A Study on Noise Environment near Rajindra Hospital and its Control

A dissertation submitted in partial fulfillment of the requirements for the degree

of

Master of Engineering

in

Production Engineering

by

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JULY-2015

CERTIFICATE

I hereby declare that the research work entitled "**A Study on Noise Environment near Rajindra Hospital and its Control**" is an authentic record of my work carried out as requirements for the award of the degree of **Master of Engineering** in **Production Engineering** at **Thapar University, Patiala** under the supervision of **Dr. S.P. Nigam (Visiting Professor)** and **Mr. Daljeet Singh (Assistant Professor)**, Mechanical Engineering Department, Thapar University, Patiala during July, 2014 to July, 2015. No part of the matter embodied in this report has been submitted to any other university or institute for the award of any degree.

Date: 15/7/2015

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It is certified that the above statement made by the student is correct to the best of our knowledge and belief.

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Abstract

Noise is one of the developing problems in our modern society. Traffic noise is the main source of noise problem. Noise has become a serious problem in the Rajindra hospital as complaints arise from people visiting the hospital. Noise studies and noise abatement standards are available to protect the health and safety of people visiting in the hospital. A – Weighted equivalent noise level (LA_{eq}) in the area of hospital should not be more than 50 dB(A) because area of 100 m around the hospital is declared as silence zone by Central Pollution Control Board India (2000). But Sound pressure level more than recommended level in the area of hospital affects the health of patients as well as other staff members or people visiting hospital. These concerns have developed the use of barriers along the roadside to protect patients or other people in the hospital. Noise investigation was done at the emergency entrance inside the hospital and near the main entrance of hospital facing the emergency ward. Acoustical design of barrier having height of 6.4 m (21 ft) was obtained by using a nomograph to control the noise level inside the hospital

Total achievable attenuation obtained from nomograph is 7 to 7.5 dB(A) including attenuation being already provided under the existing condition This attenuation is mainly provided by a wall of height approximately 3.6 m (12 ft) which already exists. As barrier height of 3.6 m (12 ft) is already existing, therefore additional 2.7 m (9 ft) barrier is required to get attenuation of 7.5 dB(A). Barrier is provided between the two entering gates of Rajindra hospital of about 215 m all along parallel to the highway. Certain regulatory measures will also be useful for attenuating more noise level. A strict implementation of smooth traffic flow would lead to a substantial improvement in the noise environment at the emergency ward entrance. Blowing of horn should be strictly prohibited, no overtaking of vehicles should be allowed in any circumstances. This would obviate of unnecessary acceleration, a speed limit zone be provided and make sure that people follow it strictly and the heavy vehicles like buses and trucks be rerouted, if possible will be very useful for attenuating noise if strictly implemented.

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Nomenclature

A	=A – Weighted Level
CPCB	=Central Pollution Control Board
dB	=Decibel
FHWA	=Federal Highway Administration
I.L.	=Insertion Loss
kHz	=Kilo-Hertz
L_{eq}	=Equivalent Sound Pressure Level
L_I	=Sound Intensity Level
L_{max}	=Maximum Sound Pressure Level
L_{min}	=Minimum Sound Pressure Level
L_p	=Sound Pressure Level
N	=Fresnel's Number
NRC	=Noise Reduction Coefficient
p	=% of Truck Traffic Ratio
Pa	=Pascal
Q	=Traffic Volume
SPSS	=Statistical Package for Social Sciences

Greek Symbols

δ	=Path Difference
λ	=Wavelength

Chapter 1

Introduction to Noise

1.1 Introduction

Noise is one of the developing problems in our modern society. Regular exposure to an extreme noise causes the risk of permanent loss of hearing [1]. Throughout the world government has made many laws for securing the health status of employees by providing them healthy and satisfactory working conditions and expelling out unsafe practices. By keeping in view the environmental safety, the work atmosphere should be planned and established. In this connection safety also implies that noise is kept at an intensity which is not likely to cause health issues.

The safety organizations should have to play role in measurement and control of noise and take initiation in planning of innovative work methods and processes.

A noise control program should include the following:

1. Preparing a noise map after making measurement in all areas
2. Setting target noise levels for all areas.
3. A description of all measured planned, cost analysis, and the attenuation expected.
4. Setting priorities within the plan to attain the agreed target, stating start and end times.

1.2 Sound and Noise

Sound is a physical disturbance in the medium i.e. gas, liquid or solid that can be detected by human ear. The medium through which sound waves travel must have mass and elasticity. Hence sound waves will not travel through a vaccum. Sound waves in air are caused by variations in pressure above and below the static value of atmospheric pressure i.e. approximately 10^5 Pascal's. Therefore Sound is a wave motion which occurs when a sound source sets the nearest particle of air into motion. Sound propagates in the air with a speed of approximately 300 m/sec, in liquids 1500 m/sec (water), in solid 5000 m/sec (steel). [1]

Noise is causing a serious problem to industries, residential areas, near highway because of its effects on human's health and their environment.

The major issues of the noise are:

- industrial noise
- traffic noise
- community noise

1.3 Noise and Man

The advancement of society is giving rise to latest sound sources that are producing higher and higher noise levels. Noise is one of the most broadly and most commonly. Noise affects man physically, psychologically and socially. Noise can

- harm hearing
- hamper in communication
- cause sleepiness
- lessen efficiency
- Causes headache, nausea and general feeling of uneasiness

Living in noisy surrounding for a longer period of time can cause serious effects on hearing sensitivity organs of the inner ear that will lead to permanent loss of hearing capability of a person. The risk of hearing loss also increases with the increase in sound level.

After spending a short period in extreme noise and then moving to a calm area can make it very difficult to hear quiet sounds. This form of hearing loss is called temporary loss. The normal hearing returns after a period of time. The audible frequency range detected by human ear is 20 Hz to 20 kHz. A sound wave with frequency more than 20 kHz or less than 20 Hz has no significant effect on the body. [1]

It is not only hearing which can be influenced by intense audible noise, noise can also influence blood circulation and cause stress and other psychological effects. Industrial noise is often associated with other problems of the industrial environment, air pollution for example, having joint effects on health and well- being.

In order to carry out conversation, the level in a place can be at most 65 to 70 dB (A). It is known though, that sound levels about 100 dB can give rise to headache and tiredness.

Limit of work generally varies from 85 dB(A)to 90 dB(A) averaging in day for 8 hours. According to ISO time spent in a noise environment to be halved for each 3 dB rise in noise level above set limit. If the 8 hour is set at 90 dB(A) then, for example, 93 dB(A) exposure is allowed for 4 hours. [4]

1.4 Noise Sources

There are two types of sound sources

- Point source
- Line source

1.4.1 Point Sources

A sound source can be considered as a point source, if its dimensions are small as compared to distance to the receiver and it radiates an equal amount of energy in all directions. Typical point sources are industrial plants, aircraft and individual road vehicle. The sound pressure level decreases 6 dB whenever the distance to a point source is doubled. [2]

1.4.2 Line Source

A line source may be continuous radiation, such as pipe carrying fluid, or may be composed of large number of point sources so closely spaced that their emission may be considered as line connecting them. The sound pressure level decreases 3 dB, whenever the distance to a line source is doubled. [2]

1.5 Decibel

The intensity of sound is normally presented as a sound level using the unit decibel, dB. A sound level change of 1 dB can just be detected by the human ear. If a sound level is increased by 10 dB anywhere within the range of hearing the ear perceives it as a doubling its loudness. A drop of 10 dB is similarly perceives as a halving in loudness. Loudness is the subjectively perceived attribute of sound which enables a listener to order their magnitude on a scale from soft to loud. [2]

1.5.1 Decibel Scale

Sound pressure is measured on a logarithmic scale known as the decibel (dB) scale. On this scale, a value of 0 dB(A) is equal to a sound pressure level (SPL) of 20 μPa.

- 0 dB(A) is the threshold of hearing for most humans.
- A value of 140 dB(A) is threshold of pain

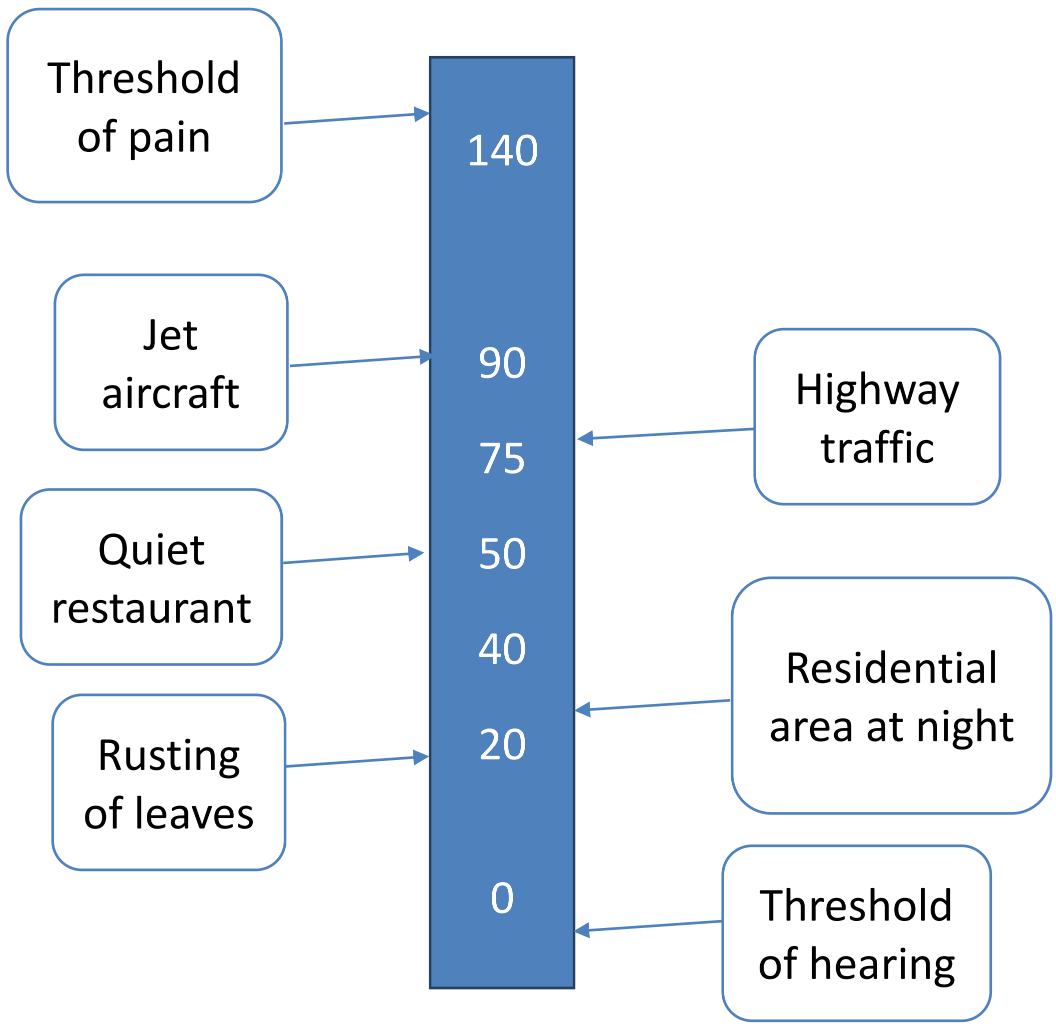


Figure 1.1: Decibel Scale [2]

1.6 Some Acoustic Concepts

Some properties of sound are discussed below:

1.6.1 Frequency, Hertz

The sound wave frequency expresses the number of vibrations per second in units of hertz; Hz. Sound exists over a wide frequency range. Audible sound for young people lies between 20 Hz to 20 kHz. Sound with frequency under 20 Hz is called infrasound and sound over 20 kHz is called ultrasound. [2]

1.6.2 Amplitude

The amplitude represents the strength of sound wave. Greater disturbance at the source will results to greater strength of wave and greater amplitude. [2]

1.6.3 Pure Tones

A pure tone is a sound wave with single frequency whose position is the frequency and height is the sound level. A musical note contains many pure tones with different frequencies and intensities. [2]

1.6.4 Sound Level Measurement

When measuring the intensity of a sound, an instrument which duplicates the ear variable sensitivity to sound of different frequencies is usually used. This is attained by building a filter into the instrument with a similar frequency response to that of the ear. [2]

1.6.5 A- Weighting Filter

The filter used in sound level measurement is -weighting filter. Measurements with this filter are called A-weight d sound level measurements. This is called a-weighted filter because it conforms to the international standardized A-weighting curves. The A-weighting filter emphasizes the frequencies between 1 kHz and 6.3 kHz, in an effort to simulate the relative response of the human ear. [2]

1.6.6 Sound Pressure Level

The amplitude of a sound wave can be quantified by measuring the associated pressure disturbance. In other words we need to measure the change in pressure from its ambient value. This change in pressure is termed as acoustic pressure [2]. The sound pressure level ($L_{p)}$ in decibels, corresponding to a sound pressure (p), is defined by

$$L_p = 10log_{10}\frac{p}{p_o}$$

p= Sound pressure

p_o= Reference sound pressure (20 µPa)

1.6.7 Equivalent Sound Pressure Level

The sound from noise sources generally fluctuates throughout a given period of time. An average value can be measured, the equivalent sound pressure level (L_{eq}). The L_{eq} is the equivalent continuous sound level which would deliver the same sound energy as the actual fluctuating sound measured in the same time period. [2]

$$L_{eq} = 10log\frac{1}{T}\int\frac{p^2}{{p_o}^2}dt$$

Leq = Equivalent sound level (dB)

T = Time period(s)

P = Sound pressure (Pa)

P_o = Reference sound pressure (20 µPa)

1.6.8 Sound Intensity Level

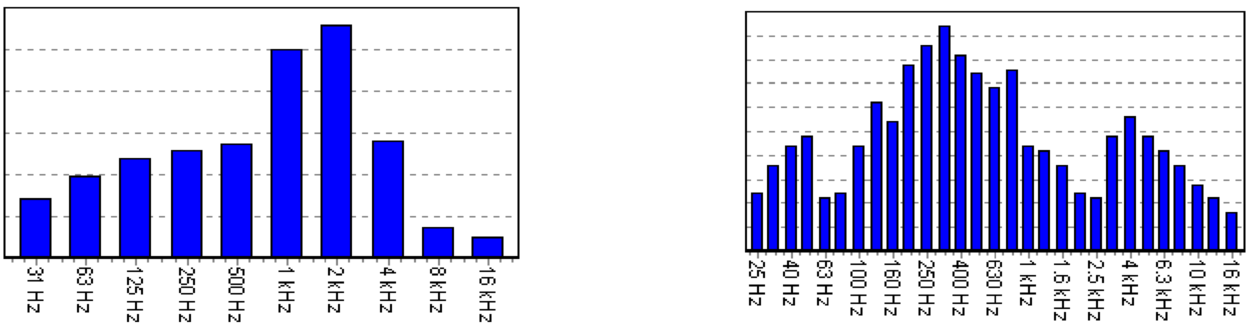
Sound intensity level (L_I) in decibels is equal to 10 times the ratio of sound intensity (I) to the reference sound intensity (I_o). [2]

$$L_I = 10log_{10}\frac{I}{I_o}$$

Where $I_{o\,=}\ 10^{-12}$ W/m^2

1.6.9 Octave Band Filters:

For detailed investigation of complex sound, the frequency range of 20 Hz to 20 kHz can be split into sections or bands. This is done electronically within a sound level meter. These bands usually have a bandwidth of 1/1 Octave or 1/3 Octave. An octave band is a frequency band where the highest frequency is twice the lowest frequency. [2]



(a) (c)

Figure 1.2: Frequency Spectrum (a) 1/1 Octave band (b) 1/3 Octave band [W.2]

1.6.10 Addition of Noise

Noises from various sound sources jointly create a sound level higher than that from any single source. The dB values are not directly added as they are already logarithmic quantities. Addition of noise is shown in Table 1.1. Two equally strong sound sources together generate a sound level of 3 dB than one alone and ten equal sources produce a 10 dB higher sound level. [4]

Table 1.1 Addition of Noise [4]

