculated and displayed in cartographic maps using noise measurements and sound observation surveys thereby showing that noise levels at all the previously chosen places were higher than allowed, with Ashram recording the worst noise levels with $L_{eq}$ values ranging from 67.4 dB (A) to 82.3 dB (A).

Mishra et al. [80] used GIS to map out spatial distribution of traffic noise levels in Delhi city and analyse it and found that ambient noise levels surpassed the CPCB-recommended limits and were inversely correlated with the number of vehicles at ten separate locations where field measurements were made. With only a minor percentage variation from measured values, the produced noise maps offered precise forecasts and abled the authorities to identify noise hotspots.

The community of smartphone users was utilised by Kumar et al. [81] to propose a novel method supported by a fuzzy logic-based classification of noise for monitoring noise pollution caused by transportation which employed a client application to gather and process noise data, which was then transmitted to a server and shared as visual noise levels on Google® Maps. Results from several locations in India's northern region revealed that noise levels were typically greater than established criteria.

One of the major concerns that affects how urban areas are described as having noise pollution from traffic has been recognised by Sonaviya et al. [82] using various GIS noise mapping models to predict noise levels. The output findings from computer noise models were added as data input and contour maps for noise were created using the interpolation techniques.

Singh and Davar [83] concentrated on the issue of noise pollution and how it affected people's lives in Delhi State by conducting a cross-sectional survey and found that loudspeakers and autos were the main causes of noise pollution, with religious noise hurting females slightly more than males. Noise pollution disrupted communication, kept people awake, decreased productivity, and had extreme impacts including deafness and mental collapse.

Prasad et al. [84] used a noise dosimeter to measure the levels of noise pollution caused by train movement at various points along a railway track in Mysuru city and discovered that noise from railway traffic can have a negative impact on the neighbourhood, particularly in areas with rapid train movement.

# CHAPTER 3

# MATERIALS AND METHODOLODY

## 3.1 STUDY AREA

The National Capital Territory of Delhi, that comprises New Delhi, the country's capital, is the subject region for this research project. Since Delhi spans Yamuna River, primarily on its western or right bank, it shares borders with states of Haryana in other two directions as well as state of Uttar Pradesh in east. According to 2011 census, Delhi city had a population greater than 11 million, whereas NCT had a population greater than 16.8 million. It spans a surface area of 1,484 $km^2$.

One of the best ways of transportation in India is the railway. There are a total of 47 railway stations in Delhi, of which 5 are prominent ones: New Delhi Railway Station, Old Delhi Railway Station, Hazrat Nizamuddin Railway Station, Anand Vihar Railway Station, and Delhi Sarai Rohilla. New Delhi railway station, located between Ajmeri Gate and Paharganj, is one of the busiest in India, serving 360,000 passengers on average each day. In addition to this, residents who live close to railways are highly vulnerable to noise pollution.

To carry out the study in Delhi, two distinct railway stations were chosen (Figure 3.1) namely Delhi Sarai Rohilla and Sabzi Mandi railway station. Locations for noise impact study were chosen based on population density in areas around the specific train station and mainly according to their land use patterns i.e., residential zones. Every location employed a GIS tool to comprehend the spatial distribution of noise from railroads. Table 3.1 lists general characteristics of chosen study locations.

Table 3.1. General characteristics of the study locations

| S.No. | Location | Type of Zones | Latitude | Longitude |
|---|---|---|---|---|
| 1. | Delhi Sarai Rohilla | Residential | 28.6628° N | 77.1852° E |
| 2. | Sabzi Mandi | Residential | 28.6685° N | 77.2004° E |

Table 3.2. Schedule of noise level data collection

| S.No. | Station Name | Station Code | Date of Survey |
|---|---|---|---|
| 1. | Delhi Sarai Rohilla | DEE | 24-05-2023 & 25-05-2023 |
| 2. | Sabzi Mandi | SZM | 27-05-2023 & 28-05-2023 |

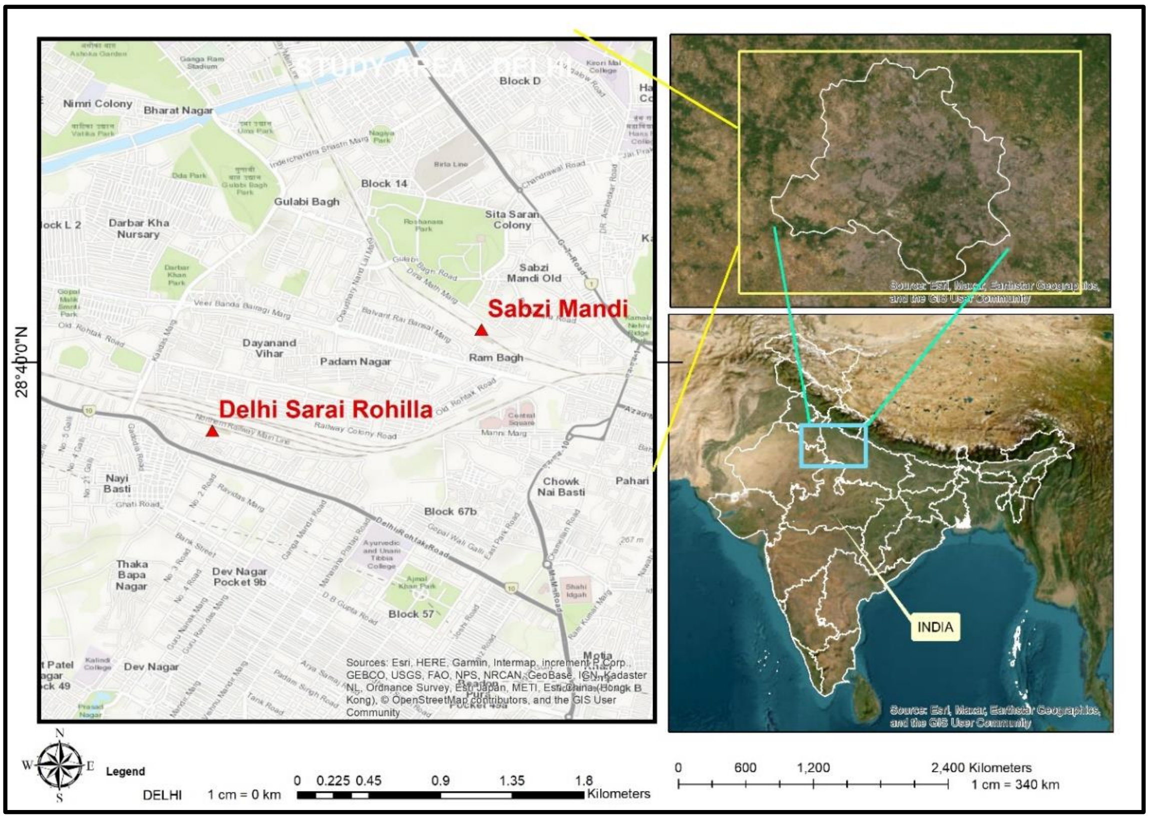


Figure 3.1. Selected Locations of the Study Area

## 3.2 TOOLS AND TECHNIQUES

### 3.2.1 Sound Level Meter

Not every frequency of sound is as sensitive to human ear. It is easier to hear sounds with a few thousand hertz than low frequency sounds. The sound detected by a microphone is filtered using an A-weighting filter to take this sensitivity variation into account. Noise levels are measured and tracked using sound/noise level metres. They abide by the International Electro-technical Commission's (IEC) standards. The following categories for sound level metres are recognised by international standards:

a) Class 0: Laboratory reference
b) Class 1: Precision
c) Class 2: Field use
d) Class 3: Survey

The CESVA SC 310 (Figure 3.2), a versatile, easy-to-use type 1 integrated sound level metre that can measure all essential elements for acoustic evaluation was utilized for measuring Sound Pressure Level (SPL). It is capable of measuring every function required to determine the fundamental indices for the acoustic assessment, including S, F, I function, equivalent continuous level, percentiles, impulsiveness indices, peak level, sound exposure level, short functions, etc. and with all frequency weightings as a sound level metre as well as a real-time spectrum analyser for 1/3-octave and entire octave bands using Type 1 filters. Due to its modularity, SC310 can be upgraded with additional measurement options like 1/3-octave band spectrum analysis, FFT analysis, and reverberation time measurement. Data on noise monitoring were gathered at two distinct Delhi railway stations. Because the ambient noise level varied more than usual during the study period, $L_{eq}$, the noise framework, was used to calculate noise level. The information was gathered for approaching, passing, and departing trains.


Figure 3.2. Sound Level Meter

### 3.2.2 Noise mapping using GIS

On a noise map, sound pressure levels of a given geographic area are visually depicted over a given period of time. A GIS database management system is used for gathering, storing, managing, and regulating noise data. The accuracy of noise maps is also enhanced by the integration of GIS with mathematical modelling and spatial data analysis. The results are made more precise by data simplification, calculation algorithms, and interpolation techniques. GIS is therefore becoming more and more significant in the examination of potential effects of noise pollution. Figure 3.3 depicts the GIS-based structure for generating noise maps.

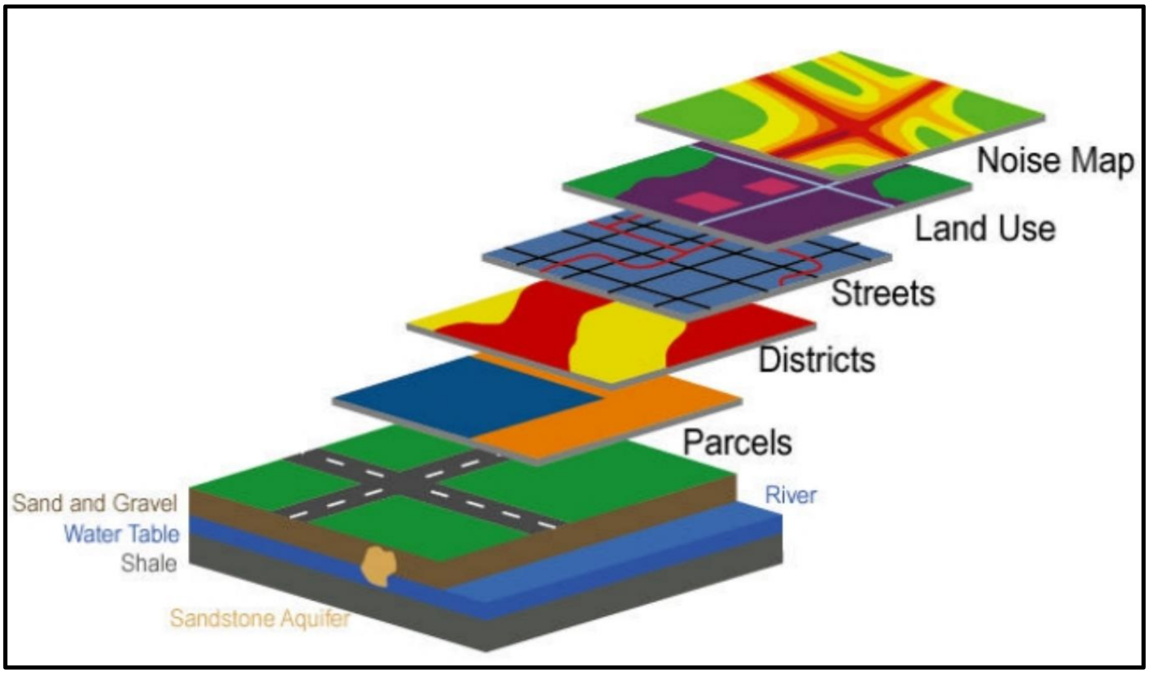


Figure 3.3. GIS-based framework for Noise Mapping

Source: [85]

Processes involving noise mapping can take advantage of various features and improvements provided by the robust GIS programme ArcGIS version 10.7.1 as it is allows us to produce precise and thorough noise maps. It can handle big datasets, has improved 3D visualisation tools, increased mapping capabilities, and better data management facilities. ArcGIS database management system has been used to gather, store, manage, and control noise data. The chosen site locations are given the coordinates after the shape file for the Delhi location has been created. Then, GIS interpolation methods are employed to construct noise contours.