When two decibel value differ by(dB)	**Add to higher value(dB)**	**Example (dB)**
0 to 1	3	50+51=54
2 to 3	2	62+65=67
4 to 9	1	65+71=72
10 or more	0	55+65=65

1.7 Sound Waves:

The dominant frequency of the noise produced by an impact is dependent upon the speed of the force, pressure or velocity change, which give rise to the noise. [1]

There are two types of sound waves:

- High frequency sound waves
- Low frequency sound waves

1.7.1 High Frequency Sound Waves:

A rapid change produces a shorter pulse which has higher dominant frequency e.g. when playing tennis the ball is in contact with the bat or table only for very short time. The dominant frequencies are therefore high. [1]

1.7.2 Low Frequency Sound Waves:

The longer they are in contact which has lower dominant frequencies e.g. when bouncing a basketball on the floor, the ball is contact with the floor for a relatively long time. The dominant frequency is therefore low. [1]

1.7.3 Characteristics of Sound Waves

- Slow repetitions give rise to low frequencies and fast repetitions give rise to high frequencies.
- Low frequency sound waves bend round obstacles and through openings. [1]

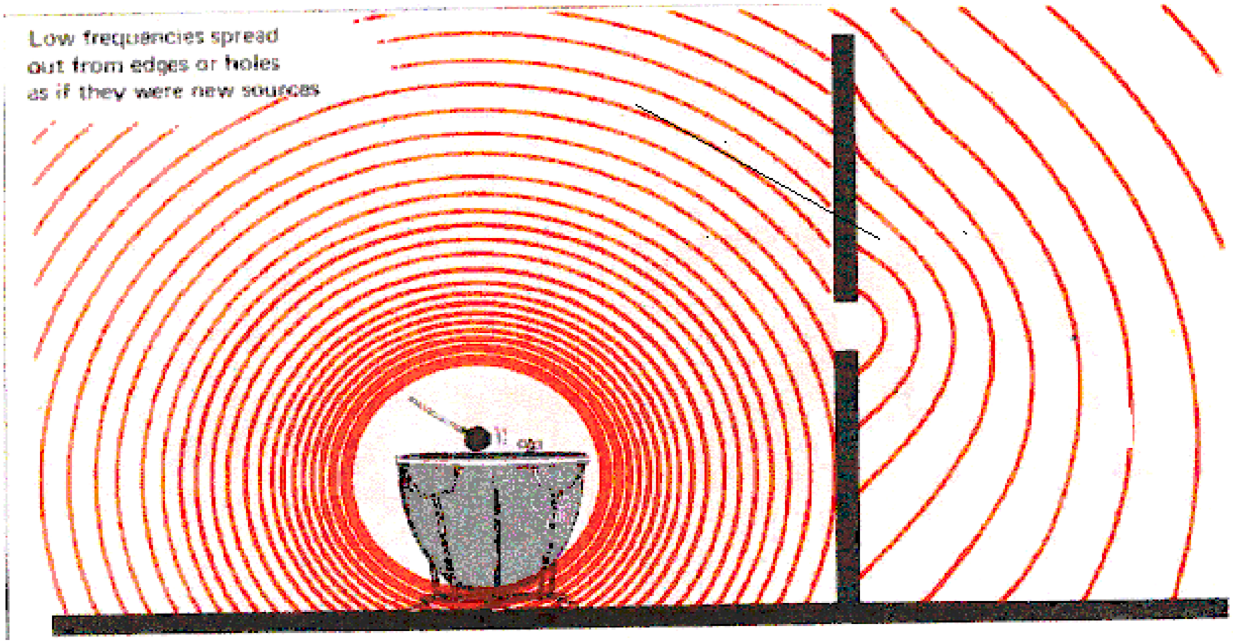


Figure 1.3: Low Frequency Sound Wave [1]

- High frequency sound waves are highly directional and easy to reflect [1].

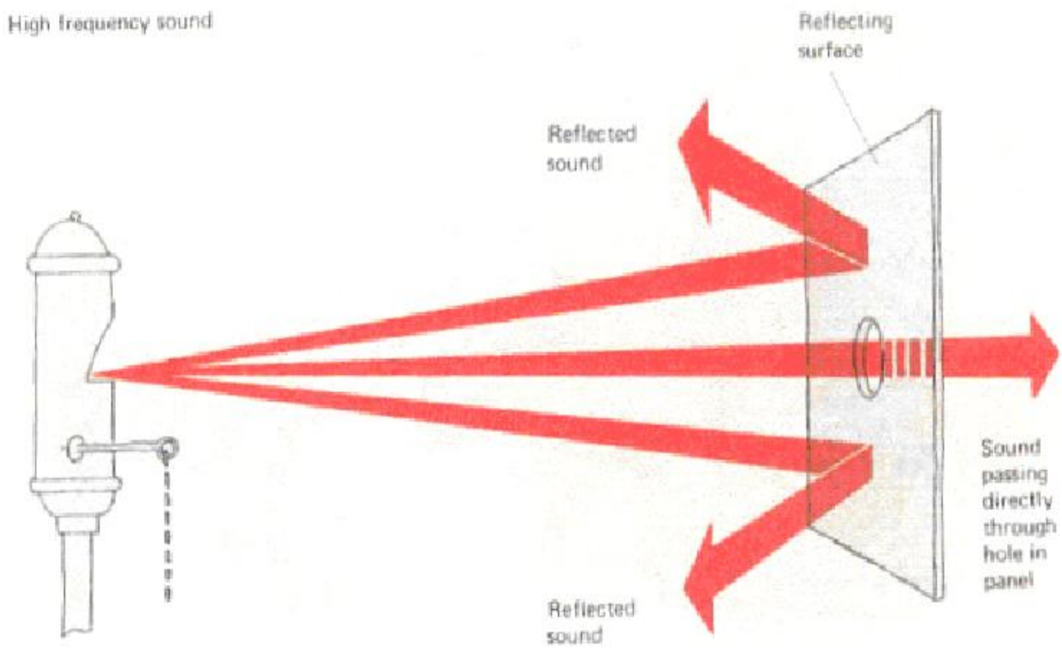


Figure 1.4: High Frequency Sound Wave [1]

- Close to the source high frequency noise annoys more than low frequency. [1]

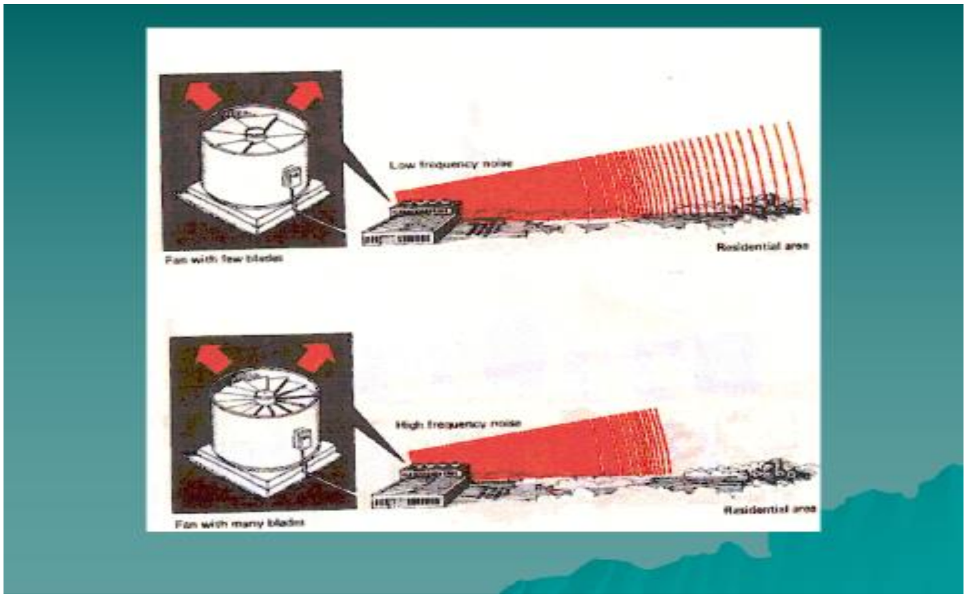


Figure 1.5: High Frequency Annoys More Than Low Frequency [1]

Chapter 2

Noise Control

2.1 Introduction

Noise control is the technology to achieve satisfactory noise environment that is economically and operationally reliable. The acceptable noise environment may be essential for an individual, a group of people, an entire community or a piece of equipment that can't work properly in extreme noise. [1]

2.2 Noise Transmission

The transmission of sound from a source to a listener is shown in figure. The source may represents not one, but many sources of noise e.g. all the vehicles on road in a particular region. The paths are numerous e.g. the listener hears a piano in the apartment overhead. Some of the sound may be transmitted to the listener along direct air path out of the window of the apartment overhead, along an outside path and through the listener's window called air-borne path. Some of the sound radiated by piano strikes the walls, forcing them to radiate sound called solid-borne path. Receiver may represent a single person, a group of people, an entire community or a piece of equipment whose operation is effected by noise. [2]

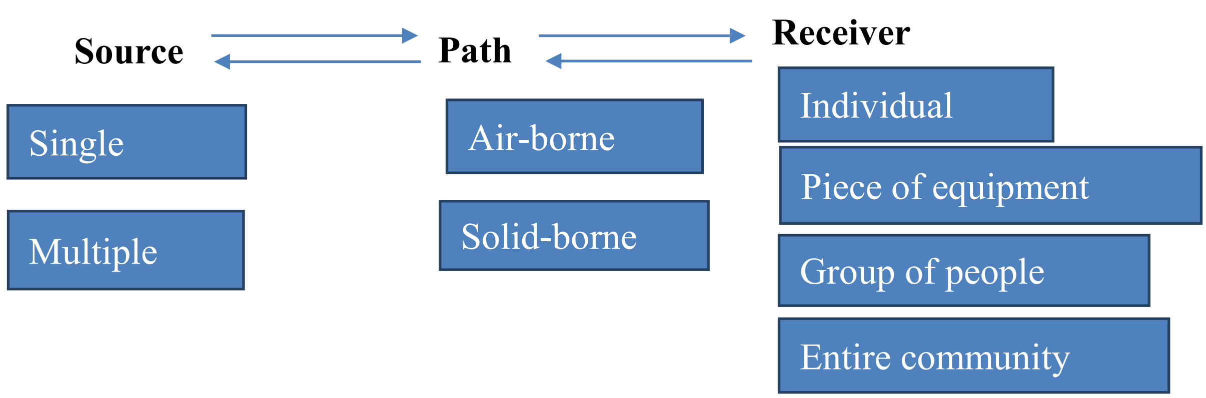


Figure 2.1: Noise Transmission [2]

2.3 Noise Control Techniques

There are various methods for controlling noise. These measures may be classified in three categories:

- Noise Control at the source
- Noise control of the transmission path
- Noise control at the receiver

Which method or which combinations of methods are employed depends on the amount of noise reduction that is required and on economic and operational considerations in solving a specific noise control problem. [2]

2.3.1 Noise Control at the Source

One important method of controlling noise at the source is to reduce the amplitude of the forces which result in the generation of noise, for example, by balancing rotating masses.

Another method is to reduce the motion of components which are set into vibrations; for example, the vibration of panels which are set into vibration may be reduced by application of vibration damping materials. Changes in the usual procedure of operation may be an effective noise control technique. [2]

Some factories, adjacent to residential areas, suspend or reduce noise operations at night, when the normal activity is a community diminishes; the factory noise becomes more noticeable.

2.3.2 Noise Control of the Transmission Path

Another general technique of noise reduction is that of controlling the transmission path so as to reduce the energy that is communicated to the receiver. This may be done in a number of ways: [2]

Siting: In the open air, maximum attenuation should be provided by increasing the distance between the source and the receiver. Since many noise sources do not radiate uniformly in all directions, by altering the relative orientation of the source and the receiver a considerable reduction in noise level at the receiver may be possible. A site should be chosen that will take advantage of the natural terrain to provide additional shielding of the receiver from the source.

Building Layout: The careful planning of the location of rooms within a building, with respect to the relative position of the noise sources and those areas in which quiet conditions are desired, may result in considerable economy by reducing the extent of the noise control measures that otherwise would be required.

Barriers: Barriers in the open air can be effective when they are large in size compared with the wavelength of the sound to be deflected. For example, barriers which make an angle of 45° with respect to the horizontal have been used in the noise field of jet air fact engines to reflect the high frequencies toward the sky.

Enclosures: Considerable attenuation may be provided by the use of a properly designed enclosure around a noise source or around the receiver.

Absorption: One of the most effective means of attenuating sound in its transmission path is by means of absorption. Suppose a number of machines are in a large office. Most of the noise from these sources that reaches workers on the opposite side of the room is reflected by the calling, walls, and the floor. Therefore the use of sound absorption in the form of acoustical materials on the ceiling provides attenuation in the path between the source and receiver. Such absorption also reduces the level of the sound which reaches the workers after a multiplicity of reflections from the walls, ceiling and floor.

2.3.3 Noise Control at the Receiver

The following noise- control techniques may be employed where the noise level at the receiver is excessive: [2]

Ear Protection Devices: Ear plugs, car muffs and helmets provide an economical means of reducing the noise exposure of industrial workers.

Booths: In many cases it is impractical or uneconomical to reduce the noise level to which a worker is exposed; it is better to provide a booth or partial enclosure for the worker.

Hearing Conservation Programs and Education: Education forms an important component of such a program. In some cities where noise has been a serious problem, both industrial and government installations have improved their relations with the community by interesting it in their noise problem and showing the community the constructive steps taken to minimize the disturbance.

Exposure Control: Under some circumstances it is impracticable to reduce extremely intense noise levels in areas where people must work to levels which are considered acceptable for the usual working period. A noise level that is not acceptable for a specific period of time may be acceptable for a shorter period. Therefore one noise control technique is the rotation of personnel so that work assignments in the intense noise area are of a limited period of time.

2.4 Introduction to Acoustic Barrier

A sound barrier is any solid obstacle that blocks the line of sight from sound source to receiver. Therefore sound barriers reduce the noise level which arrives at receiver. Noise barriers reduce the sound which enters a community by absorbing it, transmitting it, reflecting it back, or forcing it to take a longer path. This longer path is also named as diffracted path. Barriers can be used outdoors for reducing noise entering in the sensitive land use areas like residential area, hospital area, libraries, and parks. Traffic noise can be effectively shielded by barriers. The use of barriers is mainly suitable when it is not possible or would be too expensive to reduce noise. The first type of barriers to be presented is flat or vertical barriers also known as regular noise barrier.

Modern barriers are modified versions of the regular barrier and these barriers can be absorbing, tilted, multi-edge profile. Some have specially formed tops such as random edges or forming a T-, L-, Y- or Q-shape. For each of the above mentioned barrier types, a summary of the study is presented and the barrier performance expressed in dB, important considerations that have to be taken into account in order to benefit from any noise barrier. These are for example the location of the barrier, its length, its cost and the influence of the atmospheric conditions.

Without a screen, the sound propagates directly between the source and the receiver. Figure 2.3 shows the direct path length c between the source S and the receiver R. When a screen is placed between S and R, the space is divided into two zones i.e. a brightened zone and a shadow zone. All observation points in the shadow zone perceive a reduction of the sound level while those in the illuminated zone get very little advantage from the barrier. [4]

2.5 Physical Principles of Noise Barriers

The introduction presents some basic physical principles of noise barriers. These are necessary to understand to know about the sound behavior around noise barriers and also to identify where an optimization of such barriers is possible. [4]

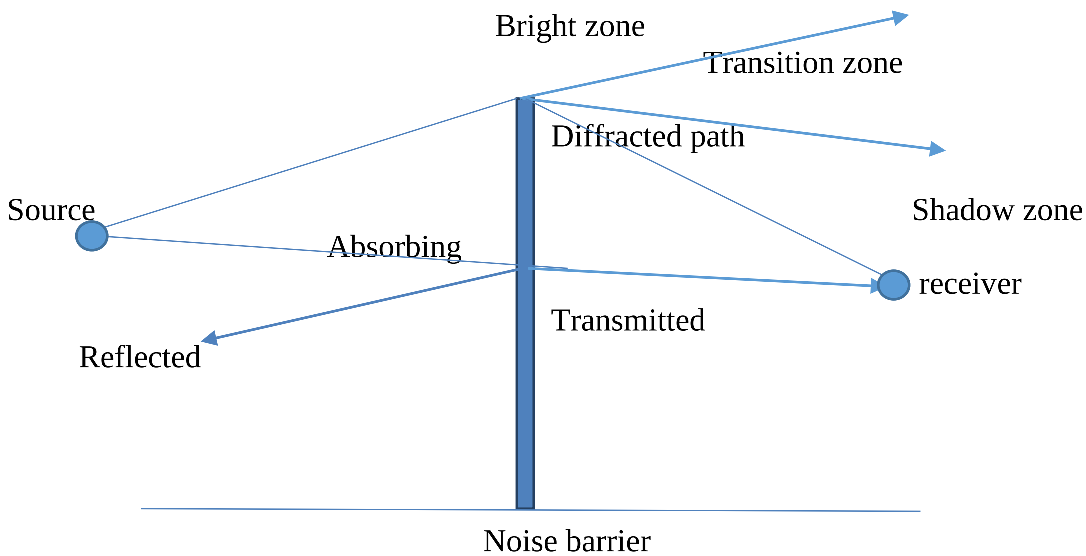


Figure 2.2: Barrier Absorption, Transmission, Reflection and Diffraction[4]

2.5.1 Path Length Difference

The noise reduction in the shadow zone depends on the difference between the direct path length (c) and the indirect path length (a+b) travelled by the sound between the source and the receiver. This path length difference is denoted $\delta = a + b - c$ [4]

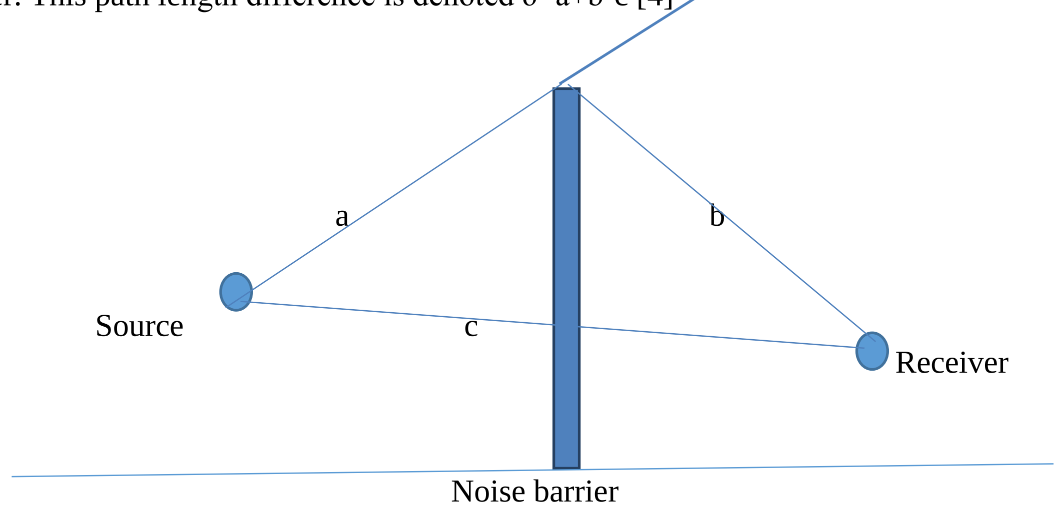


Figure 2.3: Path Length Difference [4]

2.5.2 Barrier Insertion Loss

Another important concept to understand is by dB the sound level is dropped at a specific observation point when building a screen. In other words, how large is the screen effect in dB. This is called the barrier Insertion Loss and is calculated as [2]

$$IL_{barrier} = L_{p\,(before)} - L_{p\,(after)}$$

2.5.3 Fresnel's Number

The sound is actually made of different frequencies which do not react the same way when encountering a noise barrier. It is used in predicting the attenuation provided by a noise barrier positioned between a source and a receiver. The acoustic performance of a noise barrier can be defined in terms of the Fresnel number The Fresnel Number is computed as follows:

$$N = \pm 2\frac{\delta}{\lambda}$$

Where δ is defined above and λ is the wavelength of the sound in air. With this Fresnel number it can be seen that the lower the frequency, i.e. the longer the wavelength, the lower N. In other words, noise barriers are less effective for low frequency noise. [2]

2.5.4 Diffraction

The bending of sound waves around an obstacle, can occur both at the top of the barrier and around the ends. Higher frequencies are diffracted to a lesser degree; while lower frequencies are diffracted deeper into the "shadow" zone behind the barrier. Therefore barriers are more effective in attenuating higher frequencies. [4]

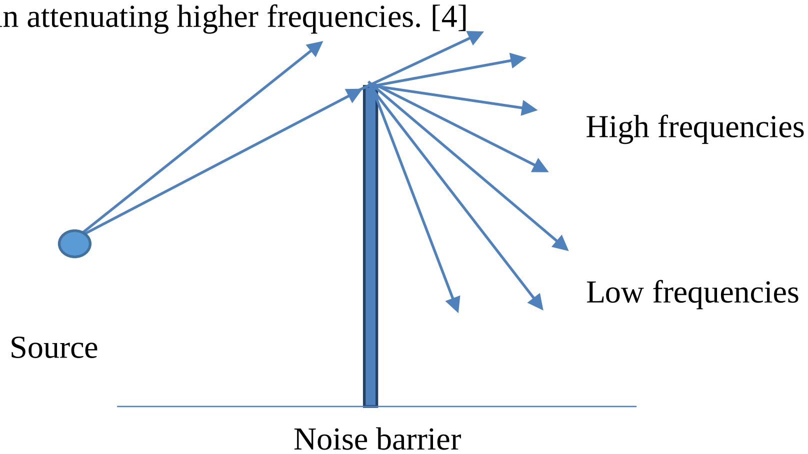


Figure 2.4: Barrier Diffraction [4]

2.5.5 Barrier Absorption

The amount of incident sound that a barrier absorbs is typically expressed in terms of its **Noise Reduction Coefficient** (NRC). NRC is a number which is the average value of the absorption coefficient of the material at different frequencies. Absorption coefficient of a material is a measure of sound absorptive property of a material. NRC values can range from zero to one; where zero indicates the barrier will reflect the entire sound incident upon it and one indicates the barrier will absorb the entire sound incident upon it. [4]

2.6 Types of Acoustic Barriers

- Thin Barriers
- Thick Barriers

2.6.1 Thin Barriers

A thin barrier is one that attenuates the sound by single diffraction. A solid fence, of the type usually constructed to be a noise barrier and a free standing wall are examples of thin barriers. The barrier thickness of thin barriers is less than 3 m (10 ft). [2]

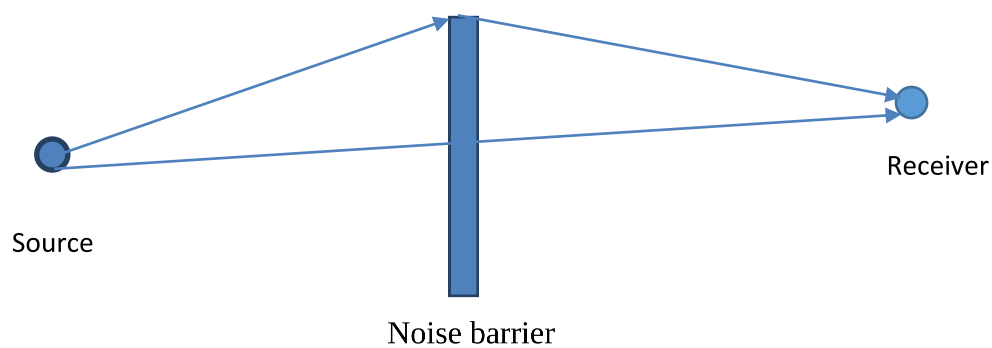


Figure 2.5: Thin barrier with single diffraction [2]

2.6.2 Thick Barriers

A thick barrier is one that attenuates the sound by double diffraction. A building or an earth berm is the examples of the thick barriers. The barrier thickness of thick barriers is not more than 3 m (10 ft). [2]

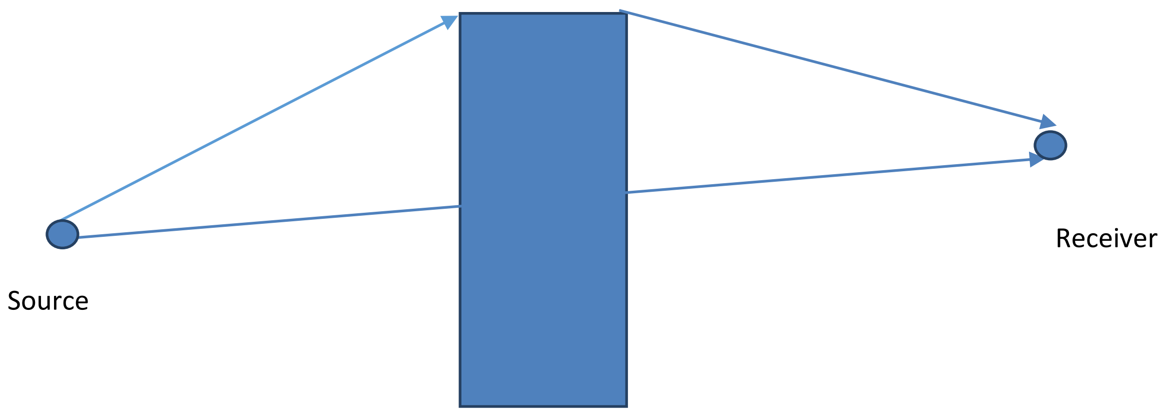


Figure 2.6: Thick barrier with double diffraction [2]

2.7 Other types of Acoustic Barriers

Few more types of barriers are discussed below: [4]

2.7.1 Earth Berms, Walls

Earth berms are mounds or embankments of earth created along a highway to block the line-of-sight between the highway and noise sensitive areas such as residential housing, schools, hospitals, etc. The mass of the berm effectively attenuates the transmission of sound. Similarly, solid walls placed along a highway reduce the noise level on the receiver side of the wall. Walls are the most common method of highway noise abatement and have been constructed from a variety of materials.

2.7.2 Ground-Mounted

Ground-mounted noise barrier systems are barriers constructed into or placed on top of the ground. Three basic types of ground-mounted noise barrier systems:

- **Noise berms:** - Noise barriers created from natural earthen materials such as soil, stone, rock, rubble, etc. in a natural, unsupported condition are termed, noise berms. These types of barriers are typically constructed with surplus materials available on the project site or from materials transported from an offsite location. The source and accessibility of such material are factors which can considerably affect the cost of such systems. Noise berms normally engage more space than a wall type of barrier.

- **Noise walls**: Most noise wall systems are fabricated off-site; i.e., all of the components for this type of noise wall (foundation components excluded) are fabricated in a plant, then transported to the project site, and assembled on-site. Noise wall systems fabricated on-site include only cast-in-place concrete walls.
- **Combination noise berms and noise wall systems:** Many noise barrier systems include a portion of the barrier height obtained through use of an earth berm with the remainder of the required height achieved by placing a noise wall on top of the berm.

2.7.3 Structure - Mounted

The types of noise walls used on structures, the concerns related to structure-mounted noise walls, and the general design and construction techniques used to address these concerns. There are two primary types of structure-mounted noise walls:

- **Noise walls on bridges**: A number of techniques have been successfully employed to attach noise walls to bridges
- **Noise walls on retaining walls:** Retaining walls are typically constructed to retain a highway fill section (where the adjacent ground is lower than the highway grade) or to retain the adjacent ground (where the highway is in cut in relation to the adjacent ground). In either case, the possibility exists that the installation of a noise barrier wall may be warranted either as a part of the retaining wall.

2.8 Tops of Barriers

There are few researches regarding varying the shape of the top of a barrier for the aim of reducing its height and possibly attaining the attenuation characteristic of a larger barrier. The technical motivation is that additional reduction can be achieved by increasing the number of diffractions occurring at the top of the barrier. The top of barrier may be of following type. [4]

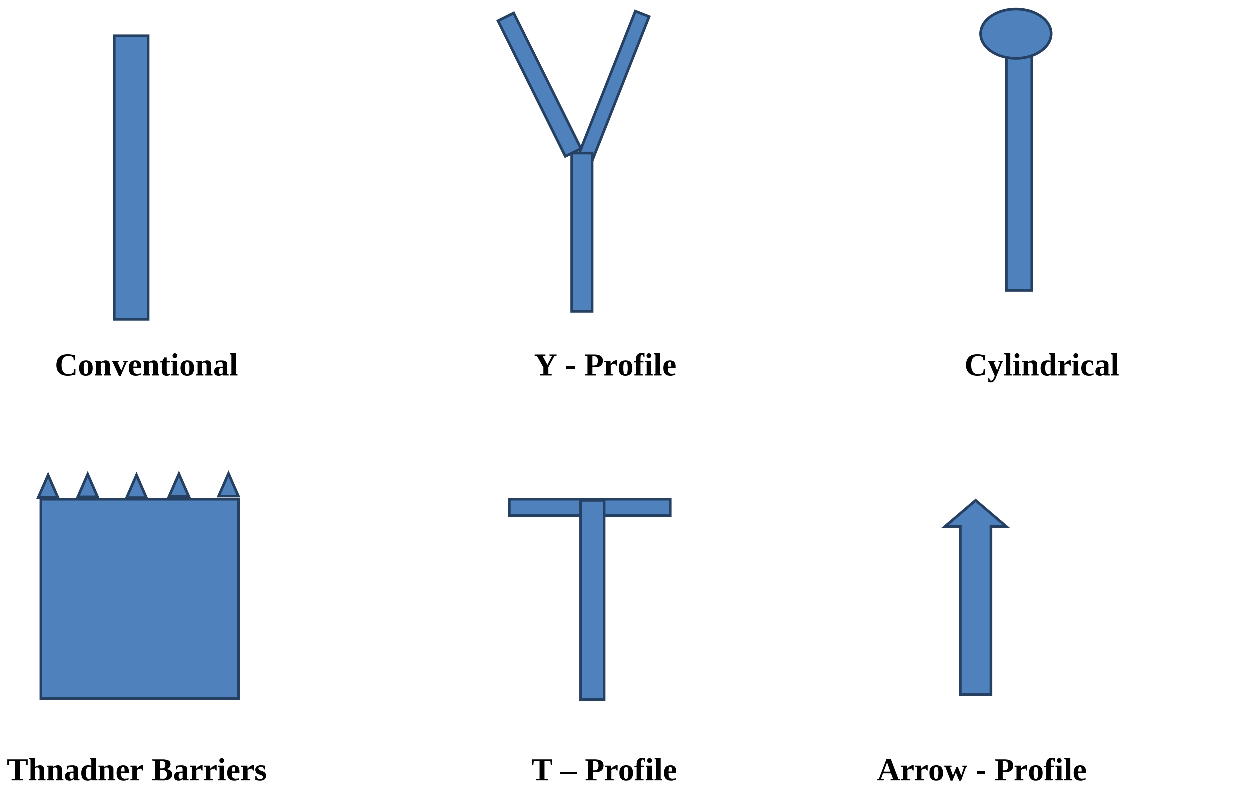


Figure 2.7: Tops of Barrier [4]

2.9 Noise Barrier Materials

- Concrete
- Brick and Masonry Block
- Metals like steel, aluminum and stainless steel
- Wood, Plastics, Recycled Rubber
- Glasses
- Composites in which product composed of two or more primary materials, such as or wood mixed with concrete. [4]

Chapter 3

Literature Review

3.1 Introduction

In our modern world with rapidly expanding environment one of the developing problem is that of noise. Noise control is the technology of obtaining an acceptable noise environment. Noise barriers are one of the most effective ways to reduce road traffic noise. Noise barriers reduce the sound which enters a community by absorbing it, transmitting it, reflecting it back, or forcing it to take a longer path. To understand the phenomena of barriers researches has been carried out.

3.2 Literature Review

The following are the gist of various researches:-

G.F. Butler has given a suggestion for improving attenuation provided by acoustic barriers [5]. He used absorbing material at the edges of the barrier which helps to absorb the energy of sound rays. Absorbing material was used only at edges because of high cost of construction and maintenance of the barriers constructed with completely absorbent material. The attenuation provided by barrier with absorbing edges up to 5dB.