### 3.3 MONITORING OF NOISE AT VARIOUS LOCATIONS

#### 3.3.1 Sarai Rohilla Railway Station

About 4 kilometres (2.5 miles) separate Sarai Rohilla railway station (station code: DEE) from the old Delhi railway junction. The Northern Railway zone's Delhi Division is in charge of its administration. At this station, trains from Delhi to Gujarat, Rajasthan, Punjab, and Haryana have stoppage. It is the starting point for more than twenty trains, including AC and Duronto trains. Residential land usage is visible in Delhi Sarai Rohilla Railway Station's immediate vicinity. Approximately 1 km from the railway station is the closest metro stop, "Shastri Nagar" located on the Red Line.

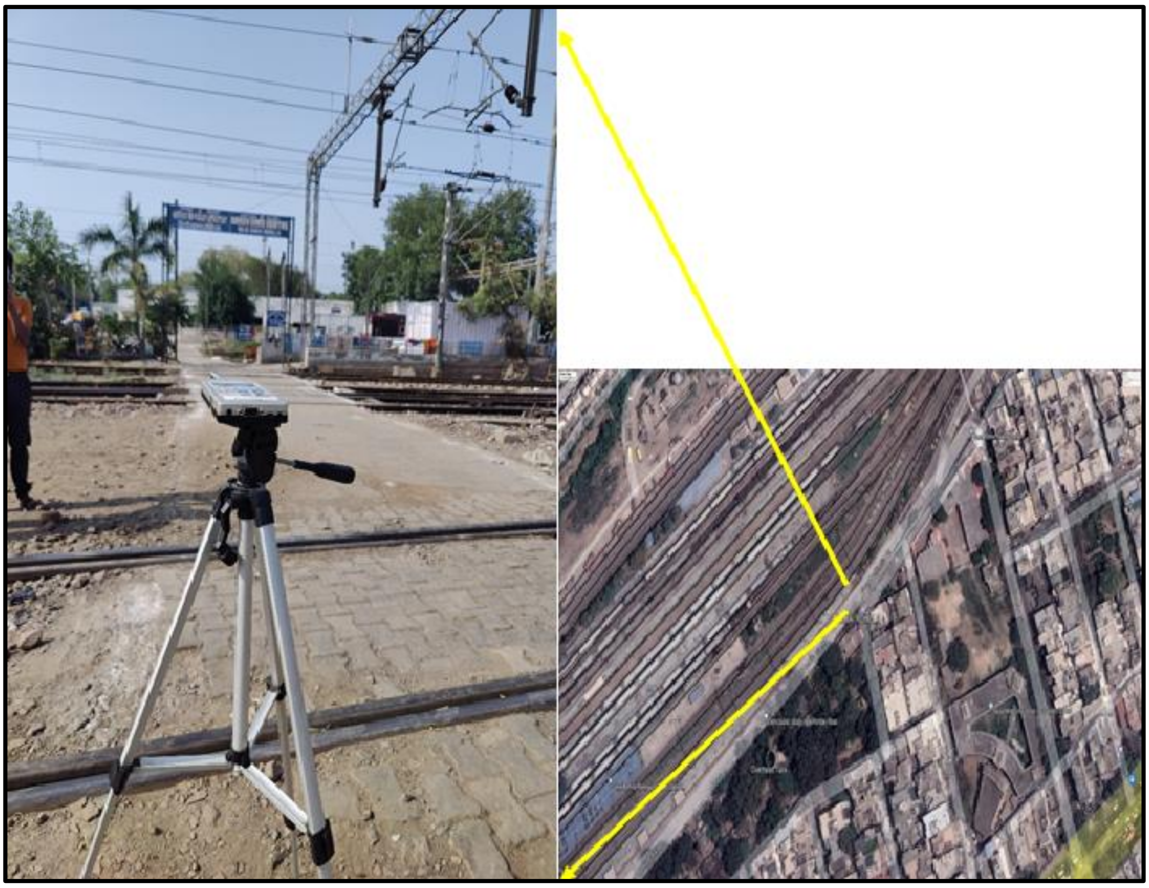

**Figure 3.4**. Noise monitoring at Sarai Rohilla Railway Station

#### 3.3.2 Sabzi Mandi Railway Station

In NCT of Delhi's North East neighbourhood is the Sabzi Mandi Railway Station. Sabzi Mandi's station code name is "SZM." The station is frequented by trains on a regular basis, including express trains and cargo/parcel trains, with the latter being particularly important for the transportation of perishable commodities. The Sabzi Mandi Railway Station is located in the residential sector of Delhi, more precisely in the Azad Market neighbourhood, according to the city's land use pattern. There are over 132 trains that pass through the Sabzi Mandi (SZM) junction each day.

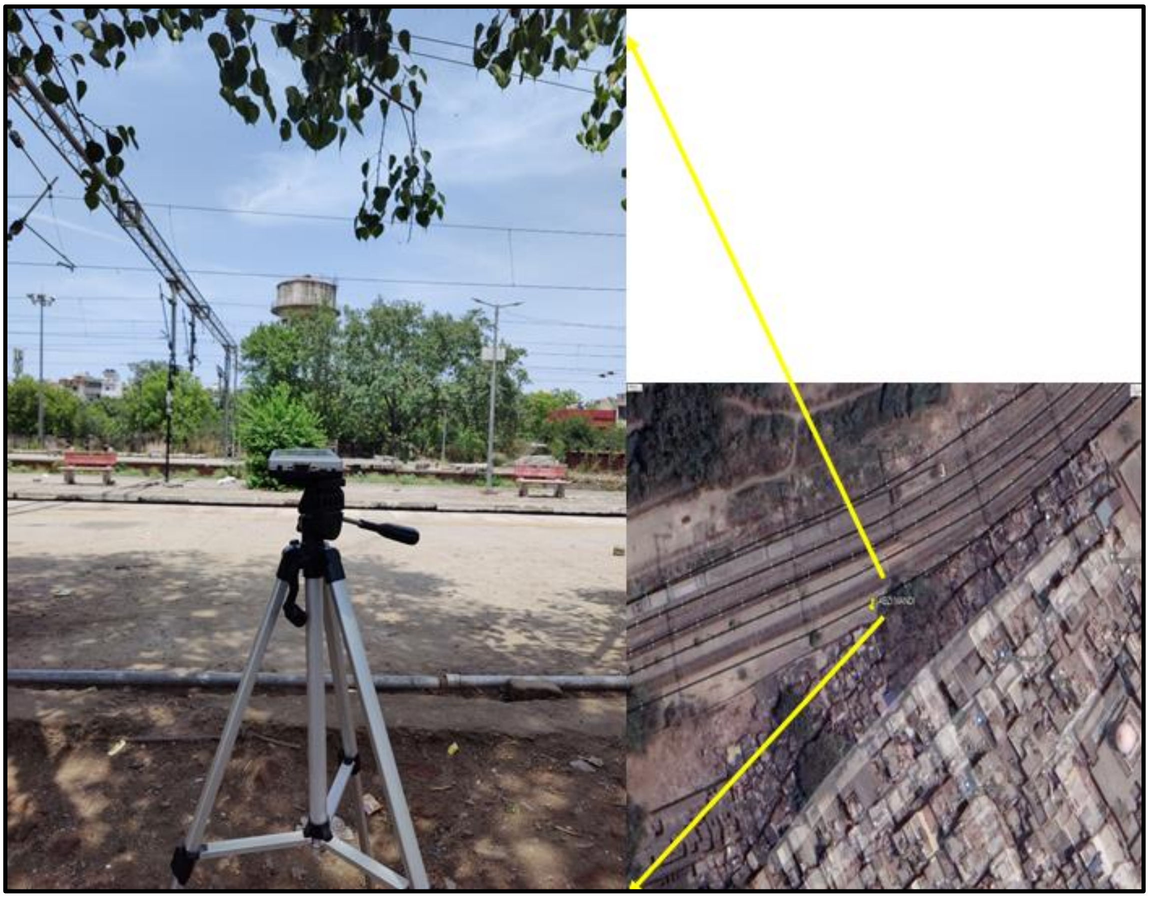

**Figure 3. 5.** Noise monitoring at Sabzi Mandi Railway Station

### 3.4 QUESTIONNAIRE SURVEY

To analyse railway traffic noise effects on health of people, a questionnaire was created to elicit responses from people. There are two sections to it. Personal information, including age, sex, contact information, educational background, and distance from the railway, is covered in the survey's first portion. The second portion of questionnaire includes questions about sources of noise pollution, length of time spent in current residence, knowledge of noise pollution, etc. and questions about health issues such disturbance, headache, sleep disturbance, irritability, blood pressure, and stress. This survey's questions are framed in terms of the psychological and physiological effects on people. All participants were asked how much noise bothered, irritated, or bothered them when they were at home, categorising their responses as “not at all”, “slightly”, “moderately”, “very” and “extremely”. They were also requested rate the disturbance or annoyance caused to them by the railway noise on a scale of 0 to 10. This survey would be useful in understanding and assessing the human health status in relation to rail traffic in the Delhi region.