G. R. Watts described the performance of an existing barrier can be improved by attaching multiple edge profile at the top of the barrier [6]. The performance was improved because of decrease of sound energy of sound waves passing over the top of the barrier and diffracted in the shadow zone behind the barrier due to multiple edges attached at the top of barrier. The performance was improved over 3dB of simple barriers.

G.R. Watts et al**.** improved the performance of existing barrier [7]. They added a Sound interference type barrier profile to existing noise barrier to improve its performance. The performance was improved due to extra distance travelled by sound rays because of interference type barrier profile as compared to existing barrier. The performance was improved by 1.9 dB (A) when compared with a simple barrier of same height.

E.V.Haaren et al. described that ray acoustics can be used to investigate the effectiveness of noise barriers [8]. They used four types of barriers which were both absorbing and reflecting and a high speed train as a source. Insertion losses up to 15 dB (A) was obtained. The result was depending upon number of rays and order of reflection. He found that the difference was 0db to 3db between the numerical results were compared with the experiment results. Therefore ray acoustic can be the effective tool to investigate noise barrier.

G.R.Watts et al. investigated the effects of sound absorptive material in noise barriers on roadside noise[9]. Sound absorptive materials used for reducing noise reflected from noise barriers and also increased the effectiveness of barrier. Two sites were chosen where a noise barrier had been established. At one site 3.7 m high barriers had been established on both sides of the road and at the other site a single 3 m high barrier had been established. Both barriers were manufactured with identical material. Traffic face of barriers was highly absorptive but other side of barriers was reflective. Measurements of traffic noise were made close to the roads both behind and opposite the barriers and then measurements were repeated after the sides of barrier had been reversed such that the reflective side faced the traffic. It was found that at both sites there was an increase of noise of generally less than 1 dB when the barrier face was changed from sound absorptive to reflective. Predictive models had overestimated the effect of absorptive barriers.

W. F. Cheng et al. analyzed the performance of the inclined barrier [10]. The far side of barrier was tilted at 0º, 10º and 15º to the traffic road. The performances of tilted barriers were compared with the conventional barrier. The noise level was reduced by 4, 6 and 10 dB respectively. The problem of reflection noise was shifted to a higher receiver at angle10º, 15º.

H.P. Lee et al. compared the performances of straight edge barriers and random edge barriers with different profiles [11]. The result showed that the attenuation provided by random edge barriers were more than straight edge barrier. This attenuation can be increased by increasing jaggedness.

J. Foreseen et al. had taken measurements of noise reduction in the presence of atmospheric turbulence and that measurements were compared with the predicted data [12]. Atmospheric turbulence causes scattering of sound, which can reduce the performance of sound barriers. The data were recorded simultaneously under both calm and windy conditions. They found that noise level behind the barrier increases due to scattering of sound waves in the presence of atmospheric turbulence by comparing the measured and the predicted data which gives accurate results.

T.Ishizuka et al. tested the performance of fifteen barriers having different shapes and surface condition [13]. The heights and widths of the barriers were standardized and the insertion losses for six receiver positions were averaged and compared. They found that 3m high soft T-shaped barrier gives the highest performance. Its performance was same as a 10 m high plain barrier. It had also shown that absorbing and soft edges improve the efficiency of the barrier.

A.Shukla et al. conducted an experimental study to determine the effect of cenospheres [14], on the acoustic properties of cement matrix and asphalt concrete. Cenospheres are hollow spherical particles formed during the coal burning process when gaseous trapped in a viscous molten medium. This study was conducted to develop lightweight sound absorbing material. Different volume fractions of cenosphere with varying diameter and thickness were added to cement and asphalt concrete to determine their acoustic characteristics. In results it was shown that sound absorption coefficient of cement increases when volume fraction of cenosphere increased from 0% to 40 % but further increase in volume fraction of cenosphere decreases the sound absorption coefficient of cement. As compared to cenosphere rich cement, the sound absorption coefficient of asphalt concrete decreased with an increase of cenosphere volume fraction. The decrease was due to the spherical shape of cenosphere as they slip into the voids and reduce the number of pores in the asphalt concrete.

Y.W. Lam et al. investigated the acoustic performance of T-shape noise barrier with different absorbing materials on the top [15]. The absorption properties of the diffusers were modified with different sequences, by filling the wells with fiberglass, by covering the well entrance with wire meshes, and by putting perforated sheet either on the top surface or inside the wells. The numerical and experimental results on diffuser barriers with rigid and absorptive covers were compared. Among the tested models the best method of treating diffuser barriers with absorbent agents to be a perforated sheet on top or inside the diffuser wells. It was found that by increasing the absorption ability of fiberglass or high resistance wire meshes had negative effect on the efficiency of a barrier. It was shown that, if the increase in absorption destroys the effect of resonance in wells, it will also have negative effect on the insertion loss performance of the barrier.

C.Cianfrini et al. had done an experimental verification of the acoustic performance of diffusive roadside noise barriers and that performance was compared with the reflecting barriers [16]. The attenuation had increased not only in the shadow zone but also in the unprotected zone i.e. immediately above the barriers. The performance was increased because of decreasing the multiple reflections in diffusive barriers.

N.Han et al. applied absolute value of sound intensity instead of sound pressure in Active noise control systems to increase the insertion loss of noise barriers [17], sound pressure was used in previous works. The absolute value of the mean active sound intensity was chosen to obtain extra sound insertion loss in the dark area of a hybrid active noise barrier system. In this strategy by minimizing near-field sound intensity at discrete locations, far-field noise reduction can achieve which was more than that of sound pressure control. Results show the active sound intensity control was able to provide better far-field noise reduction than the squared sound pressure control. Further research should be paid on practical implementation of the intensity control systems.

M.Baulac et al. improved the acoustical efficiency of T-shaped noise barriers whose top is covered with a series of wells [18]. The shape of the protection i.e. the depths of the wells on the top and the flow resistivity of absorbing materials were considered to improve the performance of barrier. The results show that the efficiency of such barriers increases with the number of wells considered on the top surface. The improvement in global efficiency compared with a flat top surface T-shaped barrier can be up to 2–3 dB(A) for 5 – 9 wells.

S.K.Lau et al. described the performance of a noise barrier within an enclosed space [19]. A new method was proposed that incorporates the effect of two theories i.e. classical diffuse field theory and ray tracing method. The classical diffuse-field theory in which the barrier was considered to divide the original room into two rooms that was acoustically coupled by the energy that passes over and around the barrier edges and room surfaces. The ray tracing method in which the sound waves were assumed to behave as light rays. Acoustic rays are reflected by solid surfaces, losing energy at each rebound due to surface absorption. Therefore a new method was proposed that incorporates the effects of both theories between room surfaces.

K.M.Li et al. presented theoretical and experimental studies for the acoustic performance of parallel absorbent noise barrier [20]. The addition of sound absorption materials at the inner surface of barrier improved the performances of the parallel noise barriers in the shadow zone. This improvement was insignificant above the barrier.

D.Greiner et al. modified the shape of the Y barrier to minimize the sound level. Reduction of noise and cost of the barrier were considered [21]. A noise barrier was situated between fixed position sound source and receptor. The barrier shape was modified to minimize the sound level at receptor. Two successive improved shapes of Y-barrier were obtained which had 15% and 30% improved performances.

H. S. Yang et al. determined the acoustic effects of green roof systems [22]. In this study, a series of measurements were carried using green roof systems. The results showed that such green roof systems can reduce SPL effectively at the receiver side. By adding leaves on the green roof there is only a small noise reduction but if optimized absorption treatment, noise reduction up to 4 dB (A) can takes place. The position of the green roof system affected the pattern of SPL reduction differently at different frequency ranges.

S. Grubesa investigated the performance of noise barriers that had surfaces inclined towards the noise source and the surface facing away from the noise remains perpendicular to the ground [23]. The results showed that the inclined barriers attenuate 1dB lower than T-shaped barrier. The addition of absorptive materials on the barrier surface did not improve the insertion loss, and in reality it would only increase the production costs.

S. K. Lau conducted a study to minimize acoustic pressure with linear array of control sources and a perpendicular linear array of error sensors which were placed on the top of a noise barrier [24]. An additional reduction of acoustic pressure in shadow zone was founded because of spacing of the linear control sources and error sensors and particular angular orientation. Two error sensors were more effective than single error sensor. Therefore by utilizing two control sources and places error sensors in line with the diffracting edge will realize Active Noise control capabilities over a wide frequency range. This strategy is used to create quiet zone near the barrier. More reduction of acoustic pressure is possible by increasing number of control source.

A.L. Rahman et al. had given a review on attenuation of noise by using absorption material and barriers [25]. In the review he had given an introduction on synthetic and organic materials for acoustic absorbers. The synthetic material causes many problems in health therefore organic materials such as agriculture waste can be used as absorbing material which will provide good health and also promote agriculture. They suggested that date palm fiber as a absorbing material become the new area of study to reduce noise level.

F. Koussa et al. estimated the acoustic performance of conventional and low height gabions noise barriers[26]. Situ and scale model measurements at a scale of 1:10 had been carried out to assess the basic acoustic properties of a 3 m high gabions barrier. There was a good agreement between these two measurements which results that noise gabions protections can be significant for environmental noise reduction. Low height gabions noise barriers was effective only for receivers of limited height and the insertion loss values can reach 8 dB(A) behind the barrier. Natural gabions noise barriers can be useful in reducing transportation noise in urban area. The implementation and maintenance of gabions is very easy.

J. Y. Hong et al. investigated the noise barrier performance of five different barriers types: aluminum, timber, translucent acrylic, concrete, and vegetated barriers [27]. The main aim of the study was to increase the use of environmental noise barriers because noise pollution had an adverse effect in the environment grow. These five barrier types were taken in a real urban environment and the noise reduction of these five barrier types were predicted. The results of the experiments shown that low frequency component had a dominant effect on noise attenuating performance of barriers. It was shown that noise barrier performance according to the barrier material significantly affected the environmental quality at 55 dB(A) . In addition, vegetation cover had a significant effect on noise barriers. The findings suggest that using vegetation to cover barrier could be a practical means to improve overall environmental quality and also improve noise barrier performance.

G. H. Yoon et al. studied the optimal material distributions of rigid and porous materials for noise barriers [28]. Acoustic topology optimization techniques were used previously to obtain the topological design result of noise barrier only for rigid materials. Some optimization examples with different acoustical conditions and design requirements were investigated. This research applied acoustic topology optimization method to the optimal design of noise barriers considering both rigid and porous materials. T-shaped noise barrier is used for better barrier performance. Some relevant research had studied the attachment of diffusers or porous materials at the top of the T-shaped barrier. It was found some noise barriers were optimized for various geometric and environmental conditions by applying the present acoustic topology optimization approach.

T. V. Renterghem et al. analyzed various ways of reducing transport noise by natural meansm[29]. They include vegetated surfaces applied to faces or tops of noise walls and on buildings and roofs, gabions, vegetation belts like tree belts, earth berms for noise abatement. The ideas presented had been tested in the laboratory to assess or develop the noise abatement they could provide. Some situ experiments were also discussed. Such natural devices had the potential to reduce transport noise if they were designed well. Their applicability strongly depends on the available space reserved for the noise abatement and the receiver position.

3.3 Literature Gap

- Barriers studies are not much available for Indian conditions.
- Acoustical design of barriers using nomograph has not been studied for Indian conditions to get a desirable quiet environment.

Chapter 4

Experimentation

Noise is one of a very great problem in our modern society. In India, the traffic Noise increases day by day as number of vehicles increases on highway. Therefore traffic noise is the main source of noise in India. Noise affects people health and interferes in communication. Noise studies and noise abatement standards are prepared to protect the health and safety of people.

4.1 Noise Limits

Some noise limits have been given to maintain the noise level at a specific place according to the importance of that area. These standards are shown in Table 4.1 and Table 4.2

Table 4.1: Noise limits published by Central Pollution Control Board in year 2000 under environment pollution act (1986) [W.5]

Category	Noise limits in dB(A) L_{eq}	Description of activity/category
A	75	Industrial area
B	65	Commercial area
D	55	Residential area
E	50	Silence Zone includes 100 meters around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority

The Federal Highway Administration regulations state has been given noise levels for certain site conditions. The Federal Highway Administration (FHWA) is a division of the United States Department of Transportation that specializes in highway transportation. These are shown in Table 4.2

Table 4.2: Noise Abatement Criteria by FHWA (1972) [4]

Category	L_{eq} Equivalent sound pressure level	Description of category
A	57 (exterior)	Land on which serenity and quiet of extraordinary significance and serve as important public need and where preservation of those qualities is essential if the area is to continue to serve its intended purpose
B	67 (exterior)	Picnic areas, schools, libraries, churches, hotels, libraries, residences and hospitals
C	72 (exterior)	Developed lands
D	72 (exterior)	Undeveloped lands
E	52 (interior)	schools, libraries, churches, hotels, libraries, residences and hospitals

4.2 Noise problem at Rajindra Hospital

Rajindra hospital is one of the most popular hospitals in Patiala. The noise pollution in the hospital area is due to the vehicles traveling through the highway in front of the hospital. Traffic noise is further increase by bicycle traffic, pedestrian and local business. Hundreds of people visit every day, the road traffic produces noise which is annoying the people very much.

In general the noise inside the hospital is due to following causes:-

- Visitors conversation
- Road traffic noise around the hospital
- Noise of vehicles inside the hospital
- Noise due to chirping of birds

Although the noise level due to chirping of birds is sometimes as high as more than 65 dB (A), but it is not very annoying as it is the part of nature. No serious efforts may be made to reduce it. The noise due to visitor's loud conversation is very annoying. It can be controlled by suitable sign installed at number of sensitive places and proper direction to the visitors. Noise due to vehicles around the hospital is the main factor which increases the noise level inside hospital. Vehicles moving in low gears accelerating, horn blowing results into further noise pollution. Noise pollution inside the hospital due to vehicles running inside should be banned to reduce noise level.

Sometimes loudspeakers are installed near the hospital because of some local advertisement or strikes. These can be controlled as law already exists against the use of loudspeaker but it is not implemented properly. Use of loudspeakers around the sensitive area can be banned easily once a decision is made.

4.3 Objective

The source of noise within the hospital is partly due to the people conversation and partly due to the road traffic inside and outside the hospital. The recommended maximum noise level within area of 100 m around the hospital is L_{eq} = 50 dB(A) according to environment pollution act (1986).

The objective of this work is to measure the noise levels in and around the Rajindra hospital and if the noise levels are above the recommended level then to suggest ways and means to reduce the noise level. In this whole dissertation work concept of source, path and receiver plays a key role in proper analysis of problem.

4.4 Work Plan

It is necessary to establish the noiseless environment as much as possible at Rajindra hospital. Therefore the study consists of investigating the following aspects:

1. Detailed investigation of the noise level at the entrance of emergency ward and outside the hospital.
2. Measurement of noise levels L_{eq}, L_{max}, $L_{min.}$

3. All the above measurements to be repeated to cover variations on different days in a season.
4. Assessment of highway noise.
5. Undertaking traffic noise survey.
6. Establishing of different parameters affecting traffic noise.
7. Investigating of noise standards.
8. Formulation of mathematical model for noise prediction.
9. Study of noise control measures.
10. Acoustical design of barriers.

4.5 Vehicle Traffic Noise and its Characterization

Highway traffic consists of large number of vehicle of different types and classes. Highway noise is the noise produced at observer point by all these moving vehicles on highway. The overall noise is dependent on the characteristics of the vehicle flow and relative proportions of vehicle types included in the flow. Relative proportion depends on the type of highway and the time of day. Knowledge of these factors is thus necessary to define the characteristics of highway noise and to predict the associated noise level in the surrounding area. In the assessment of highway noise, it is acceptable and convenient to assume the main categories of vehicles i.e. automobiles and heavy trucks.

Automobiles include the motorcycles, cars and three wheelers having gross vehicle weight ratings of less than 4536 kg. Heavy trucks include buses and heavy trucks having gross vehicle weight ratings of more than 4536 kg.

4.6 Effects of Various Factors on Traffic Noise

Traffic noise that result from the vehicles flow on highway will be considered in writing environmental impact statement. The prediction of traffic noise is more complicated due to the fact that highways are not flat, straight or free from natural environment variations. The factors like vehicle speed, density, traffic mix, and width of median are not constant. Therefore, for traffic noise each of these parameters are to be taken into account. Traffic noise depends on the following factors: [2]

4.6.1 Traffic Parameters

i. **Traffic volume, Q:** The noise level near the highway depends on the number of vehicles. The noise level increases with an increase in traffic volume. Traffic volume is defined as the total number of vehicles flowing per hour. The numbers of vehicles passing through a fixed point on the road are to be counted. The traffic volume may be sub-grouped into heavy vehicles and automobiles for duration of 15 minutes. Several measurements of traffic noise are to be taken in different time slots from morning to evening.

ii. **% of Truck traffic mix ratio, p:** Trucks and buses are contributing more noise to the environment, when compared to automobiles. The ratio of heavy trucks and buses to total traffic is called truck traffic mix ratio. This is compute in terms of percentage. An increase in this ratio will increase the noise level.

iii. **Speed of vehicles, V:** If the vehicle is travelling within its limited range of road speeds, the noise produced is related to the engine, which would vary with each vehicle type. Many vehicles are either accelerated or de accelerated when passing the measurement position.

A video camera can be used to record traffic in the field and perform counts off-line at a later time. This approach, however, would require strict time synchronization between the acoustic instrumentation and the camera.

4.6.2 Roadways Characteristics

i. Pavement width
ii. Flow characteristics
iii. Gradient
iv. Surface finish

4.6.3 Observer Characteristics

i. Observer distance and relative height
ii. Element size
iii. Shielding

4.7 Analysis of Data

A relation is found to exist between two or more variables. The following steps are followed for the analysis of data:

Steps

1. Collect data showing corresponding values of variables.
2. Plot the graphs between Leq vs Log Q, Leq vs p; from the scatter diagram it is possible to visualize a nature of relationship between variables.
3. The problem of curve fitting can be carried out using linear regression analysis by software IBM SPSS. Mathematical equation, Leq can be developed by regression analysis.

4.8 Methods of Prediction

Various researchers had tried to estimate the traffic noise with the help of a mathematical expression in term of the various parameters. Basically two approaches had been used for predicting the traffic noise. [2]

1. Nomograph procedure
2. Computerized prediction

4.8.1 Prediction of Highway Noise by Nomograph

Nomograph procedure is valid for moderately high volume of freely flowing traffic on infinitely long, unshielded, straight, level roadways. A curved road may be considered to be straight if it deviates from straight by less than 10 percent of the observer distance "D" for a distance 5D from the nearest point. This acceptance adjusted in Figure 4.1

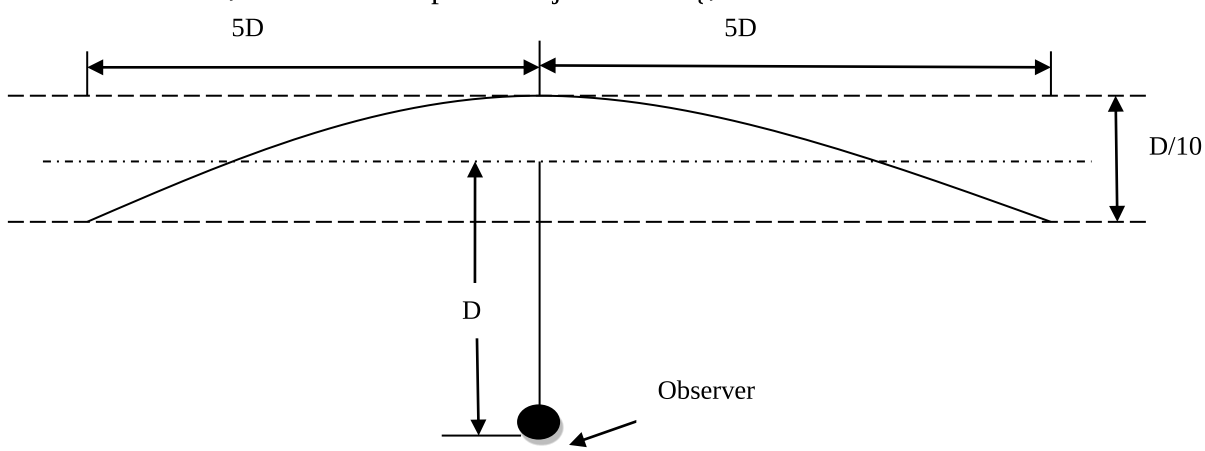


Figure 4.1: Permissible curvature for approximately straight road [3]

A curved road may be divided into two or more approximately straight segment as shown in Figure 4.2

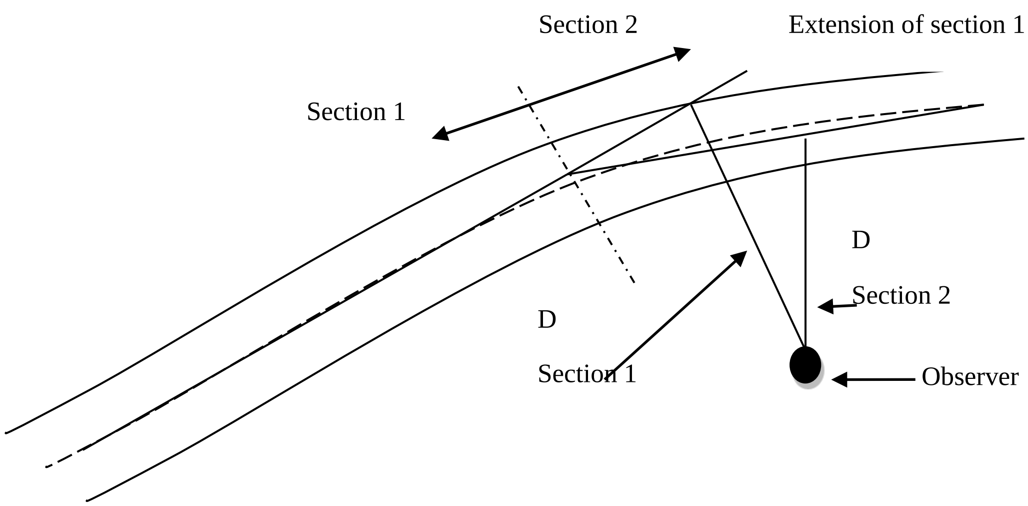


Figure 4.2: Curved roadways approximated by two straight sections [3]

If the highways are divided into sections then noise levels associated with each are combined as shown in following equation.

$$L_{10\ total} = 10 \log_{10} [10^{L_1/10} + 10^{L_2/10}]$$

4.8.2 Adjustment to the Nomograph

Road surfaces

For vehicles travelling on very rough or very smooth pavement, the basic noise level computations are adjusted upward or downward, as the case may be, by 5 dB(A),in accordance with Table 4.2. For great majority of new surfaces, no adjustment is needed. Occasionally an old surface is encountered 5 dB(A) positive adjustment is needed and a very smooth coated surface warrants a 5dB(A) negative adjustments. [2]

Table 4.3: Adjustment to the automobiles levels for various road surfaces [2]

Type of surface	Description	Adjustment in dB (A)
Smooth	Very smooth	-5
Normal	Moderately rough	0
Rough	Rough asphalt pavement with large voids	+5

Road gradient

These adjustments are made only to trucks noise level. Only positive adjustments to account for the increased noise of trucks are shown in Table 4.3. These adjustments are never negative and there is no adjustment for a downhill gradient. [2]

Table 4.4: Adjustments to truck noise level for various road gradients [2]

Gradient (%)	Adjustment(dB)
<2	0
3-4	+2
5-6	+3
>7	+5

As is seen in above discussions any mathematical model which is used to predict L_{eq} level must include the following parameters.

1. Total vehicle volume/hr.
2. Percentage of heavy vehicles
3. The distance of the measurement point from the roadway.

4.8.3 Computerized Prediction

IBM SPSS software was used for regression analysis to predict the traffic noise. IBM SPSS Statistics is a comprehensive, easy-to-use set of data and predictive analytics tools for business users, analysts and statistical programmers. The software name originally stood for Statistical Package for the Social Sciences.

4.9 Method of Reducing Noise

The legislation requires that every reasonable effort be made to achieve significant noise reductions when noise impacts are identical. Table 4.1 presents noise standards for various lands – use descriptors, specified by FHWA. The standards represent balancing between that which is desirable and that may be achievable. However, the standards are the maximum values acceptable by community. Generally two methods are used to control the traffic noise.

1. Noise reduction at source
2. Noise reduction in the transmission path

4.9.1 Noise Reduction at Source

Trucks make a greater contribution to noise levels on highway than other vehicles. Motor cycles which have high noise emission levels cause intermittent high noise levels. Some vehicles which have faulty engine exhaust system can result in high noise level. The following methods may be used to control noise at source. [3]

Reducing operational noise: Some of existing vehicles are producing excessive noise as compared to specified limit. In such cases arrangements can be made to reduce the vehicle noise by repair.

Reducing new vehicle noise limits: New manufactured vehicles must satisfy the noise level specified by environmental protection agency.

Reducing heavy vehicles: Reducing the trucks or buses on the highway reduced the highway noise.

Reducing speed of vehicle: Reducing the speed of vehicles reduces the traffic noise.

Regulating traffic: Smooth flow of the traffic helps to preventing overtaking and horn blowing.

4.9.2 Noise Reduction in the Transmission Path

It is another technique to reduce the noise level which is annoying receiver. Selection of highway, the introduction of barrier, the sound proofing buildings and planting of dense trees between the source and receiver are the factors which help to reduce noise in transmission path. During planning and designing the highway schools, hospitals and libraries which are sensitive receptors should be avoided on the highway. [3]

Construction of barrier in the transmission path in reducing the noise is an important method which is explained below.

4.10 Barriers

It is one of an important method for controlling noise in the path. Any solid body that blocks the line of sight is called a barrier. This method is applied only for the long interrupted roadways. The surfaces having acoustically soft and absorbent material provides a more effective acoustic screen. Height, length and shape decide noise reduction level. More importance is given to the stability and maintenance of barrier. Height of barrier is limited upto 6 meter. Mass of barrier also plays important role in the noise reduction as mass of 5kg /m^2 to 10 kg/m^2 would result in attenuation of 10 dB(A). The attenuation depends on the geometry of source – barrier – receiver system. Trees have minor effect on reducing traffic noise. In winter when leaves are gone, the sound reduction becomes negligible. [4]

4.10.1 Acoustical Design of Barrier

. If the noise barrier is continuous, free of cracks and holes, fairly dense, then the noise energy transmitted through a barrier is likely to be insignificant when compared to noise energy reaches other side of barrier. If the mass of the barriers is more than 20 kg/m^2 than transmission of sound through a barrier is found to be negligible. Following steps should follow during acoustical design of barrier:

Steps

1. Locate the source, receiver and barrier top points on an accurate cross section of the site; draw a line from source to receiver and measure the length of line, called line of sight (L/S) in meters.
2. Draw a perpendicular line from the barrier top to line L/S. Measure the length of this line, Barrier Break in L/S in meters.
3. Measure Barrier Position in meter, the shorter of the two segments on line L/S created by intersection with line Barrier Break in L/S.
4. Mark the L/S length on the L/S scale on the left side of nomograph and draw a line from point through point on Barrier break in L/S scale to lone Turn B.
5. On the bottom of the nomograph, draw a line from the appropriate point on the L/S scale through the appropriate point on the Barrier Position scale to line Turn A.

6. From the points determine in steps 4 and 5, proceed horizontally from Turn B and vertically from Turn A to an intersection point.
7. From the intersection line follow the curved lines to line Turn C.
8. Draw a line from Turn C to appropriate point on the L/S scale intersecting the pivot line.
9. Proceed horizontally from the pivot line to the appropriate curved line representing the angle at the receiver subtended by a barrier.
10. Proceed vertically to the line of barrier attenuation to get the assuming insertion loss.

4.11 Limitation of Problem

During the course of dissertation work, following problems were felt:

4.11.1 Limitation of Time Frame:

The statistical mathematical model always depends upon sampling size. The study involving traffic noise indicates that flow of traffic is highly random in nature therefore large number of samples collected at different time intervals at one observation spot. Because of limited time construction of barrier physically was not possible during study.

4.11.2 Limitation of getting permission to construct barrier physically

Rajindra is a government hospital; therefore getting permission to construct a barrier was not possible during dissertation work because of limited time. Moreover cost to construct a barrier is very high. But in the future, barrier will be the only option for reducing traffic noise in the hospital area due to increase in traffic in India day by day.

4.12 Methodology

The methods and techniques used in the measurement and analysis of data by using a sound level meter are discussed below:

4.12.1 Definition of Problem

First step in noise measurement is to define the problem clearly:

1. Measurements are taken to evaluate complaints resulting from community annoyance which is being caused visitors in the Rajindra hospital.
2. These measurements are to be taken Rajindra hospital
3. Winds on a microphone produces a noise may be seriously affect the accuracy of a measurement. This wind noise can be reduced significantly by the use of wind screen. These screens are commonly porous foamed plastic that fit over the microphone and have negligible effect on frequency response of the microphone
4. The required acoustic data are L_{eq}, L_{max}, L_{min}.
5. Allied data required is the number of vehicles that pass through a fixed point on the highway in a given period of time and in particular the number of heavy trucks/buses that pass through.
6. ± 0.5 dB (A) is the required accuracy.
7. Major sources of noise are vehicles pass through the nearby highway and that due to the visitor's vehicles and ambulances in the hospital area.
8. During the day time the traffic intensity is very high on the highway. There is no restriction on the usage of horns and the type of vehicles. There will be lot of traffic disturbance due to vehicles carrying by visitors.

4.12.2 Measurement Procedure

For traffic noise problems information about equivalent continuous sound level L_{eq} and maximum and minimum sound level i.e. L_{max} and L_{min} are obtained using Sound Level Meter. The Sound Level Meter was suitably calibrated. The microphone was mounted on a tripod at a suitable predetermined spot at a height of about 1.2m from the ground. The noise level near the highway depends on the number of vehicles. The noise level increases with an increase in traffic volume (Q). The numbers of vehicles passing through a fixed point on the road are to be counted. The traffic volume should sub-group into heavy vehicles and automobiles for duration of 15 minute.

Figure 4.3: Sound Level Meter positioned near the main entrance of hospital

Trucks and buses are contributing more noise to the environment, when compared to automobiles. The ratio of heavy trucks and buses to total traffic is called truck traffic mix ratio (p). This is compute in terms of percentage. An increase in this ratio will increase the noise level. A large number of sets of 15 minutes readings have been taken on the sound level meter on different dates/timings in order to account for statistical variation in traffic flow. Timings for measurement of noise level are 10:30am to 12:30pm and 2:30pm to 4:30 pm

Q, p, Leq, Lmax, Lmin measurements are taken and shown in tables. For the purpose of analysis for control measure Leq, noise level has been used. Lmax gives the idea to the maximum noise level and Lmin to the minimum noise level. Lmax represents the cases of vehicles horn blowing continuously, vehicles without proper silencer etc.

Sound level meter SC310 and Bruel & kjaer 2250 were used to measure the noise level outside and inside area of hospital respectively. The following settings were kept on the sound level meter for the above measurements:

Time weighting	fast
Present time	15 minute
Frequency weighting	A
Displayed parameters	L_{eq}, L_{max}, L_{min}

4.13 Instrument Used

Sound level meter: **S**ound level meters are used for all noise measurements in dB(A). Components of a sound level meter include a microphone with preamplifier, an amplifier, frequency weighting, input gain control, time-averaging and an output indicator or display. Accuracy of sound level meter depends on its. There are three types of sound level meters available: Types 0, 1, and 2. Type 0 sound level meters are used for laboratory purposes, where the highest precision is required. Type 1 or Type 2 sound level meters are acceptable for use in traffic noise analyses for Federal-aid highway projects. Two sound level meters SC310 and Bruel & kjaer 2250 are used for measurements.

Figure 4.4: Sound level meter SC310

Figure 4.5: Bruel&Kjaer 2250

Chapter 5

Result and Discussion

Rajindra Hospital is one of the oldest hospitals in the state of Punjab, in India. It was founded in October 1953. Rajindra Hospital, Patiala with 900 beds was attached to the college in early 1954. It is situated on National Highway 64.