### 3.5 EFFECTS OF NOISE EXPOSURE

Noise exposure has an ongoing negative impact on people's health as well as the health of entire communities. Numerous locations, including the house, the office, aeroplanes, factories, and transportation, can produce excessive noise. Exposure may have harmful impacts on one's health, such as irritability, disturbed sleep, communication problems, poor academic performance, higher levels of stress, and altered social behaviour. Long term exposure to noise has been associated with an increased risk of hearing loss, hypertension (high blood pressure), and ischemic heart disease. The possibility of adverse health effects is influenced by the duration (short or long term), intensity (decibels), and frequency of noise exposure [86]. In the current study, detrimental effects to ambient noise exposure, which are mentioned in Table 3.3 below, are contrasted with the average variation of $L_{eq}$ values. The data in the table was derived from the 1994 Health Council report of committee on Noise and Health, an international division of the Health Council of the Netherlands [8].

Table 3.3. Examples of noise-exposure related effects

| EFFECT | EXPOSURE TYPE | MEASURE* | dB(A) | LOCATION OF ASSESSMENT |
|---|---|---|---|---|
| Hypertension | Environmental | $L_{dn}$ | 70 | Outdoors |
| Ischemic heart disease | Environmental | $L_{dn}$ | 70 | Outdoors |
| Annoyance | Environmental | $L_{dn}$ | 42# | Outdoors |
| Hearing Impairment | Environmental | $L_{Aeq,24h}$ | 70 | Indoors |

| | | | | |
|---|---|---|---|---|
| Disturbance of Sleep pattern | Sleep | $L_{Aeq,8hr}$ | <60 | Outdoors |
| Sleep Quality | Sleep | $L_{Aeq,8hr}$ | 40 | Outdoors |
| Mood Next Day (sleep disturbance) | Sleep | $L_{Aeq,8hr}$ | <60 | Outdoors |

*Noise levels in this table are represented as equivalent sound level ($L_{Aeq}$), monitored over time and the day-night level ($L_{dn}$), which compares sound level over a 24-hour period with sound levels at night.

#for the environmental impulse noise, observation threshold for percentage of highly annoyed people is around 12 dB (A) lower.

### 3.6 DATA COLLECTION

There are two methods for measuring noise levels: static noise measurement and ear level noise measurement. When measuring static noise, sound level meter installed on a tripod that is nearly 1.2 metres above ground, continuously records the SPL of the surrounding area. The SLM is held about between 0.1 and 0.2 metres away from the subject's ear canal when measuring ear level noise. Measurements of static noise were chosen for this study.

Data on noise levels were gathered using a Sound Level Metre from 2 different Delhi railway stations. In May 2023, data collecting took place over two days at each railway station from 10:00 pm in night to 6:00 am in morning. Because ambient noise level varies throughout the study period, the $L_{eq}$ noise framework was utilised to calculate the noise level. A total of 30+ pieces of information are gathered from each site location for the questionnaire survey. Data were collected at random, and any that included no information were further discarded from the study.

The noise impacts can then be identified by merging the outcomes from two sets of data. Size and level of detail of the data affect the work's accuracy.

### 3.7 CALCULATION

In the research process, the study region is chosen or identified, noise levels are measured, noise maps are created, and the noise maps are projected using a geographic information system (GIS). $L_{eq}$, which stands for equivalent continuous sound level and denotes exposure to sound levels throughout time, was used to indicate noise levels that sound level meter had detected. The obtained $L_{eq}$ at each time interval was then averaged to get overall $L_{eq}$ using the following equations,

$$L_{eq} = 10\,log_{10}\left\{\frac{1}{T}\int_{t_1}^{t_2}\left(\frac{P_{rms}(t)}{P_{ref}}\right)^2 dt\right\} \quad \text{Eq.1}$$

$$Average\ L_{eq} = 10 * (\frac{1}{n}(10^{(\frac{Leq_1}{10})} + 10^{(\frac{Leq_2}{10})} + \cdots + 10^{(\frac{Leq_n}{10})})) \quad \text{Eq.2}$$

where,

$L_{eq}$ = Equivalent continuous linear weighted sound pressure level

T = Time interval

$P_{rms}$ = Sound pressure (in Pascal)

$P_{ref}$ = Reference sound pressure (20 μPascal)

n = Number of t duration measurements

The gathered information is then contrasted with permitted limits established by Central Pollution Control Board, Community Noise Guidelines of World Health Organisation (WHO), and 1994 Health Council report of committee on Noise and Health in the Netherlands. The inverse distance-weighted (IDW) approach of spatial interpolation in ArcGIS is used to analyse the data. After that, the results are used to produce noise maps for Delhi using ArcGIS.

## 3.8 FRAMEWORK METHODOLOGY

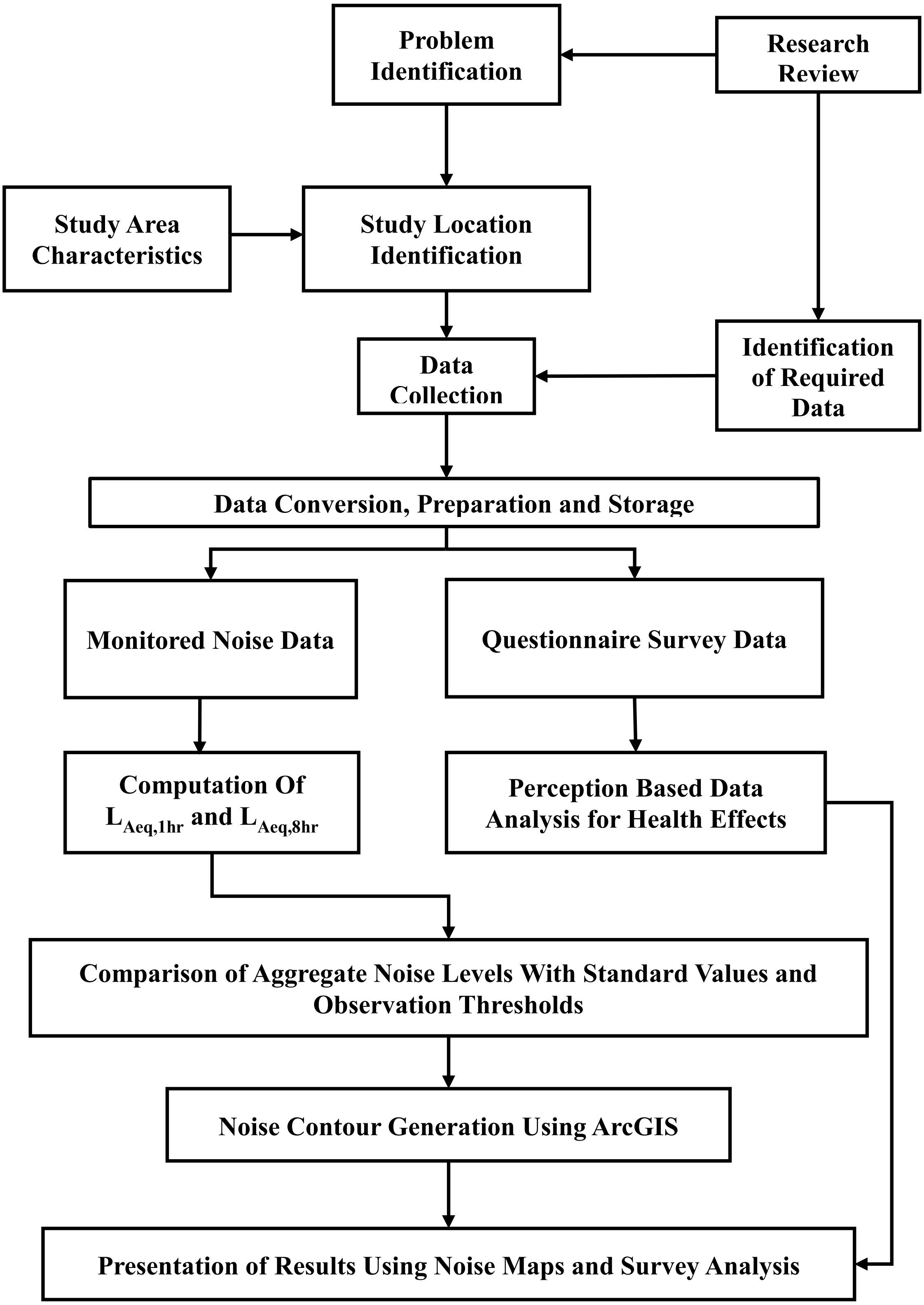


Figure 3.6. Framework Methodology

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 TEMPORAL DISTRIBUTION OF NOISE LEVEL

Noise levels were monitored at both railway stations for 2 consecutive days and obtained results are depicted in the form of temporal distribution along with the comparison against the night time CPCB standard limits for ambient noise.

### 4.1.1 Temporal distribution of Noise at Sarai Rohilla Railway Station

At Sarai Rohilla Railway Station, average noise levels varied from 63.8 to 77.6 dB (A) during the study period as shown in the Figure 4.1. The monitored noise level was 42 to 73% higher than the CPCB ambient noise limit for night time in a residential zone which is 45 dB (A) at the location.