This national highway lies between the government medical college and Rajindra hospital. The public enters in the hospital through two gates. Traffic on highway and one gate which is adjacent to a major bus stop and a complicated parking creates noise problem in the hospital area.

5.1 Nature of noise Problem

In order to assess the nature of the noise problem in the area of the hospital which is frequented by the visitors, a preliminary noise investigation was done. A preliminary survey of the area revealed that the emergency ward in the hospital is facing noise problem. Preliminary noise measurements indicated that L_{eq} at the emergency gate of Rajindra hospital is more than 50 dB(A) which is the maximum required limit. It is therefore very necessary to investigate properly and incorporating of feasible noise control measures to achieve a calm and quiet acoustic environment. A major contribution to the noise climate in these areas is due to the vehicular traffic which is flowing on the highway and shouting by family members of patients admitted in the hospital. This highway carries vehicular traffic throughout the day with percentage of heavy vehicles. The highway is about 66.8 m (220 ft) away from the emergency gate. The noise was aggravated by the horn blowing, a characteristic of Indian driving pattern, and accompanied by rapid accelerations and overtaking of the vehicles.

5.2 Site Selection

A mathematical model specific to the situation has to be formulated for predicting the traffic noise. To achieve this objective, a site A was selected which is 7.5 m (24.6 ft) away from the center line of inner lane of the highway facing the emergency ward of Rajindra hospital. In order to determine the existing noise level in the hospital entrance to the emergency ward as site B was selected at 66.8 m (220 ft) away from the center line of road of inner lane.

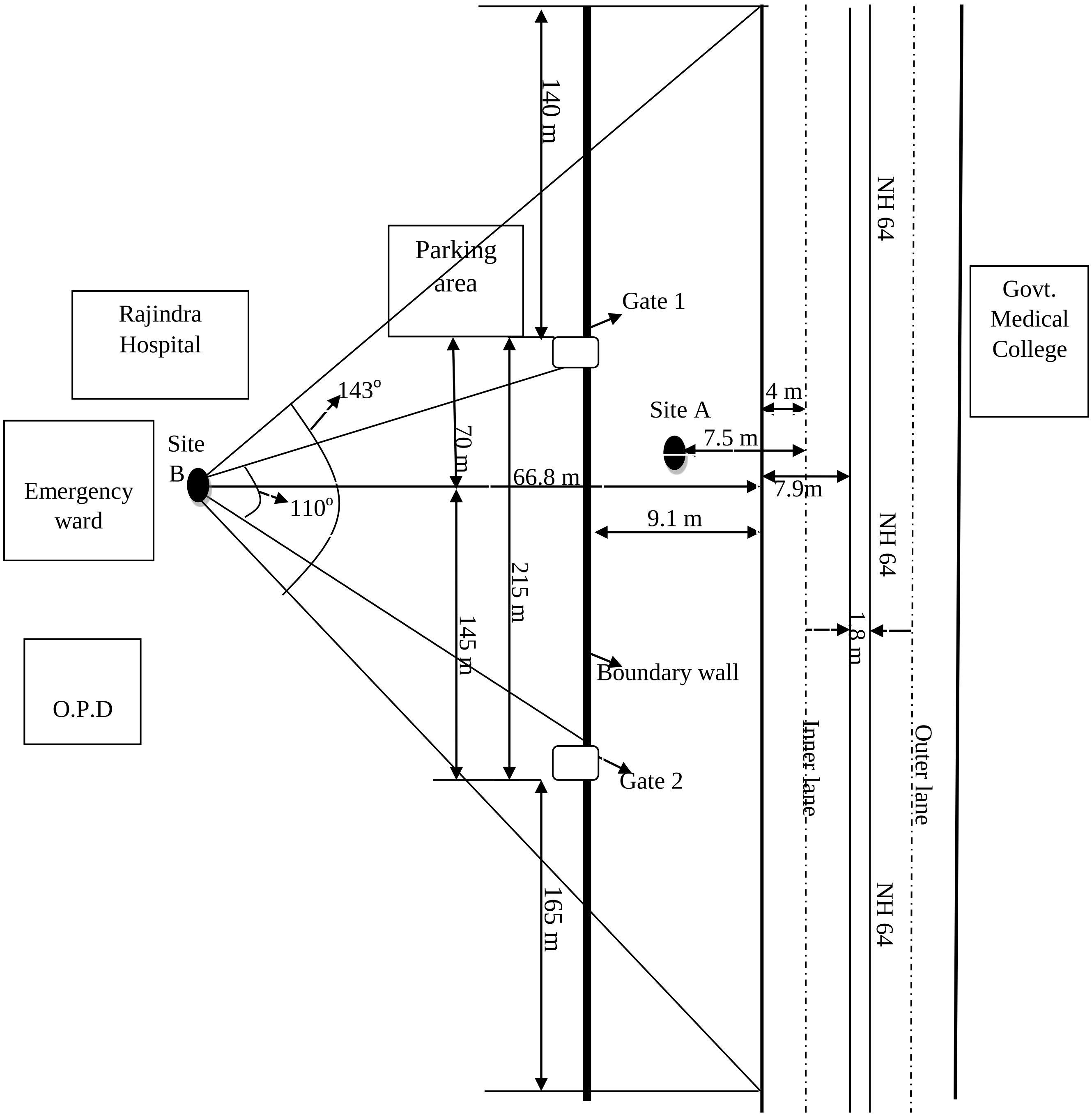


Figure 5.1: Site Description

5.2.1 Measurements

Traffic noise was measured at the selected sites by using sound level meters. SC310 sound level meter at site A and Bruel and Kjaer 2250 sound level meter was positioned at site B. The vehicles count at site A was also made during the measurement period.

A large number of 15 minute measurements at each site were repeated and Table 5.1 give details of these measurements made. All the sound level values are measured in dB(A).

Table 5.1: Sound Level Measurements at Site A and Site B

Leq, Lmax and Lmin values are measured in dB(A)

Site A										Site B						
Morning					Evening					Morning			Evening			
Q	p%	Leq	Lmax	Lmin	Q	p%	Leq	Lmax	Lmin	Leq	Lmax	Lmin	Leq	Lmax	Lmin	
524	7.44	78.3	107.2	59.8	446	8.96	77.6	107.5	55.5	66.7	92.5	53.4	63.9	86.7	852.	Date – 17/3/2015
515	3	77.8	102.6	56.8	495	8.87	80.7	109.0	56.3	66.3	91.3	55.0	68.0	90.1	54.6	
523	8.79	81.6	112.6	57.3	450	8.88	75.0	102.0	57.0	68.1	93.3	54.2	66.1	93.5	53.1	
506	6.71	77.1	103.3	59.0	465	8.81	76.9	98.7	56.1	67.2	91.3	53.5	64.1	81.3	52.9	Day - Tuesday
492	9.34	77.0	105.0	56.2	438	8.90	74.9	99.5	53.8	67.0	87.9	53.4	65.9	89.1	49.9	
515	9.12	76.1	101.8	54.9	453	8.50	73.4	96.9	54.3	66.0	95.4	51.3	65.3	86.3	50.1	
476	8.61	74.7	95.8	56.3	467	8.78	76.7	103.9	55.0	68.5	90.9	52.3	65.6	96.8	52.6	
473	8.66	76.2	103.8	54.5	478	9.03	80.1	107.7	59.7	67.8	95.1	53.4	65.1	93.8	51.9	

Sound Level Measurements at Site A and Site B

Site A										Site B						
Morning					Evening					Morning			Evening			
Q	p%	Leq	Lmax	Lmin	Q	p%	Leq	Lmax	Lmin	Leq	Lmax	Lmin	Leq	Lmax	Lmin	
471	8.91	80.3	105.9	56.2	484	7.64	78.0	106.8	55.7	65.6	85.3	53.4	63.3	90.8	52.3	Date – 18/3/2015
588	5.27	76.0	103.2	57.4	532	10.90	78.7	105.5	54.8	66.2	94.1	54.3	63.5	84.3	51.7	
467	6.20	74.9	98.1	53.3	433	11.08	75.4	98.3	57.0	67.3	90.1	53.2	62.7	82.2	52.4	
298	6.37	76.3	104.7	49.6	440	10.00	73.8	95.0	52.8	64.8	88.0	52.3	61.6	78.3	51.2	Day - Wednesday
437	3.59	73.0	102.3	50.3	494	11.94	75.4	101.9	56.4	63.7	85.5	52.4	62.1	82.1	53.2	
470	8.23	72.6	98.5	53.8	470	9.78	76.4	99.4	55.2	62.5	77.3	50.2	61.7	81.0	52.2	
408	7.35	72.1	95.9	52.8	417	9.14	80.9	107.5	54.5	67.5	96.8	51.6	70.1	83.2	51.6	
480	7.08	76.9	104.2	54.4	427	9.47	75.2	98.0	53.2	65.5	90.4	52.1	75.3	80.4	52.8	

Sound Level Measurements at Site A and Site B

Site A										Site B						
Morning					Evening					Morning			Evening			
Q	p%	Leq	Lmax	Lmin	Q	p%	Leq	Lmax	Lmin	Leq	Lmax	Lmin	Leq	Lmax	Lmin	
452	7.07	74.9	101.3	55.3	401	8.47	73.9	100.6	54.8	65.7	84.1	53.3	65.6	88.0	52.0	Date – 19/3/2015
528	8.14	76.2	103.5	57.5	450	8.66	74.8	99.8	53.5	63.5	85.5	53.0	65.1	85.5	51.9	
475	7.57	77.8	108.6	56.1	458	10.04	75.9	101.6	54.1	65.8	87.7	52.9	66.9	87.2	50.5	
447	7.82	75.9	98.7	54.6	449	9.57	73.1	93.5	53.4	67.2	89.1	53.9	67.2	89.4	51.6	Day – Thursday
489	8.17	79.0	105.2	56.4	469	7.88	73.4	94.7	55.1	65.3	88.1	54.3	66.2	86.4	51.8	
477	10.48	74.7	98.9	53.7	423	9.21	74.6	98.1	53.0	66.8	87.5	52.2	62.7	87.0	51.4	
502	9.76	74.8	98.8	54.9	456	9.42	75.3	101.0	52.2	68.4	86.4	53.6	66.6	89.6	52.1	
476	8.61	76.4	100.5	54.0	396	12.12	77.7	106.5	54.3	66.9	84.2	52.3	65.1	88.2	51.2	

Sound Level Measurements at Site A and Site B

Site A										Site B						
Morning					Evening					Morning			Evening			
Q	p%	Leq	Lmax	Lmin	Q	p%	Leq	Lmax	Lmin	Leq	Lmax	Lmin	Leq	Lmax	Lmin	
498	8.63	77.4	105.1	57.4	396	9.59	74.1	100.7	55.4	67.4	90.4	52.7	67.7	86.4	50.4	Date – 20/3/2015
479	7.51	76.6	105.0	54.4	391	9.97	73.5	95.4	55.8	70.5	88.6	53.8	66.8	81.4	52.4	
489	7.56	75.8	101.9	56.1	459	10.02	77.2	106.6	51.1	78.4	87.8	52.6	65.1	88.0	50.1	
506	7.31	79.7	108.8	53.9	518	12.54	76.6	102.2	56.0	65.2	87.0	53.2	64.3	89.8	50.6	Day - Friday
500	8.01	74.9	104.2	55.6	456	9.86	77.2	105.6	53.6	64.1	90.3	52.6	67.2	89.2	50.5	
509	9.23	77.9	103.9	56.0	421	9.02	74.7	95.3	55.2	67.1	86.6	55.1	68.9	91.7	52.1	
523	8.79	75.5	97.6	56.5	455	10.10	77.8	105.1	55.4	67.5	90.0	53.2	67.5	88.9	50.7	
517	8.12	78.1	106.2	54.0	452	10.84	78.1	105.6	54.9	67.2	88.9	52.1	65.8	87.4	50.9	

Sound Level Measurements at Site A and Site B

Site A										Site B						
Morning					Evening					Morning			Evening			
Q	p%	Leq	Lmax	Lmin	Q	p%	Leq	Lmax	Lmin	Leq	Lmax	Lmin	Leq	Lmax	Lmin	
526	9.12	75.2	101.0	54.8	475	10.31	79.2	110.0	55.5	64.3	88.0	53.6	62.7	84.1	50.9	Date – 21/3/2015
554	11.02	74.4	96.8	55.2	539	9.46	76.9	103.3	55.2	67.0	92.5	51.9	65.0	84.8	51.9	
528	10.03	76.3	98.6	53.8	484	8.47	73.7	92.8	54.8	66.9	91.8	52.6	63.5	82.1	50.6	
601	11.64	75.7	100.5	57.8	515	8.15	76.2	102.6	54.5	69.2	90.5	51.8	68.5	89.2	50.1	Day - Saturday
586	12.11	79.0	102.2	54.1	484	8.88	76.4	102.4	52.4	66.4	86.6	54.2	68.2	91.3	50.0	
537	9.12	75.1	103.9	51.8	492	9.34	75.8	102.5	55.0	68.4	89.3	53.8	68.6	87.8	51.4	
549	8.74	75.8	103.7	52.9	521	8.82	78.9	108.2	56.9	64.5	89.1	52.8	64.7	86.7	51.1	
557	7.71	78.8	109.7	54.4	457	7.43	76.0	100.8	55.4	64.8	87.2	52.4	62.8	80.5	49.9	

Sound Level Measurements at Site A and Site B

Site A										Site B						
Morning					Evening					Morning			Evening			
Q	p%	Leq	Lmax	Lmin	Q	p%	Leq	Lmax	Lmin	Leq	Lmax	Lmin	Leq	Lmax	Lmin	
458	6.76	77.2	103.4	54.4	386	9.58	76.4	103.0	56.6	65.5	84.3	50.8	63.7	89.3	49.1	Date – 22/3/2015
496	9.87	77.3	102.1	52.6	415	9.87	75.4	98.0	56.1	61.7	76.3	50.7	65.1	89.5	51.3	
490	7.34	76.8	100.3	54.8	499	7.61	74.3	96.0	55.5	63.0	80.0	50.3	62.9	87.6	50.9	
467	9.85	74.6	100.0	50.5	367	9.26	74.4	96.2	52.7	62.3	88.7	48.6	61.5	86.3	50.7	Day – Sunday
469	6.60	76.4	105.4	54.2	426	6.33	78.3	104.7	52.9	64.4	87.6	49.8	66.4	88.4	49.2	
448	7.14	75.8	97.8	54.9	390	9.48	74.8	98.6	54.5	62.2	79.3	49.2	70.6	98.6	51.9	
387	6.45	74.2	98.2	53.1	411	8.51	76.7	102.6	55.2	60.6	84.1	47.8	67.0	86.7	50.6	
454	9.03	79.0	107.9	49.5	409	8.06	79.1	110.6	56.0	62.4	86.4	48.0	70.3	87.4	52.0	

Sound Level Measurements at Site A and Site B

Site A										Site B						
Morning					Evening					Morning			Evening			
Q	p%	Leq	Lmax	Lmin	Q	p%	Leq	Lmax	Lmin	Leq	Lmax	Lmin	Leq	Lmax	Lmin	
521	7.86	74.1	96.4	58.6	432	12.5	73.8	96.8	56.6	66.7	89.1	51.4	66.8	89.2	52.3	Date – 23/3/2015
506	7.31	75.4	98.1	55.7	408	8.57	73.4	98.1	54.8	64.5	85.8	50.5	64.0	87.9	48.8	
535	7.65	76.6	102.5	56.3	434	9.90	73.1	96.2	54.6	64.4	84.4	51.4	66.4	86.0	49.0	
501	8.38	76.1	102.0	54.9	456	6.79	74.4	101.7	53.0	64.8	95.9	51.3	66.5	83.5	48.5	Day – Monday
545	6.97	76.3	101.6	56.9	440	9.77	77.7	101.8	56.2	65.4	89.1	50.7	65.7	92.3	49.3	
484	5.57	77.0	100.6	56.0	381	9.44	74.1	97.3	52.9	64.2	83.6	50.4	65.5	90.7	49.2	
497	9.85	72.5	94.4	56.9	448	8.25	78.3	104.3	57.2	63.9	88.0	52.1	65.1	84.6	50.8	
460	8.47	76.9	108.0	54.8	405	9.38	78.0	106.9	54.5	67.6	96.1	51.0	65.9	89.7	49.5	

5.2.2 Findings

An analysis of collected data indicates the following:

For Morning:

1. At site A, which is 7.5 m (24.6 ft) from the center line of inner lane the L_{eq} levels mostly range between 74 dB(A) to 78 dB(A).
2. Lmax and Lmin level mostly range between 98 dB(A) to 112.6 dB(A) at site A and at site B.
3. At site B, which is at the gate of emergency ward the L_{eq} levels mostly range between 64 dB(A) to 69 dB(A).