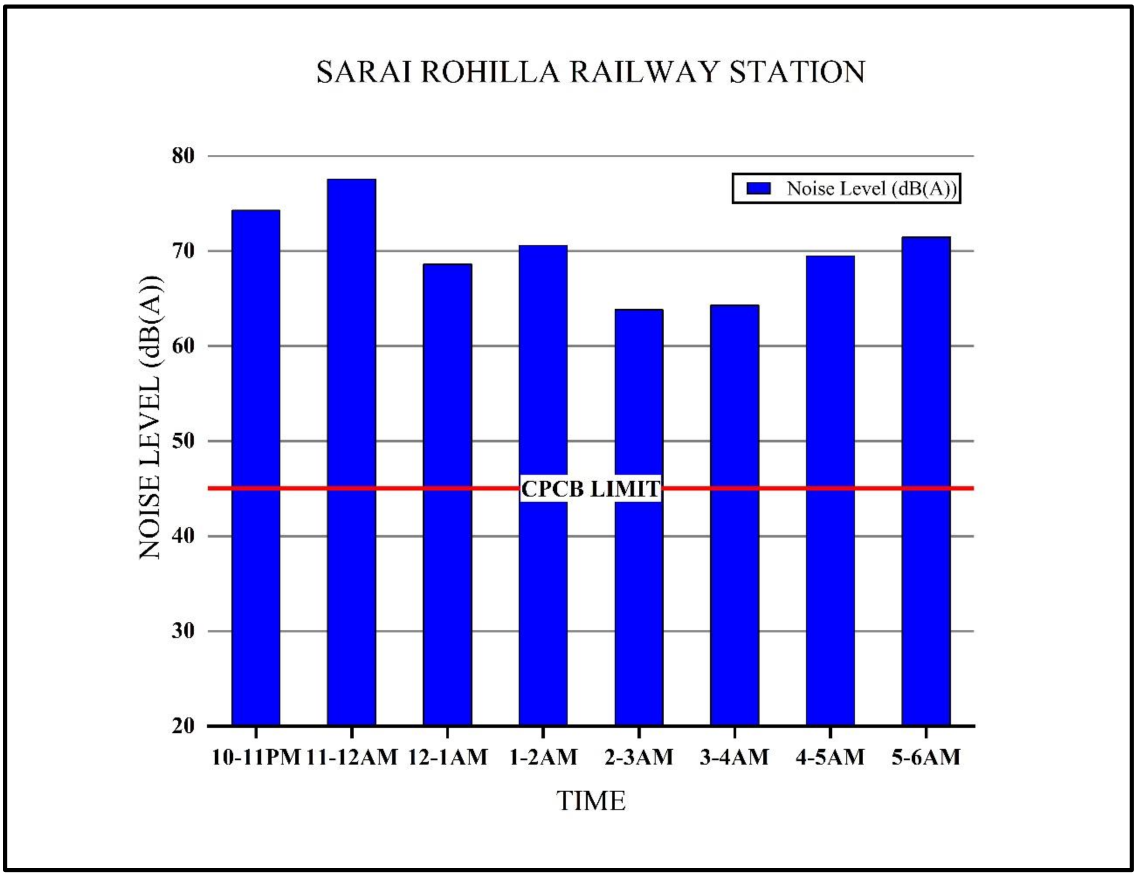


**Figure 4.1.** Noise monitoring variation at Sarai Rohilla Railway Station

### 4.1.2 Temporal distribution of Noise at Sabzi Mandi Railway Station

At Sabzi Mandi Railway Station, average monitored noise levels varied from 56.7 to 79.8 dB (A) during night time as shown in the Figure 4.2. The monitored noise level was 26 to 77% higher than the CPCB ambient noise limit for night time in a residential zone which is 45 dB (A) at the location.

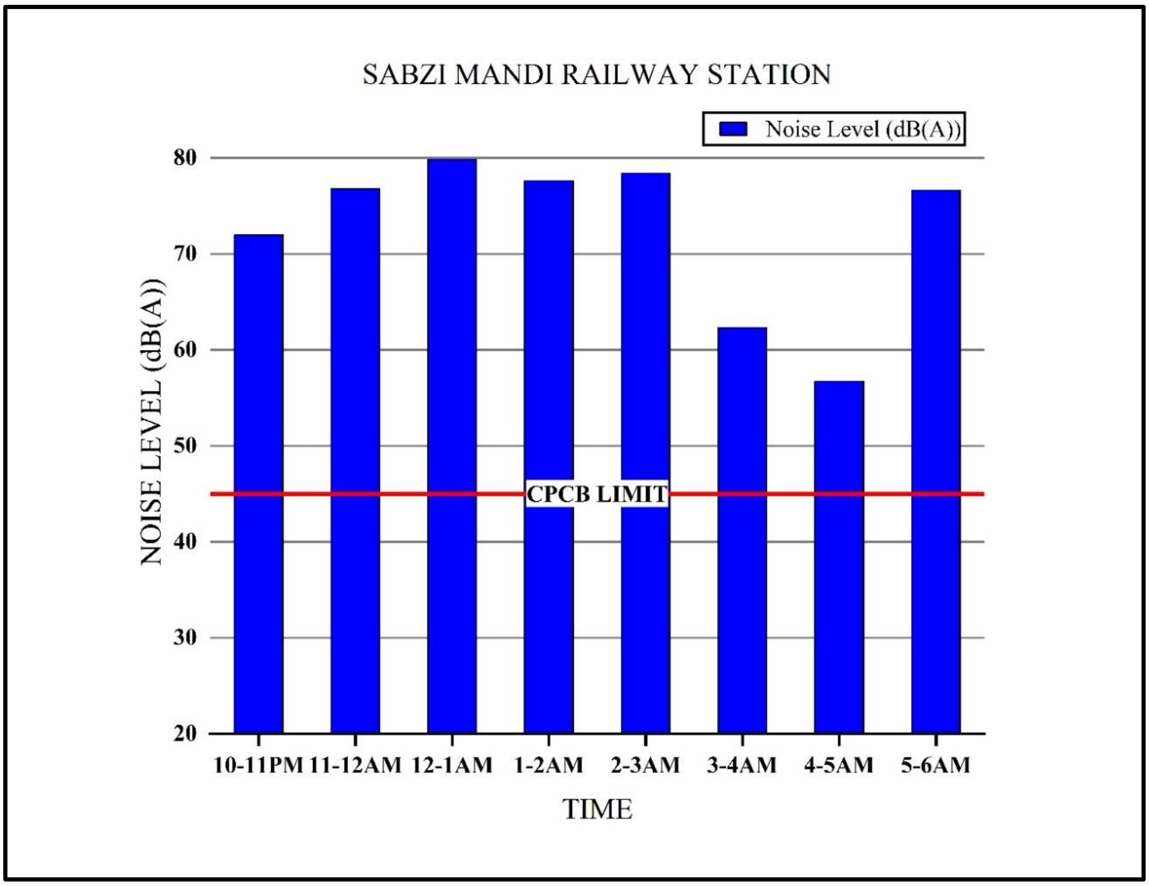


**Figure 4.2.** Noise monitoring variation at Sabzi Mandi Railway Station

## 4.2 HEALTH IMPACT ESTIMATION

Using the equation (2), the obtained $L_{eq}$ for each 1 second time interval were then averaged to get overall $L_{eq}$ for the time period of study, i.e. for night time duration of 8 hours from 10:00 pm in night to 06:00 am in morning. These $L_{eq}$ values were then compared with the observation thresholds provided in the Table 3.3 in order to predict the potential effects due to night time noise exposure.

Based on the overnight average $L_{eq}$ value obtained at the location of Sarai Rohilla and Sabzi Mandi railway station, health impacts that can be predicted are Sleep Disturbance and

Subjective Sleep Quality. The comparison of the calculated $L_{eq}$ values with the observation thresholds for these 2 health effects is represented in the Figure 4.3 and Figure 4.4**.**

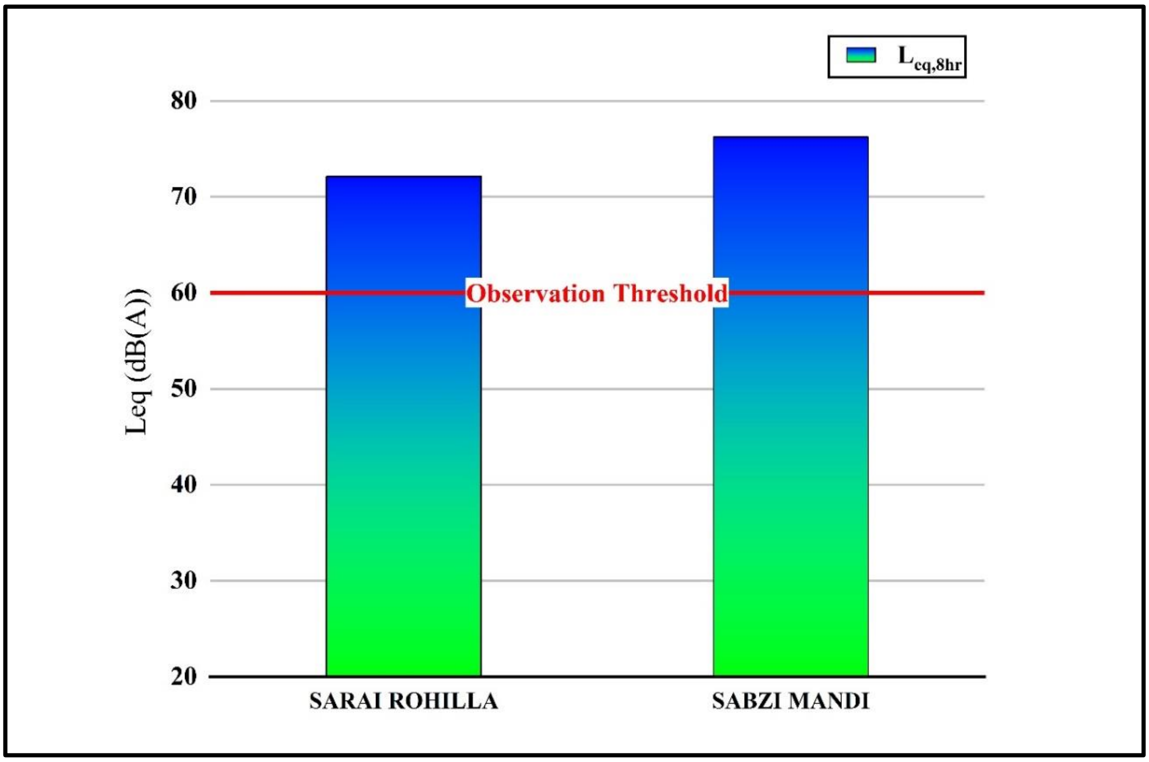


**Figure 4.3**. Comparison of Sleep Disturbance threshold with $L_{eq,\ 8hr}$

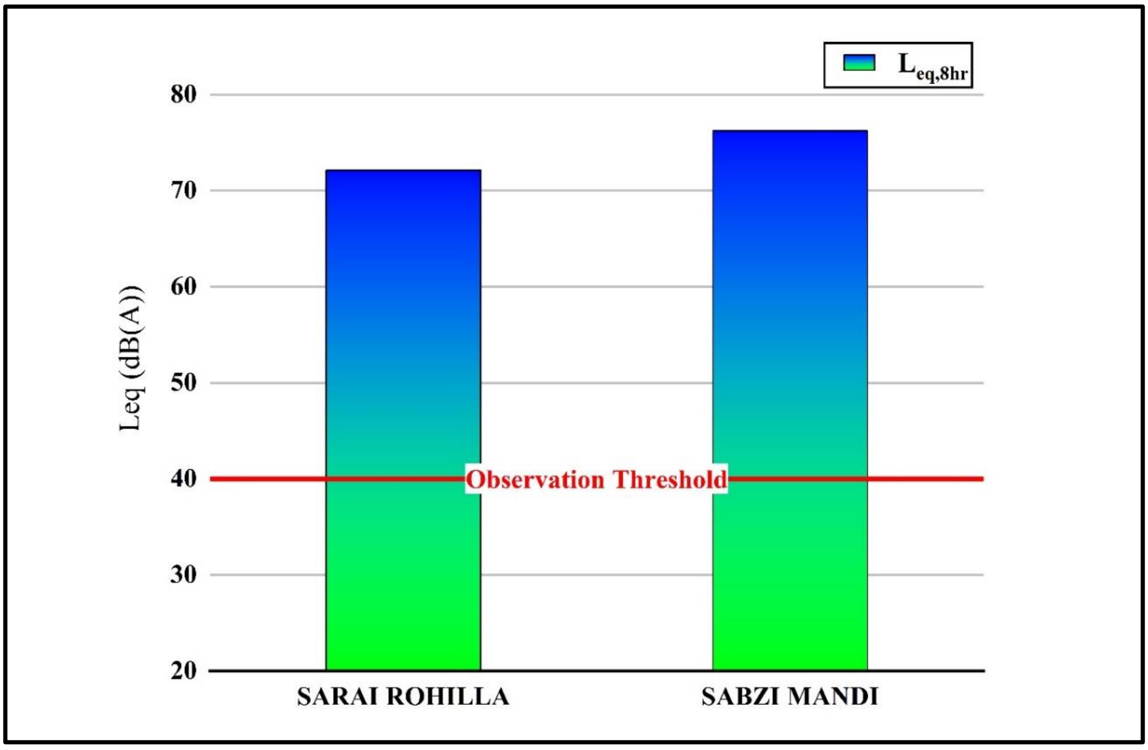


**Figure 4.4.** Comparison of Subjective Sleep Quality threshold with $L_{eq,\ 8hr}$

## 4.3 NOISE MAPPING OF THE SELECTED LOCATIONS

The noise pollution levels in the city have been measured and visualised by making use of this procedure. Geographical Information System (GIS) for Noise Mapping of Delhi was used to create noise maps for each of the chosen locations from 10:00 pm in night to 6:00 am in morning. Noise levels at the 2 railway stations varied from a minimum of 56.7 dB (A) to a maximum of 79.8 dB (A), where cumulative $L_{eq}$ value for the 8 hour duration for Sarai Rohilla Railway Station came out to be 72.1 dB (A) and for Sabzi Mandi Railway Station the obtained $L_{eq}$ was equal to 76.2 dB (A).

There were no readings for the two selected locations that showed the monitored noise to be lower than CPCB Standards for Ambient Noise Level. The cumulative noise result is shown in the Figure 4.5.

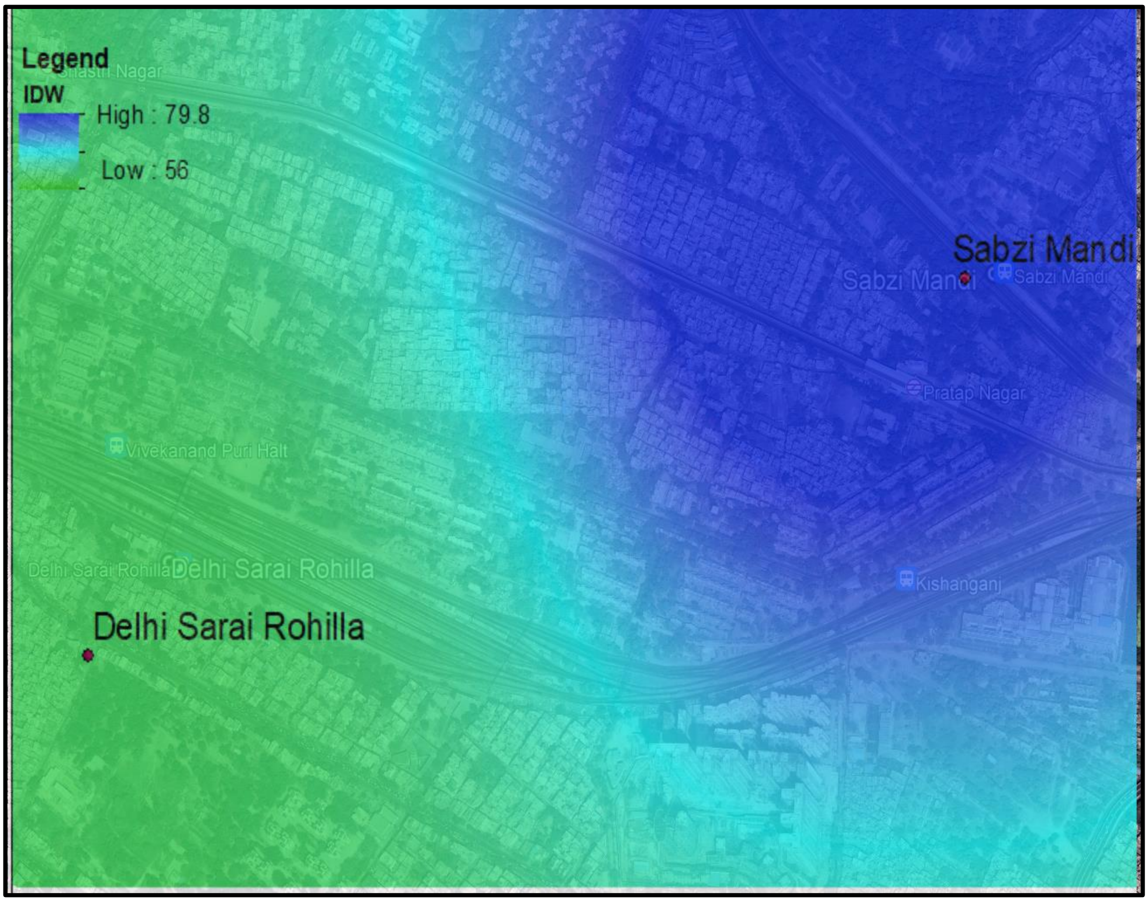


**Figure 4.5**. Noise mapping showing variation of noise levels from 10 pm to 6am

## 4.4 ANALYSIS OF QUESTIONNAIRE SURVEY

The questionnaire was designed using random sampling to take into account the participants' ages, genders, educational backgrounds, and work position. Comparatively speaking, male respondents were more eager to do the poll than female respondents. Over the 2 research locations in Delhi, a total of 102 data were gathered. Almost equal amount of survey data was collected from both the locations of Sarai Rohilla railway station and Sabzi Mandi railway station. Out of 102 data set, the respondents below the age of 18 were 17.6%, between the ages of 18-30 were 37.3%, 30-45 were 27.5% and above the age of 45 were 17.6%. The education status above high school grade was only 40%. Out of the 102 respondents, 74.5% were residents, 11.8% were shopkeepers/workers and the remaining 13.7% included rickshaw, cycle and bike drivers. The employment status of the respondents was approximately 50%.

99% of respondents were aware about the presence of railway noise in the region but only 21.6% were aware about the existence of any rules and regulations regarding noise pollution. More than 85% of respondents were living/ working at the study locations for a period more than 5 years which has led to their exposure to the railway noise for a long duration. The population was greatly affected by the noise from rail traffic during the morning (76%) and night time (79%).

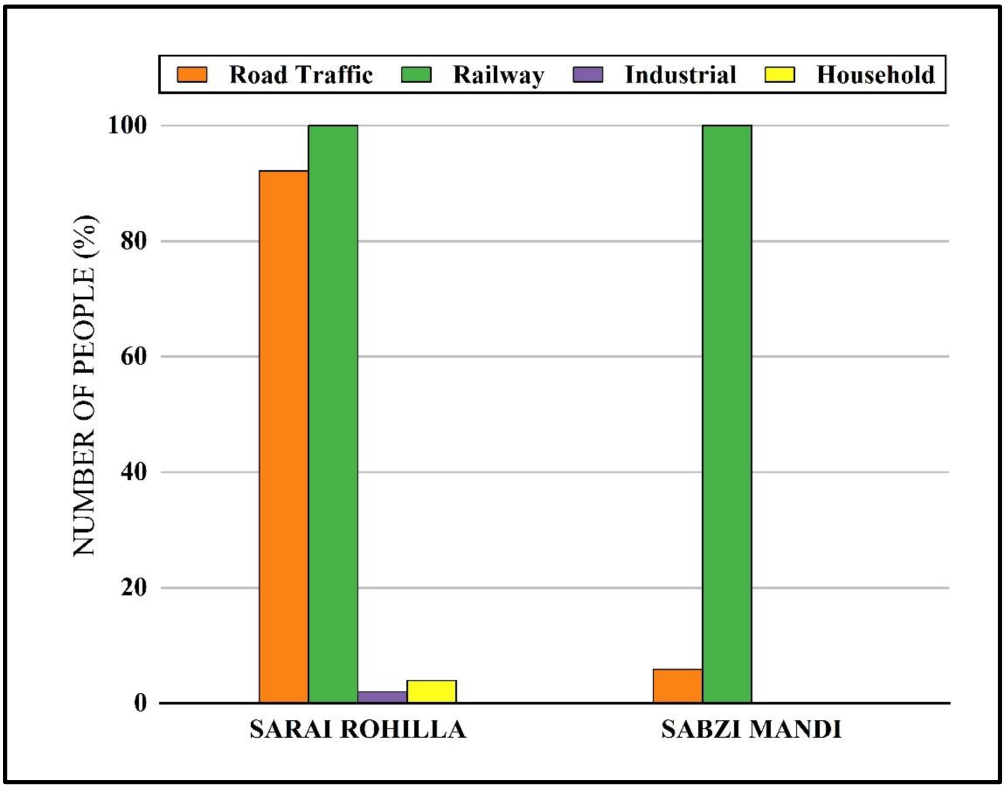


**Figure 4.6.** Major sources of noise pollution at selected locations

The Figure 4.6 shows major sources of noise pollution around boundaries of train stations. For those who live close to railroads, it is evident that transportation, namely railway, contribute significantly to noise pollution. More than 80% of the noise, as determined from the data, is caused by train operations.

### 4.4.1 On the basis of Gender

Sleep disturbance, irritation and fatigue show the same trend for both male and female respondents. The hypertension cases for females are almost double than that of males. Females are observed to be developing slightly more cases of stress as compared to males. Almost 90% of the respondents are suffering irritation and almost 80% are suffer from headache due to railway noise. The cases of hearing loss are also more in the case of females as they spending more time at the residence in comparison to males.

The results of investigation as shown in the Table 4.1 of the Heath Effect based on gender reveal that women are more vulnerable to the risk of noise exposure.

**Table 4.1.** Gender based analysis of questionnaire survey

| HEALTH EFFECTS | GENDER | |
|---|---|---|
| | MALE | FEMALE |
| **Data Set** | 88 | 14 |
| **Sleep Disturbance (%)** | 86.36 | 85.71 |
| **Irritation (%)** | 89.77 | 92.86 |
| **Headache (%)** | 81.82 | 78.57 |
| **Hypertension (%)** | 26.14 | 50.00 |
| **Stress (%)** | 76.14 | 85.71 |
| **Fatigue (%)** | 78.41 | 78.57 |
| **Hearing Impairment (%)** | 73.86 | 78.57 |

### 4.4.2 On the basis of Age Group

The analysis based on the groups showed that sleep disturbance, irritation and headache show almost similar trend across all the age groups living in the vicinity of the railway stations as shown in Table 4.2. The cases of hypertension and fatigue are very high in the ages above 45.

Damage to hearing is high in the ages below 18 as the ears are more sensitive to the impulses of railway noise. The cases of stress are more prominent in the groups below the ages of 18 years and above the ages of 45 years.