For Evening:

1. At site A, L_{eq} levels mostly range between 73 dB(A) to 78 dB(A).
2. Lmax and Lmin level mostly range between 96 dB(A) to 110.6 dB(A) at site A and 84 dB(A) to 96 dB(A) at site B.
3. At site B, L_{eq} levels mostly range between 64 dB(A) to 68 dB(A).

- The above behavior probably is due to the fact that the percentage of heavy vehicles on the highway. The attenuation in L_{eq} level is in the range of 3 dB(A) to 4.5 dB(A) per doubling of the distance expected. This attenuation occurs due to the divergence of sound wave.
- The temperature, humidity and wind conditions were found in the normal range and therefore do not adversely affect the sound transmission.
- Site B has some natural shielding because of trees planted in the hospital.
- It is seen that the L_{eq} levels at site B are above the recommended value of 50 dB(A). Hence control measures based on the conditions need to be recommended for site B.

5.3 Control Measures

The possible control measures to improve the noise environment at the gate of emergency ward of the Rajindra hospital are discussed in the following three categories:

5.3.1 Measures at the receiver end

5.3.2 Measures in the transmission path

5.3.3 Regulatory measures

These are discussed below:

5.3.1 Measures at the Receiver End

The unnecessary loud talking by the people does cause annoyance. There is need to educate people in this regard and importance of providing a noise free climate.

5.3.2 Measure in the Transmission Path

The major contribution to the noise climate at the hospital is due to traffic flow on the highway. It is observed that the total attenuation in L_{eq} level from the road to the emergency ward of hospital is about 6 dB(A), but the level at the hospital still above the recommended level of 50 dB(A).

This attenuation provided by a wall of height approximately 3.6 m (12 ft) is 5dB(A). Various geometrical parameters are given in Fig. 5.2 and the attenuation provided by barrier is shown on nomograph in Fig. 5.3. and Some attenuation provided by divergence and ground effects.

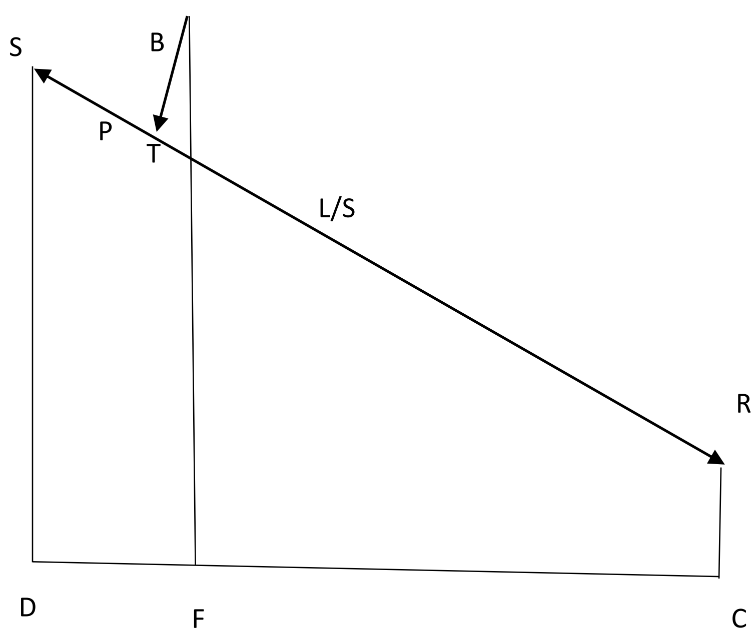


Figure 5.2: Various geometrical parameters for barrier height 3.6 m (12 ft) [2]

Line of sight (L/S)	= SR = 66.8 m (220 ft)
Barrier Position	= ST = 10.6 m (35 ft)
Height of Receiver	= RC = 1.5 m (4.9 ft)
Horizontal Distance	= CD = 64.31 m (211 ft)
Height of Source	= SD = 2.74 m (9 ft)
Break in the Line of Sight (B)	= ET = 1.31 m (4.2 ft)
Barrier Height	= EF = 3.6 m (12 ft)
Distance of Barrier from the Centre line of near lane of Highway	= DF= 9.14 m (30 ft)

Some steps are to be follow to obtain the attenuation provided by nomograph [2]. These steps are:

Steps

1. Mark the L/S length 66.8 m (220 ft) on the L/S scale on the left side of nomograph and draw a line from 1.31 m (4.2 ft) through point on Barrier break in L/S scale to line Turn B.
2. On the bottom of the nomograph, draw a line from the 66.8 m (220 ft) on the L/S scale through the 10.6 m (35 ft) on the Barrier Position scale to line Turn A.
3. From the points determine in steps 1 and 2, proceed horizontally from Turn B and vertically from Turn A to an intersection point.
4. From the intersection line follow the curved lines to line Turn C.
5. Draw a line from Turn C to 66.8 m (220 ft) on the L/S scale intersecting the pivot line.
6. Proceed horizontally from the pivot line to the appropriate curved line representing the angle at the receiver subtended to 140^{o} by a barrier.
7. Proceed vertically to the line barrier attenuation. The attenuation of 5 dB(A) is provided by existing wall of 3.6 m (12 ft).

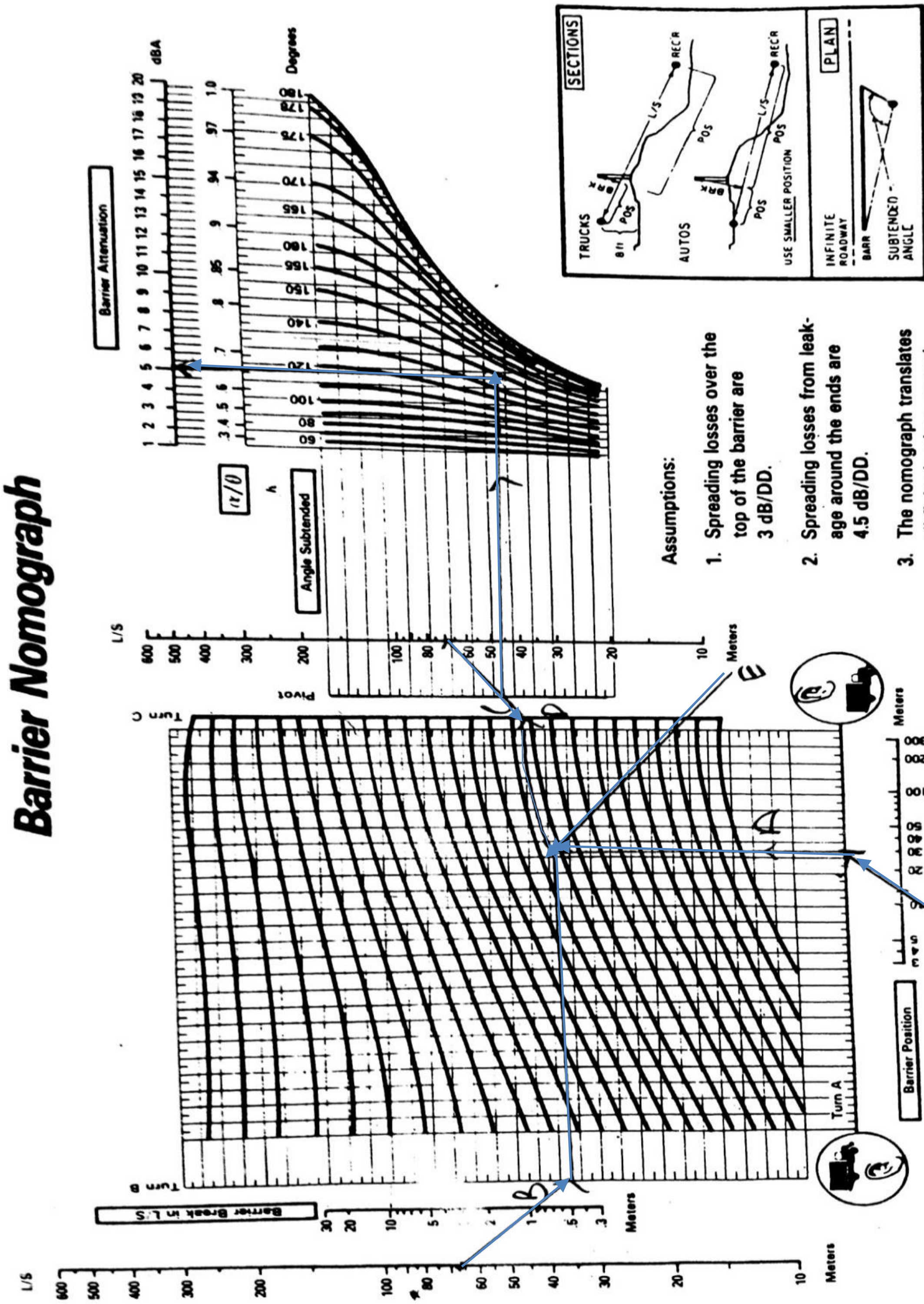


Figure 5.3 Attenuation prediction for existing barrier of height 3.6 m (12 ft) by using nomograph [2]

Providing a barrier

A barrier of certain length and height is proposed to be constructed along the highway.

Evaluation of the necessary height of the barrier

It is evident that from the above discussions, the situation is that of a finite highway with a partial barrier. The subtended angles in Fig. 1 are

$\Theta = 143^o$ $\alpha = 110^o$

Giving $\alpha / \Theta = 0.75$ which corresponds to a infinite roadway with a partial barrier subtending an angle of $0.77 \times 180^o = 140^o$

As seen from the barrier nomograph given in Fig. 5.5 the topographical limit on the total achievable attenuation as 7 to 7.5 dB(A) including attenuation being already provided under the existing condition. The average source height of automobiles has been considered 0.5 m above the road surface. The various geometrical parameters are given in Fig 5.4.

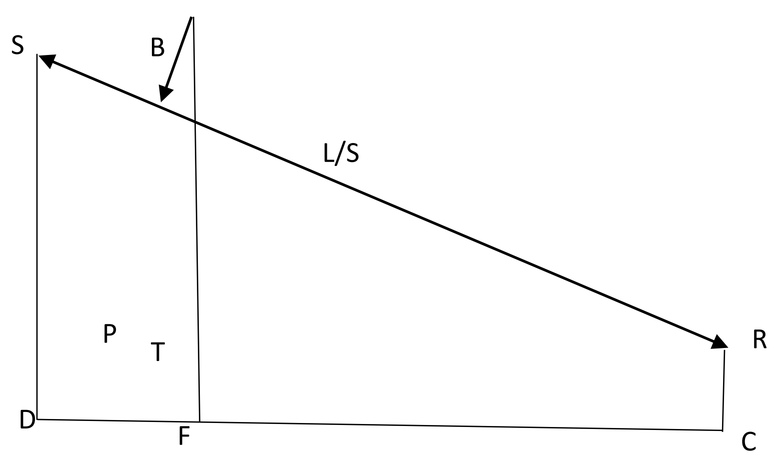


Figure 5.4: Various geometrical parameters for barrier height [2]

Line of sight (L/S)	= SR = 66.8 m (220 ft)
Barrier Position	= ST = 10.6 m (35 ft)
Height of Receiver	= RC = 1.5 m (4.9 ft)
Horizontal Distance	= CD = 64.31 m (211 ft)
Height of Source	= SD = 2.74 m (9 ft)

Break in the Line of Sight (B) = ET = 3.2 m (10.5 ft)

Barrier Height = EF = 6.4 m (21 ft)

Distance of Barrier from the

Centre line of near lane of Highway = DF= 9.14 m (30 ft)

Some steps are to be follow to obtain the Barrier break from the nomograph. These steps are:

Steps

1. Drop a vertical line from 7 dB(A) barrier attenuation to meet 140^{o} angle subtended curve.
2. From the above point draw a horizontal line to meet pivot line at point D.
3. Join 66.8 m (220 ft) point on the right L/S line with the point D extend it to meet turn C line at C.
4. Join 66.8 m (220 ft) point on the L/S line at the bottom with the 10.5 m (35 ft) point on the barrier position line to meet turn A line at A and draw a vertical from this meet a parallel contour line draw from C at E.
5. Draw a horizontal from E to meet turn B line at B.
6. Join B with 66.8 m (220 ft) point on the left L/S line to intersect the barrier break of about 3.2 m (10.5 ft).

This corresponds to a barrier height of about 6.4 m (21 ft) at a distance of 9.14 m (30 ft) from the center line of the inner lane of road. As barrier height of 3.67 m (12 ft) already existing, therefore we have to construct a barrier of 2.7 m (9 ft). Barrier is provided between the two entering gates of Rajindra hospital of about 215 m all along parallel to the highway. No correction is needed for the road gradient and road surface as these are found to be within normal values. A panel of steel having height 2.7 m (9 ft) can be mounted on the present wall of 3.67 (12 ft) to make a height of 6.4 m (21 ft). Wall of concrete may also be constructed on the present wall to make a corresponding height of barrier.

It would be seen that the above analysis is based on an approximation of the roadway being considered as a straight line with no obstruction in the path of sound ray to the receiver.

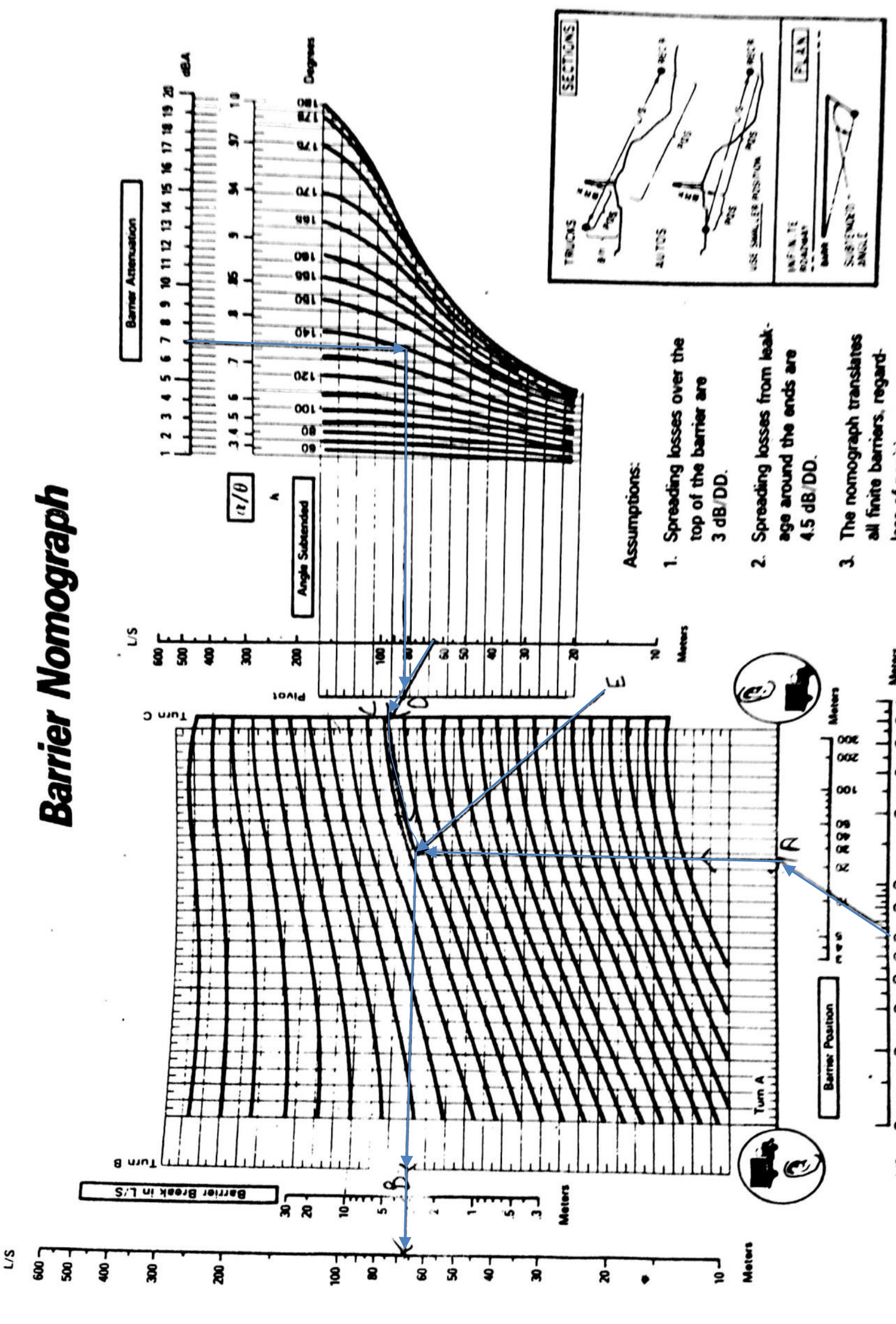


Figure 5.5: Proposed Barrier height formulated by nomograph [2]

5.3.3 Regulatory Measures

Certain regulatory measures for traffic flow are very strongly recommended. A strict implementation of these would lead to a substantial improvement in the noise environment at the emergency ward entrance. These are listed below:

I. The whole stretch of road infront of the hospital should be declared as a "Silence Zone" and blowing of horn should be strictly prohibited.