Therefore, it can be concluded that physiological effect of rail traffic noise is inversely proportional to psychological effect.

**Table 4.2.** Questionnaire analysis based on the Age Group

| HEALTH EFFECTS | AGE | | | |
|---|---|---|---|---|
| | **Below 18** | **18-30** | **30-45** | **Above 45** |
| **Data Set** | 18 | 38 | 28 | 18 |
| **Sleep Disturbance (%)** | 88.89 | 84.21 | 89.29 | 83.33 |
| **Irritation (%)** | 94.44 | 94.74 | 82.14 | 88.89 |
| **Headache (%)** | 77.78 | 81.58 | 82.14 | 83.33 |
| **Hypertension (%)** | 22.22 | 21.05 | 25.00 | 61.11 |
| **Stress (%)** | 88.89 | 68.42 | 75.00 | 88.89 |
| **Fatigue (%)** | 77.78 | 73.68 | 75.00 | 94.44 |
| **Hearing Impairment (%)** | 94.44 | 63.16 | 85.71 | 61.11 |

### 4.4.3 On the basis of Data Collected From

The residents were most affected by the noise pollution caused by rail traffic. Survey data could not be gathered from pedestrians, car, bus, and truck drivers. The loss of hearing is observed the most in the case residents and officials working near the vicinity of the railway stations. Sleep disturbance, irritation and headache show the similar trends in the case of officials and shopkeepers/workers. Stress and fatigue are experienced to the similar extent by residents and shopkeeper/worker.

In conclusion, the categories that are in constant contact with the railroads i.e., officials (police, guard) and residents are the ones, most affected by impact of rail traffic noise. The obtained results of the survey analysis are shown in the Table 4.3.

**Table 4.3.** Questionnaire analysis based on Data Collected From

| HEALTH EFFECTS | DATA COLLECTED FROM | | | | | |
|---|---|---|---|---|---|---|
| | **Official (Police, Guard)** | **Shopkeeper/ Worker** | **Resident** | **Pedestrian** | **Rickshaw, Cycle And Bike Driver** | **Car, Bus, And Truck Driver** |
| **Data Set** | **12** | **12** | **76** | **0** | **2** | **0** |
| **Sleep Disturbance** | 66.67 | 66.67 | 92.11 | 0.00 | 100.00 | 0.00 |
| **Irritation** | 83.33 | 100.00 | 89.47 | 0.00 | 100.00 | 0.00 |
| **Headache** | 75.00 | 75.00 | 82.89 | 0.00 | 100.00 | 0.00 |
| **Hypertension** | 58.33 | 25.00 | 26.32 | 0.00 | 0.00 | 0.00 |
| **Stress** | 91.67 | 75.00 | 76.32 | 0.00 | 50.00 | 0.00 |
| **Fatigue** | 91.67 | 75.00 | 76.32 | 0.00 | 100.00 | 0.00 |
| **Hearing Impairment** | 83.33 | 58.33 | 76.32 | 0.00 | 50.00 | 0.00 |

### 4.4.4 Noise Annoyance

For individuals who live near railways, noise from rail traffic is the main cause of annoyance [45]. In order to measure the extent of noise annoyance near train stations, survey participants were requested to rate the effect on a scale from zero to ten. Respondents were instructed to select a value of zero if they were not at all annoyed and a value of 10 if they were extremely annoyed. 'Slightly' was allotted the values from 1 to 3 on the opinion scale, 'Moderately' was allotted the range from 4 to 7 and the answer 'Very' was provided with the range 8 to 9.

Due to the high noise level, annoyance is a common problem that people experience for long period of time. Figure 4.7 represents annoyance due to noise exposure faced by the respondents at the study locations especially during night time ranging from 10:00 pm to 06:00 am. All observations lie in the higher band of the annoyance axis. Clear observation can be made that majority of the population of respondents is annoyed to the 'Very' extent. This points to the fact that annoyance being a psychological issue requires large amount of attention during the planning of noise mitigation strategies.

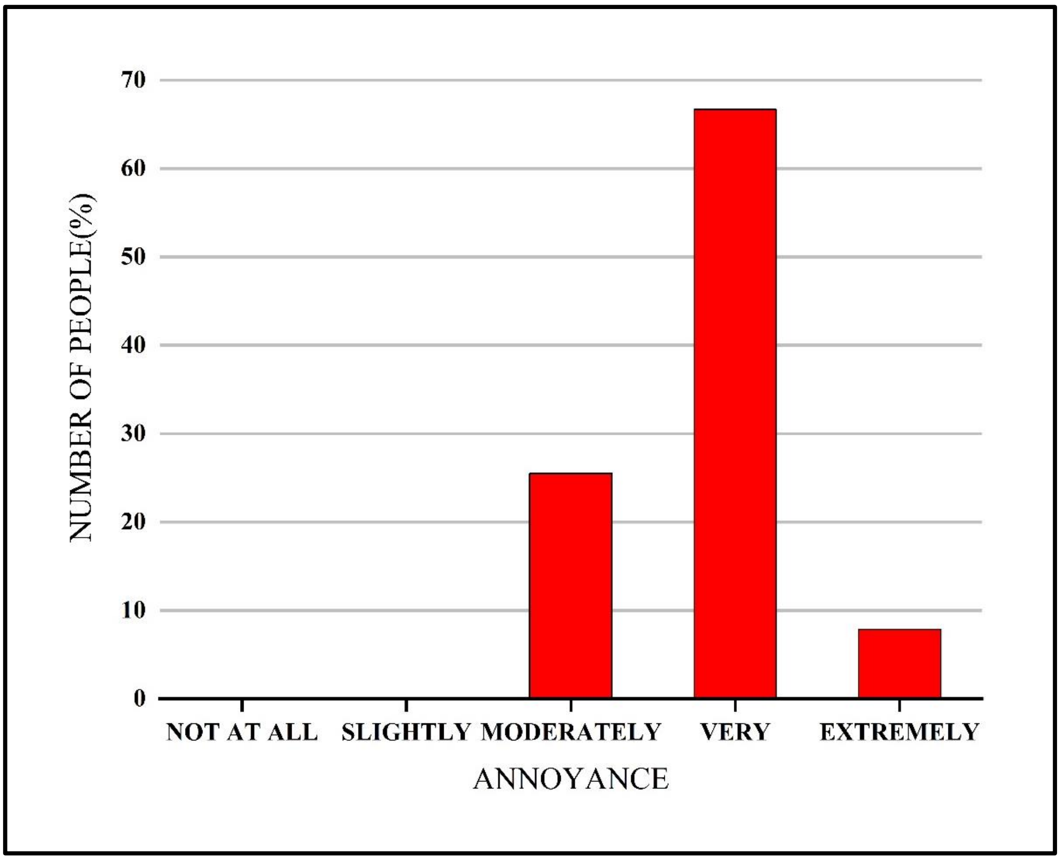


**Figure 4.7.** Number of people annoyed due to railway noise pollution

# CHAPTER 5

# CONCLUSION AND FUTURE RECOMMENDATIONS

## 5.1 CONCLUSIONS

Noise pollution doesn't leave behind any traces that can serve as a memory of its unpleasantness. Despite the fact that its effects are typically just as severe as those of other types of pollution, noise pollution is typically assigned the lowest priority for regulation and management. Railway route length has increased over time, and this has led to an increase in uncontrolled pollution due to noise and corresponding health impacts, which lead to both short and long-term psychological and physiological issues. Main goal of this project was to calculate the noise levels in two Delhi city train stations. Investigations on the causes, effects, solutions, and suggestions for reducing the excessive noise created by railroads were made.

Two railway stations in total were selected for the study, and sound level metre was used to measure the noise levels for two consecutive days at each station through the night time from 10:00 pm to 06:00 am. Suggested format for entering the collected data into the Excel sheet was followed for further investigation. It was then discovered that noise levels were higher than recommended limits established by Central Pollution Control Board in New Delhi, India, in every location.

The monitored data was also compared with the observation thresholds provided by the health council report of committee on Noise and Health, Netherlands, in order to predict the health effects arising from the exposure to rail traffic noise. The results suggested the occurrence of sleep disturbance and impact on subjective sleep quality. Spatial distribution of rail noise in Delhi city was examined using noise maps made with ArcGIS software. The relevant authorities might use the created noise map to warn people about excessive noise exposure due to rail traffic.

To validate the effect of train noise on those who live close to lines, a questionnaire was created. The results of the survey indicated that people are easily impacted by the noise of the rail traffic, and they are displaying discomfort and health-related problems. It was observed that females were more prone to be affected by rail noise exposure. On the basis of age group, the older people experienced stress, fatigue and hypertension whereas the effect on the younger people was moreover related to annoyance and irritation. Similarly, category based analysis showed that the residents and the officials near the railroads were the most affected by the rail traffic noise. The annoyance analysis depicted that the survey population was heavily affected by the rail noise and it demands serious actions to be taken for mitigation of the impacts of railway noise pollution. One limitation of the survey study was the less amount of female respondents which restricted the accuracy and efficiency of results.

## 5.2 FUTURE RECOMMENDATIONS

- To develop a health impact prediction model of rail noise that can handle Indian conditions.
- To stop people from using pressure horns and implementation of strict laws and restrictions.
- The study respondents advised taking steps to lower noise levels, including installing noise barriers, planting trees, improving technology but most emphasis was given to the reduction of honking of train horns.

## REFERENCES


[1] World Health Organization, “Burden of disease from Burden of disease from,” *World Heal. Organ.*, p. 126, 2011.

[2] G. of I. Ministry of Road Transport and Highways, “No Title,” *National Informatics Centre (NIC)*. https://morth.nic.in/#main-content

[3] Ministry of Statistics & Programme Implementation, “No Title.” https://www.mospi.gov.in/ (accessed May 04, 2023).

[4] A. K. Dasarathy, “Noise Pollution : Causes , Mitigation and Control Measures for Attenuation,” no. March, p. 136, 2015.

[5] WHO, “Chapter 11. Environmental noise,” vol. 2022, pp. 0–7, 2022.

[6] S. B. Mangalekar, A. S. Jadhav, and P. D. Raut, “Study of Noise Pollution in Kolhapur City , Maharashtra , India Abstract :,” *Online*, vol. 2, no. 1, pp. 65–69, 2012.

[7] O. Hahad, J. H. Prochaska, A. Daiber, and T. Muenzel, “Environmental Noise-Induced Effects on Stress Hormones, Oxidative Stress, and Vascular Dysfunction: Key Factors in the Relationship between Cerebrocardiovascular and Psychological Disorders,” *Oxid. Med. Cell. Longev.*, vol. 2019, 2019, doi: 10.1155/2019/4623109.

[8] W. Passchier-Vermeer and W. F. Passchier, “Noise exposure and public health,” *Environ. Health Perspect.*, vol. 108, no. SUPPL. 1, pp. 123–131, 2000, doi: 10.1289/ehp.00108s1123.

[9] S. Elias, “Chapter 8 - Impacts of Global Shipping to Arctic Ocean Ecosystems,” S. B. T.-T. to the A. Elias, Ed. Elsevier, 2021, pp. 153–207. doi: https://doi.org/10.1016/B978-0-12-821555-5.00008-5.

[10] Ministry of Environment and forest, “The Noise Pollution (Regulation and Control) Rules, 2000,” vol. 12311, no. 1110, pp. 1088–1569, 2000, [Online]. Available: http://cpcb.nic.in/divisionsofheadoffice/pci2/noise_rules_2000.pdf

[11] B. Berglund, T. Lindvall, and D. Schwela, “Guidelines for Community Noise. World Health Organization,” *Noise & Vibration Worldwide*, vol. 31, no. 4. pp. 1–141, 1995. [Online]. Available: http://multi-science.metapress.com/openurl.asp?genre=article&id=doi:10.1260/095745600149755

[12] https://www.railway-technology.com/, “No Title,” *Verdict Media Limited 2023*. www.railway-technology.com%0D (accessed May 09, 2023).

[13] Civil Engineering Portal of Indian Railways, “No Title,” *Centre for Railway Information Systems (CRIS), Ministry of Railways, Government of India*. https://ircep.gov.in/ (accessed May 04, 2023).

[14] “Top 10 Countries with Largest Railway Networks in World,” 2017. https://erail.in/blog/countries-with-largest-railway-networks-in-world/50 (accessed May 21, 2023).

[15] Https://etrainstatus.com/indian-railway-map, “Latest Indian Railway Map,” *etrainstatus*. https://www.etrainstatus.com/ (accessed May 09, 2023).

[16] https://www.mapsofindia.com/maps/india/railway-zonal-map.html, “Zones of Indian railway,” *https://www.mapsofindia.com/*. https://www.mapsofindia.com/maps/india/railway-zonal-map.html

[17] J. I. Halonen *et al.*, “Associations of traffic noise with self-rated health and psychotropic medication use,” *Scand. J. Work. Environ. Heal.*, vol. 40, no. 3, pp. 235–243, 2014, doi: 10.5271/sjweh.3408.

[18] M. Kim *et al.*, “Road Traffic Noise,” *Am. J. Prev. Med.*, vol. 43, no. 4, pp. 353–360, Oct. 2012, doi: 10.1016/j.amepre.2012.06.014.

[19] I. Railways, “Route length of railways across India from financial year 2003 to 2022,” *Indian Railways*, 2023. https://www.statista.com/statistics/1079483/india-railway-route-length/#:~:text=At the end of fiscal,the largest in the world.

[20] M. Němec, T. Gergel’, M. Gejdoš, V. Ondrejka, Z. Danihelová, and A. Danihelová, “Measurement and prediction of railway noise case study from slovakia,” *Int. J. Environ. Res. Public Health*, vol. 17, no. 10, 2020, doi: 10.3390/ijerph17103616.

[21] Y. Tong, Y. Jiang, Z. Zhou, and D. Ma, “The study of railway bridge noise monitoring and prevention,” *Proc. - 2014 4th Int. Conf. Instrum. Meas. Comput. Commun. Control. IMCCC 2014*, pp. 244–249, 2014, doi: 10.1109/IMCCC.2014.58.

[22] E. Zea, E. Fernandez-Grande, and I. Lopez Arteaga, “Separation of rail and wheel contributions to pass-by noise with sparse regularization methods,” *J. Sound Vib.*, vol. 487, no. August, p. 115627, 2020, doi: 10.1016/j.jsv.2020.115627.

[23] P. H. Trombetta Zannin and F. Bunn, “Noise annoyance through railway traffic - A case study,” *J. Environ. Heal. Sci. Eng.*, vol. 12, no. 1, pp. 1–12, 2014, doi: 10.1186/2052-336X-12-14.

[24] G. G. Wosniacki and P. H. T. Zannin, “Framework to manage railway noise exposure in Brazil based on field measurements and strategic noise mapping at the local level,” *Sci. Total Environ.*, vol. 757, p. 143721, 2021, doi: 10.1016/j.scitotenv.2020.143721.

[25] G. Demir, A. Kablan, Y. Avşar, Ü. Alyüz, H. E. Ökten, and Ş. Yalçın, “Railway Noise Pollution Prevention in Terms of Regulations: Case Study of Istanbul,” *Int. J. Environ. Sci. Dev.*, vol. 7, no. 3, pp. 198–202, 2016, doi: 10.7763/ijesd.2016.v7.767.

[26] F. Bunn and P. H. T. Zannin, “Assessment of railway noise in an urban setting,” *Appl. Acoust.*, vol. 104, pp. 16–23, 2016, doi: 10.1016/j.apacoust.2015.10.025.

[27] R. GoŁębiewski and R. Makarewicz, “Verification of two methods of railway noise propagation,” *Arch. Acoust.*, vol. 34, no. 2, pp. 177–188, 2009.

[28] A. Muzet, “Environmental noise, sleep and health,” *Sleep Med. Rev.*, vol. 11, no. 2, pp. 135–142, 2007, doi: 10.1016/j.smrv.2006.09.001.

[29] S. Pirrera, E. De Valck, and R. Cluydts, “Nocturnal road traffic noise: A review on its assessment and consequences on sleep and health,” *Environ. Int.*, vol. 36, no. 5, pp. 492–498, 2010, doi: 10.1016/j.envint.2010.03.007.

[30] A. L. Brown, “Effects of Road Traffic Noise on Health: From Burden of Disease to Effectiveness of Interventions,” *Procedia Environ. Sci.*, vol. 30, pp. 3–9, 2015, doi: 10.1016/j.proenv.2015.10.001.

[31] S. A. Stansfeld *et al.*, “Aircraft and road traffic noise and children’s cognition and health: A cross-national study,” *Lancet*, vol. 365, no. 9475, pp. 1942–1949, 2005, doi: 10.1016/S0140-6736(05)66660-3.

[32] S. AlKheder, W. Abdullah, F. Al-Rukaibi, and H. Al Sayegh, “Urban noise impact model for Kuwait new railway: impact study,” *Int. J. Environ. Sci. Technol.*, vol. 17, no. 2, pp. 755–764, 2020, doi: 10.1007/s13762-019-02513-1.

[33] S. A. Ali, “Railway noise levels, annoyance and countermeasures in Assiut, Egypt,” *Appl. Acoust.*, vol. 66, no. 1, pp. 105–113, 2005, doi: 10.1016/j.apacoust.2004.06.005.

[34] R. GoŠ†biewski and R. Makarewicz, “Railroad Noise Affected By Downward Refraction and Turbulence,” *Arch. Acoust.*, vol. 27, no. January 2002, p. 8394, 2002, [Online]. Available: http://acoustics.ippt.gov.pl/index.php/aa/article/download/418/349

[35] W. Batko and B. Stępień, “Non-parametric methods of estimation of type a uncertainty of the environmental noise hazard indices,” *Arch. Acoust.*, vol. 34, no. 3, pp. 295–303, 2009.

[36] P. H. T. Zannin, A. Calixto, F. B. Diniz, J. A. Ferreira, and R. B. Schuhli, “Annoyance caused by urban noise to the citizens of Curitiba, Brazil,” *Rev. Saude Publica*, vol. 36, no. 4, pp. 521–524, 2002, doi: 10.1590/s0034-89102002000400020.

[37] C. Popp, “Noise abatement planning in Germany - Experiences and consequences of the EU directive on the assessment of environmental noise,” vol. 89, p. S65, May 2003.

[38] D. Manvella *et al.*, “SADMAM-Combining measurements and calculations to map noise in Madrid,” in *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*, 2004, vol. 2004, no. 6, pp. 1998–2005. [Online]. Available: https://www.bksv.com/media/doc/InterNoise2004SADMAM-CombiningMeasurementsandCalculationstoMapNoiseinMadrid.pdf

[39] M. T. Obaidat, “Spatial Mapping of Traffic Noise Levels in Urban Areas,” *J. Transp. Res. Forum*, vol. 47, no. 2, 2011, doi: 10.5399/osu/jtrf.47.2.1711.

[40] K. T. Tsai, M. Der Lin, and Y. H. Chen, “Noise mapping in urban environments: A Taiwan study,” *Appl. Acoust.*, vol. 70, no. 7, pp. 964–972, 2009, doi: 10.1016/j.apacoust.2008.11.001.

[41] C. W. Law, C. K. Lee, A. S. W. Lui, M. K. L. Yeung, and K. C. Lam, “Advancement of three-dimensional noise mapping in Hong Kong,” *Appl. Acoust.*, vol. 72, no. 8, pp. 534–543, 2011, doi: 10.1016/j.apacoust.2011.02.003.

[42] W. J. Zhao *et al.*, “3D traffic noise mapping using unstructured surface mesh representation of buildings and roads,” *Appl. Acoust.*, vol. 127, pp. 297–304, 2017, doi: 10.1016/j.apacoust.2017.06.025.

[43] M. Cai, J. Zou, J. Xie, and X. Ma, “Road traffic noise mapping in Guangzhou using GIS and GPS,” *Appl. Acoust.*, vol. 87, pp. 94–102, 2015, doi: 10.1016/j.apacoust.2014.06.005.

[44] E. Bocher, G. Guillaume, J. Picaut, G. Petit, and N. Fortin, “Noisemodelling: An open source GIS based tool to produce environmental noise maps,” *ISPRS Int. J. Geo-Information*, vol. 8, no. 3, 2019, doi: 10.3390/ijgi8030130.

[45] G. Licitra, L. Fredianelli, D. Petri, and M. A. Vigotti, “Annoyance evaluation due to overall railway noise and vibration in Pisa urban areas,” *Sci. Total Environ.*, vol. 568, pp. 1315–1325, 2016, doi: 10.1016/j.scitotenv.2015.11.071.

[46] M. A. Uddin, S. M. S. Uddin Miah, and M. A. Hossan, “Noise Pollution and its Impacts Case study of Selected Rail Stations of Bangladesh.pdf,” *Stamford J. Environ. Hum. Habitat*, vol. 4, no. May, pp. 15–23, 2015.

[47] B. Griefahn, A. Marks, and S. Robens, “Noise emitted from road, rail and air traffic and their effects on sleep,” *J. Sound Vib.*, vol. 295, no. 1–2, pp. 129–140, Aug. 2006, doi: 10.1016/j.jsv.2005.12.052.

[48] R. Rylander, “Physiological aspects of noise-induced stress and annoyance,” *J. Sound Vib.*, vol. 277, no. 3, pp. 471–478, 2004, doi: 10.1016/j.jsv.2004.03.008.