II. No overtaking of vehicles should be allowed in any circumstances. This would obviate of unnecessary acceleration.

III. A speed limit zone be provided and make sure that people follow it strictly

IV. The heavy vehicles like buses and trucks be rerouted, if possible.

5.4 Regression Analysis for Equivalent Sound Level (Leq)

A regression analysis was carried out and a mathematical expression was obtained for predicting Leq level. The respective equation is as shown below.

Regression output:

Constant	47.40	
Standard error of prediction	1.89	
R Squared	0.083	
No. of observations	112	
Degrees of freedom	109	
X coefficient's	10.76	0.011
Standard error of coefficient's	3.51	0.11

$$\mathbf{Leq = 47.40 + 10.76 \, Log \, Q + 0.011 \, p}$$

Table 5.2: Predicted values of Leq by IBM SPSS at site A

Day – Tuesday Date – 17/3/2015

S.No.	Measured Leq dB(A)	Predicted Leq dB(A)	% error
1	78.3	76.7	2.0
2	77.8	76.8	1.2
3	81.6	76.7	6.0
4	77.1	76.5	0.7
5	77.0	76.4	0.7
6	76.1	76.6	-0.6
7	74.7	76.2	-2.4
8	76.2	76.2	0
9	77.6	75.9	2.1
10	80.7	76.4	5.3
11	75.0	76.0	-1.3
12	76.9	76.1	1.0
13	74.9	75.8	-1.2
14	73.4	76.0	-3.5
15	76.7	76.2	0.6
16	80.1	76.3	4.7

Day – Wednesday Date – 18/3/2015

S.No.	Measured Leq dB(A)	Predicted Leq dB(A)	% error
1	80.3	76.2	5.1
2	76.0	77.3	-1.7
3	74.9	76.1	-1.6
4	76.3	74.3	2.6
5	73.0	74.1	-1.5
6	72.6	75.8	-4.4
7	72.1	75.5	-4.7
8	76.9	76.2	0.9
9	78.0	76.3	2.1
10	78.7	76.9	2.2
11	75.4	75.8	-0.5
12	73.8	75.9	-2.8
13	75.4	76.5	-1.4
14	76.4	76.2	0.2
15	80.9	75.6	6.5
16	75.2	75.7	-0.6

Day – Thursday Date – 19/3/2015

S.No.	Measured Leq dB(A)	Predicted Leq dB(A)	% error
1	74.9	75.9	-1.3
2	76.2	76.8	-0.7
3	77.8	76.2	2.0
4	75.9	75.9	0
5	79.0	76.3	3.4
6	74.7	76.3	-2.1
7	74.8	76.5	-2.2
8	76.4	76.2	0.2
9	73.9	75.4	-2.0
10	74.8	76.0	-1.6
11	75.9	76.1	-0.2
12	73.1	76.0	-3.9
13	73.4	76.1	-3.6
14	74.6	75.7	-1.4
15	75.3	76.0	-0.9
16	77.7	75.5	2.8

Day – Friday   Date – 20/3/2015

S.No.	Measured Leq dB(A)	Predicted Leq dB(A)	% error
1	77.7	76.5	1.5
2	76.6	76.2	0.5
3	75.8	76.3	-0.6
4	79.7	76.5	4.0
5	74.9	76.5	-2.1
6	77.9	76.6	1.6
7	75.5	76.7	-1.5
8	78.1	76.6	1.9
9	74.1	75.4	-1.7
10	73.5	75.4	-2.5
11	77.2	76.1	1.4
12	76.6	76.7	-0.1
13	77.2	76.0	1.5
14	74.7	75.7	-1.3
15	77.8	76.0	2.3
16	78.1	76.0	2.6

Day – Saturday Date – 21/3/2015

S.No.	Measured Leq dB(A)	Predicted Leq dB(A)	% error
1	75.2	76.8	-2.1
2	74.4	77.1	-3.6
3	76.3	76.8	-0.6
4	75.7	77.6	-2.5
5	79.0	77.4	2.0
6	75.1	76.9	-2.3
7	75.8	77.0	-1.5
8	78.8	77.1	2.1
9	79.2	76.3	3.6
10	76.9	76.9	0.0
11	73.7	76.3	-3.5
12	76.2	76.6	-0.5
13	76.4	76.3	0.3
14	75.8	76.4	-0.7
15	78.9	76.7	2.7
16	76.0	76.0	0.0

Day – Sunday   Date – 22/3/2015

S.No.	Measured Leq dB(A)	Predicted Leq dB(A)	% error
1	77.2	76.0	1.5
2	77.3	76.5	1.0
3	76.8	76.3	0.6
4	74.6	76.2	-2.1
5	76.4	76.1	0.3
6	75.8	75.9	-0.1
7	74.2	75.2	-1.3
8	79.0	76.0	3.7
9	76.4	75.3	1.4
10	75.4	75.6	-0.2
11	74.3	76.4	-2.8
12	74.4	75.1	-0.9
13	78.3	75.7	3.3
14	74.8	75.3	-0.6
15	76.7	75.5	1.5
16	79.1	75.5	4.5

Day – Monday   Date – 23/3/2015

S.No.	Measured Leq dB(A)	Predicted Leq dB(A)	% error
1	74.1	76.7	-3.5
2	75.4	76.5	-1.4
3	76.6	76.8	-0.2
4	76.1	76.5	-0.5
5	76.3	76.9	-0.7
6	77.0	76.2	1.0
7	72.5	76.5	-5.5
8	76.9	76.1	1.0
9	73.8	75.8	-2.7
10	73.4	75.5	-2.8
11	73.1	75.8	-3.6
12	74.4	76.0	-2.1
13	77.7	75.9	2.3
14	74.1	75.3	-1.6
15	78.3	75.9	3.0
16	78.0	75.5	3.2

Equation derived from the regression analysis gives prediction within± 3.5 %

5.5 Scatter Diagrams For Log Q v/s Leq and p v/s Leq

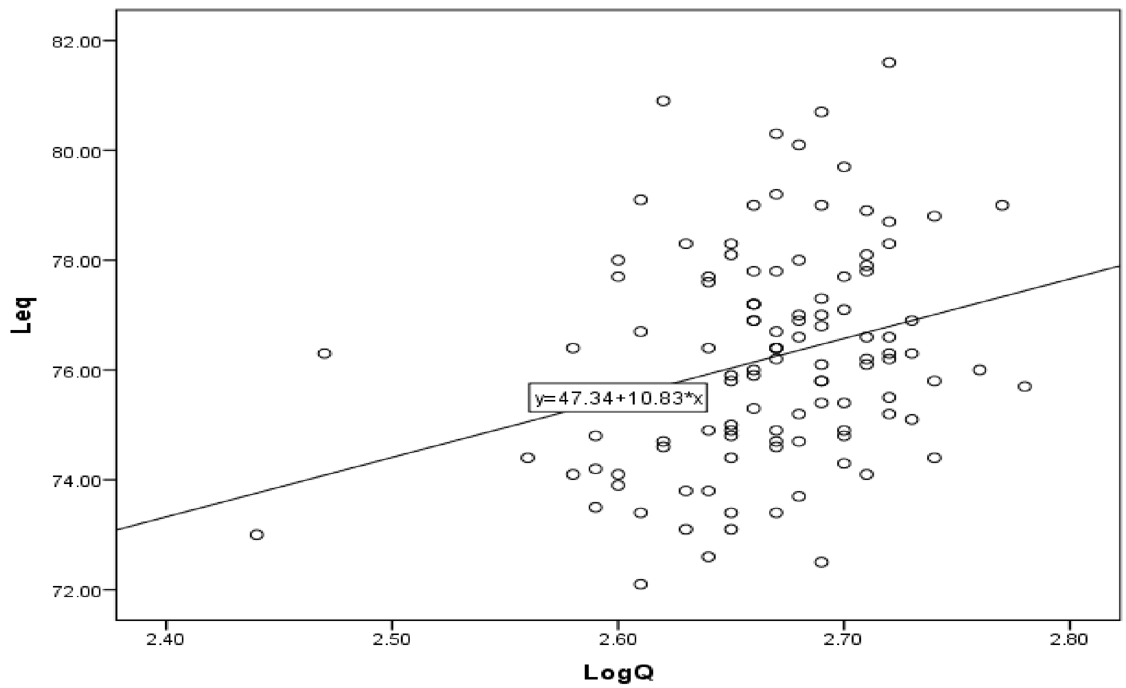


Figure 5.6: Scatter diagram for logarithmic value of no. of vehicles Log (Q) v/s Leq

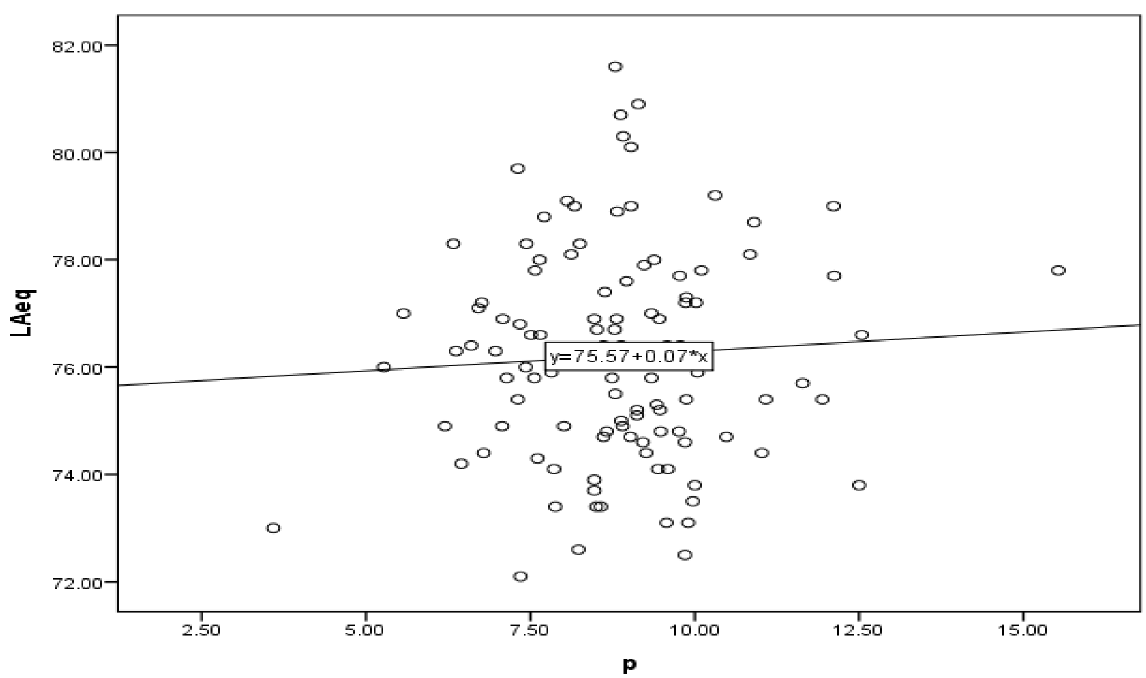


Figure 5.7: Scatter diagram for % of heavy vehicle (p) v/s Leq

The graph in Fig. 5.6 shows that if number of vehicles Q increases than the logarithmic value of Q also increases which results in high Leq level. The graph in Fig. 5.7 shows that increase in number of heavy vehicles results in high Leq level.

In both the graphs it is shown that sometimes at same value of p or Log Q, there is a much difference in Leq values. It is because of horn blowing, unnecessary acceleration during overtaking of vehicles and other environmental conditions results in high noise level which increases the Leq level.

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

Noise is one of the developing problems in our modern society. Traffic noise is the main source of noise problem. Therefore it is very important to protect people of areas near the highway because noise has very bad effects on people health. Noise has become a serious problem in the Rajindra Hospital as complaints arise by people visiting and staff of the hospital. A – Weighted equivalent noise level (LA_{eq}) in the area of hospital is more than 50 dB(A) which is the recommended level in the area of hospitals by Central Pollution Control Board India (2000) Sound pressure level more than recommended level in the area of hospital affects the health of patients as well as other staff members or people visiting hospital. Therefore a barrier design is developed by using nomograph along the roadside to protect patients or other people in the hospital. Theory of sound path and receiver is to be applied to study about the concept of barriers.

The subtended angles $\Theta = 143^o$ $\alpha = 110^o$.Giving $\alpha / \Theta = 0.77$ which corresponds to a infinite roadway with a partial barrier subtending an angle of $0.77 \times 180^o = 140^o$. As seen from the barrier nomograph given in Figure 5. the topographical limit, the total achievable attenuation is 7 to 7.5 dB(A) including attenuation being already provided under the existing condition This attenuation provided by a wall of height approximately 3.67 m (12 ft) already present at the distance of approximately 9.14 m (30 ft) from the center line of inner lane. A barrier height of 6.4 m (21 ft) obtained at a distance of 9.14 m (30 ft) from the center line of the inner lane of road by a nomograph. As barrier height of 3.67 m (12 ft) is already existing, therefore 2.74 m (9 ft) increase in barrier height is recommended to get attenuation of 7.5 dB(A). Barrier is provided between the two entering gates of Rajindra hospital of about 215 m long along parallel to the highway.

Certain regulatory measures will also be useful for attenuating more noise level. These are as follows:

- By tree plantation along the boundary wall of hospital helps to reduce noise level
- Earth Berms will also be useful to attenuating the receiver.
- A strict implementation of smooth traffic flow would lead to a substantial improvement in the noise environment at the emergency ward entrance.
- Blowing of horn should be strictly prohibited,
- No overtaking of vehicles should be allowed in any circumstances. This would obviate of unnecessary acceleration,
- A speed limit zone be provided and make sure that people follow it strictly and the heavy vehicles like buses and trucks be rerouted, if possible will be very useful for attenuating noise if strictly implemented.

6.2 Future Scope

a) In this present study effect of deceleration and acceleration for all vehicle composition was not considered. Therefore speed parameter can be included to get better results for prediction analysis.

b) In this work only heavy vehicles are counted separately for prediction of noise level. Therefore all kinds of vehicle can be separately counted to ge better results.

c) Heavy horn blowing causes high values of Lmax and consequently affects Leq. Hence detailed study of this aspect could be done and corrections could be incorporated.

d) Other factors such as road gradient, temperature conditions, humidity and wind flow could also be included in the prediction and may give better results.

e) It is found that material of barrier plays an important role to attenuation of noise. So barrier material could be included in the study to get better attenuation.

f) Barriers caps may also be included to get better attenuation.

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