[49] C. Lim, J. Kim, J. Hong, and S. Lee, “The relationship between railway noise and community annoyance in Korea,” *J. Acoust. Soc. Am.*, vol. 120, no. 4, pp. 2037–2042, 2006, doi: 10.1121/1.2266539.

[50] M. G. Smith, M. Ögren, J. Ageborg Morsing, and K. Persson Waye, “Effects of ground-borne noise from railway tunnels on sleep: A polysomnographic study,” *Build. Environ.*, vol. 149, no. July 2018, pp. 288–296, 2019, doi: 10.1016/j.buildenv.2018.12.009.

[51] J. Wothge, C. Belke, U. Möhler, R. Guski, and D. Schreckenberg, “The combined effects of aircraft and road traffic noise and aircraft and railway noise on noise annoyance—an analysis in the context of the joint research initiative NORAH,” *Int. J. Environ. Res. Public Health*, vol. 14, no. 8, 2017, doi: 10.3390/ijerph14080871.

[52] M. Arana and A. García, “A social survey on the effects of environmental noise on the residents of Pamplona, Spain,” *Appl. Acoust.*, vol. 53, no. 4, pp. 245–253, 1998, doi: 10.1016/S0003-682X(97)00067-4.

[53] W. Babisch, H. Ising, and J. E. J. Gallacher, “Health status as a potential effect modifier of the relation between noise annoyance and incidence of ischaemic heart disease,” *Occup. Environ. Med.*, vol. 60, no. 10, pp. 739–745, 2003, doi: 10.1136/oem.60.10.739.

[54] Y. De Kluizenaar, R. T. Gansevoort, H. M. E. Miedema, and P. E. De Jong, "Hypertension and road traffic noise exposure," *J. Occup. Environ. Med.*, vol. 49, no. 5, pp. 484–492, 2007, doi: 10.1097/JOM.0b013e318058a9ff.

[55] E. Murphy, E. A. King, and H. J. Rice, "Estimating human exposure to transport noise in central Dublin, Ireland," *Environ. Int.*, vol. 35, no. 2, pp. 298–302, 2009, doi: 10.1016/j.envint.2008.07.026.

[56] A. V. Moudon, "Real Noise from the Urban Environment. How Ambient Community Noise Affects Health and What Can Be Done About It," *Am. J. Prev. Med.*, vol. 37, no. 2, pp. 167–171, 2009, doi: 10.1016/j.amepre.2009.03.019.

[57] S. Stansfeld, M. Haines, B. Berry, and M. Burr, "Reduction of road traffic noise and mental health: An intervention study," *Noise Heal.*, vol. 11, no. 44, pp. 169–175, 2009, doi: 10.4103/1463-1741.53364.

[58] A. Seidler *et al.*, "Myocardial infarction risk due to aircraft, road and rail traffic noise - Results of a case-control study based on secondary data," *Dtsch. Arztebl. Int.*, vol. 113, no. 24, pp. 407–414, 2016, doi: 10.3238/arztebl.2016.0407.

[59] J. H. Ko, S. Il Chang, M. Kim, J. B. Holt, and J. C. Seong, "Transportation noise and exposed population of an urban area in the Republic of Korea," *Environ. Int.*, vol. 37, no. 2, pp. 328–334, 2011, doi: 10.1016/j.envint.2010.10.001.

[60] E. Murphy and E. A. King, "Strategic noise mapping, population exposure estimates and 'acoustical planning' mitigation analysis in a european capital city," *39th Int. Congr. Noise Control Eng. 2010, INTER-NOISE 2010*, vol. 4, pp. 2535–2542, 2010.

[61] M. J. Zare Sakhvidi, F. Zare Sakhvidi, A. H. Mehrparvar, M. Foraster, and P. Dadvand, "Association between noise exposure and diabetes: A systematic review and meta-analysis," *Environ. Res.*, vol. 166, no. January, pp. 647–657, 2018, doi: 10.1016/j.envres.2018.05.011.

[62] T. Münzel, T. Gori, W. Babisch, and M. Basner, "Cardiovascular effects of environmental noise exposure," *Eur. Heart J.*, vol. 35, no. 13, pp. 829–836, 2014, doi: 10.1093/eurheartj/ehu030.

[63] M. Basner *et al.*, "Auditory and non-auditory effects of noise on health," *Lancet*, vol. 383, no. 9925, pp. 1325–1332, Apr. 2014, doi: 10.1016/S0140-6736(13)61613-X.

[64] T. Münzel *et al.*, "Environmental stressors and cardio-metabolic disease: Part II-mechanistic insights," *Eur. Heart J.*, vol. 38, no. 8, pp. 557–564, 2017, doi: 10.1093/eurheartj/ehw294.

[65] W. Fu *et al.*, "Association between exposure to noise and risk of hypertension: A meta-analysis of observational epidemiological studies," *J. Hypertens.*, vol. 35, no. 12, pp. 2358–2366, 2017, doi: 10.1097/HJH.0000000000001504.

[66] N. Roswall, O. Raaschou-Nielsen, M. Ketzel, K. Overvad, J. Halkjær, and M. Sørensen, "Modeled traffic noise at the residence and colorectal cancer incidence: a cohort study," *Cancer Causes Control*, vol. 28, no. 7, pp. 745–753, 2017, doi: 10.1007/s10552-017-0904-0.

[67] B. Oftedal *et al.*, "Road traffic noise and markers of obesity – A population-based study," *Environ. Res.*, vol. 138, pp. 144–153, 2015, doi: https://doi.org/10.1016/j.envres.2015.01.011.

[68] S. Y. Ali and S. Chaudhury, "Study of the Railway noise level in Bolpur and Prantik Station, India," *Res. J. Recent Sci. ______________________________E-ISSN*, vol. 2277, no. April, p. 2502, 2016.

[69] V. Kanakasabai, G. Senthilkumar, and E. Chandrasekar, "Study of noise level in railway stations," *J. Sci. Ind. Res. (India).*, vol. 64, no. 12, pp. 957–959, 2005.

[70] Gaurav Sanjay Patil and Dr. G. S. Kulkarni, "Analysis of Noise Pollution in Kolhapur City and Technical Remedy to Reduce Noise Level," *Int. J. Eng. Res.*, vol. V9, no. 01, pp. 282–290, 2020, doi: 10.17577/ijertv9is010173.

[71] A. R. M. Anurag V. Tiwari, Prashant A. Kadu, "Study of Noise Pollution Due To Railway and Vehicular Traffic at Level Crossing and Its Remedial Measures," *Am. J. Eng. Res.*, vol. 99, no. 3, pp. 16–19, 2000.

[72] A. Shiva, R. Purohit, R. S. Rana, and D. K. Koli, "Noise and Vibration Emissions of Railway Bridges," *Mater. Today Proc.*, vol. 4, no. 2, pp. 3745–3753, 2017, doi: 10.1016/j.matpr.2017.02.270.

[73] L. Muralidharan, S. Gaur, C. Muralidharan, and V. K. K. Menon, "Noise Pollution of Local Train and its Impact on Students Residing Nearby Railway Station," vol. 5, no.

10, pp. 592–596, 2018, [Online]. Available: https://www.researchgate.net/publication/329988424

[74] P. Das, S. Talukdar, S. Ziaul, S. Das, and S. Pal, “Noise mapping and assessing vulnerability in meso level urban environment of Eastern India,” *Sustain. Cities Soc.*, vol. 46, no. November 2018, p. 101416, 2019, doi: 10.1016/j.scs.2019.01.001.

[75] A. N. Joshi, N. C. Joshi, and P. P. Rane, “Noise Mapping in Mumbai City, India.,” *Int. J. Innov. Sci. Eng. Technol.*, vol. 2, no. 3, pp. 380–385, 2015.

[76] N. Garg, B. S. Chauhan, and M. Singh, “Normative Framework of Noise Mapping in India: Strategies, Implications and Challenges Ahead,” *Acoust. Aust.*, vol. 49, no. 1, pp. 23–41, 2021, doi: 10.1007/s40857-020-00214-1.

[77] R. Kalaiselvi and A. Ramachandraiah, “Environmental noise mapping study for heterogeneous traffic conditions,” *20th Int. Congr. Acoust. 2010, ICA 2010 - Inc. Proc. 2010 Annu. Conf. Aust. Acoust. Soc.*, vol. 3, no. August, pp. 1829–1834, 2010.

[78] W. Alam, “GIS based Assessment of Noise Pollution in Guwahati City of Assam , India,” vol. 2, no. 2, pp. 731–740, 2011.

[79] N. Akhtar, K. Ahmad, and P. Alam, “Noise Monitoring and Mapping for Some Pre-selected Locations of New Delhi, India,” *Fluct. Noise Lett.*, vol. 15, no. 2, 2016, doi: 10.1142/S021947751650019X.

[80] R. K. Mishra, K. Nair, K. Kumar, and A. Shukla, “Dynamic noise mapping of road traffic in an urban city,” *Arab. J. Geosci.*, vol. 14, no. 2, p. 122, 2021, doi: 10.1007/s12517-020-06373-9.

[81] R. Kumar, A. Mukherjee, and V. P. Singh, “Traffic noise mapping of Indian roads through smartphone user community participation,” *Environ. Monit. Assess.*, vol. 189, no. 1, 2017, doi: 10.1007/s10661-016-5741-1.

[82] D. R. Sonaviya and B. N. Tandel, “A Review on GIS-Based Approach for Road Traffic Noise Mapping,” *Indian J. Sci. Technol.*, vol. 14, no. 12, pp. 1–6, 2019, doi: 10.17485/ijst/2019/v12i14/132481.

[83] N. Singh and S. C. Davar, “Noise Pollution-Sources, Effects and Control,” *J. Hum. Ecol.*, vol. 16, no. 3, pp. 181–187, 2004, doi: 10.1080/09709274.2004.11905735.

[84] H. G. V. Prasad, M. Y. Shariff, K. Prajwal, S. R. Kurki, and M. S. Kumar, “Analysis of Railway Traffic Noise in Mysuru City,” *Int. J. Sci. Eng. Technol.*, vol. 6, no. 7, p. 228, 2017, doi: 10.5958/2277-1581.2017.00026.2.

[85] Vinaykumar Kurakula, “A GIS-Based Approach for 3D Noise Modelling Using 3D City Models,” *Int. Inst. Geo-Information Sci. Earth*, vol. 319, no. 5864, pp. 766–769, 2007, [Online]. Available: http://www.sciencemag.org/cgi/content/abstract/319/5864/766%5Cnhttp://www.sciencemag.org/cgi/content/full/320/5875/446b?rss=1

[86] V. J. Krichagin, “Health effects of noise exposure,” *J. Sound Vib.*, vol. 59, no. 1, pp. 65–71, 1978, doi: 10.1016/0022-460X(78)90479-0.