STATISTICAL ANALYSIS AND MODELLING OF NOISE POLLUTION IN DELHI DURING ODD-EVEN VEHICLE RATIONING PROGRAMME

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

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IN

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Submitted by

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CERTIFICATE

This is to certify that Mr. PIYUSH VERMA (2K14/ENE/14), M. Tech. student in the Department of Environmental Engineering has submitted a dissertation on "STATISTICAL ANALYSIS AND MODELLING OF NOISE POLLUTION IN DELHI DURING ODD-EVEN VEHICLE RATIONING PROGRAM" in the partial fulfilment of the requirement for the award of degree of Masters of Technology in Environmental Engineering during the academic year 2016-17. It is remarked the work done by student was accomplished under my guidance and supervision.

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Date :

Place: Delhi

Declaration of Originality

I hereby declare that this project work and report is completely my own work and I amthe sole author of this report. Any additional sources of information, quotations and techniques of work from other people are fully acknowledged and duly cited in accordance with the standard procedure of referencing. I undertake that this report is the true copy of my work as approved by my supervisor. This report has not been submitted for any other degree to any other University or Institution.

(Piyush Verma)

Acknowledgement

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ABSTRACT

Traffic noise is one of the most common problems in metro cities like Delhi which encounters this problem ever since the rising population and vehicle growth. Thus under section 2(a) of Air (Prevention and Control of Pollution) Act, 1981, noise has been defined as a pollutant. To combat air and noise pollution the Government of Delhi had launched a restrict and control measure process called odd-even vehicle rationing program in January'16 and April'16 which imposed a driving restriction based on the license number plate of the vehicle. In this present research, efforts have been made to evaluate noise pollution from the statistical study of noise parameters during odd-even program at selected sites against the limits prescribed under Ambient Air Quality Standards in respect of Noise by Ministry of Environment and Forests (The Noise Pollution, Regulation and Control, Rules 2000). A continuous 30 days noise data was taken from CPCB Real Time National Noise Monitoring Network during the month of April'16 which marks the beginning of second phase of odd-even vehicle rationing program. The aim of the study is to study its effectiveness and extent of violation. For the study, A-weighted hourly average for peak hours of L_{10}, L_{50} and L_{90} during daytime and A-weighted daily average of L_{eq} was taken. The noise levels were undertaken for 30 days intervals from 1st April'16 to 30th April'16. The equivalent noise levels were statistically observed using various multiple statistics software. Noise Pollution level (NPL) and Traffic Noise Index (TNI) has been calculated from L_{10}, L_{50} and L_{90} percentile noise levels to check the level of noise pollution at survey sites. Relative change in equivalent noise level for forecasted and actual data has been observed under the study. Additionally mathematical noise modeling has been done to predict the equivalent noise levels for odd-even program using equations of model. Statistical and mathematical analysis of the noise indices and equivalent noise level demonstrates the fall in noise pollution during odd-even program to a certain extent but still it is above the prescribed noise limits and the city continues to suffer severe noise pollution problems.

CHAPTER I

INTRODUCTION

1.1 General Introduction

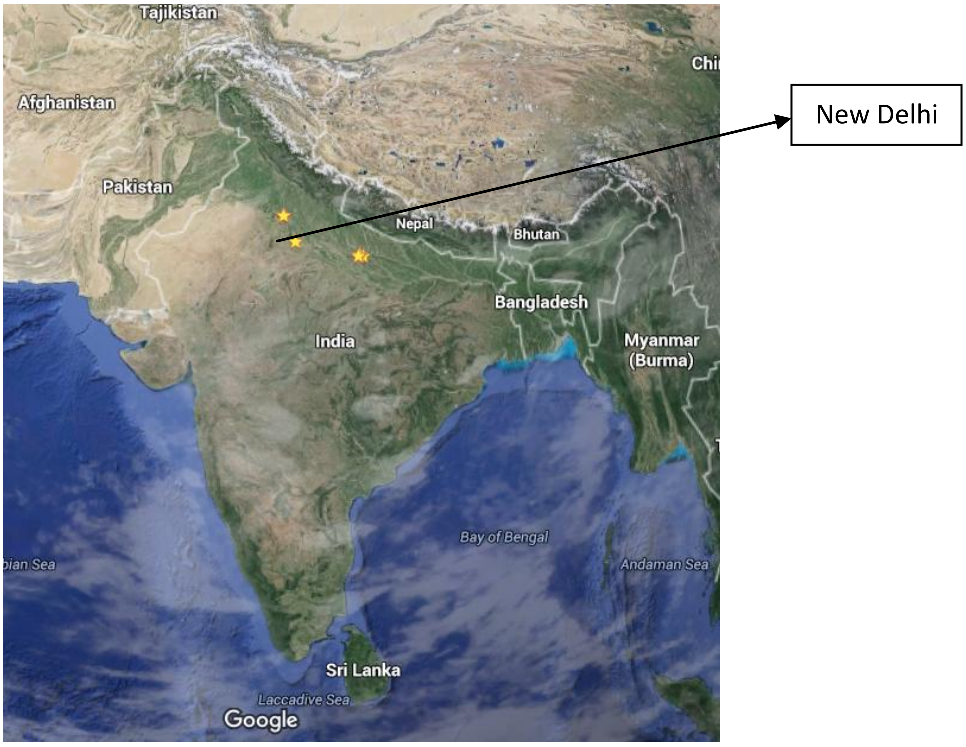
Delhi is the capital of India located at 28.38° North and 77.13° E. The city is cataloged under metropolitan city of India and is one of the busiest places internationally. Extended across the banks of river Yamuna the city is landlocked by several states around it. There are 3 most significant geological locations: the Yamuna plain, the ridge & the Gangetic Plains. Both the plains provide fertile soil to the city providing greater scope for habitat growth and rehabilitation. Average height of Delhi is 293m above sea level that ropes its ridge like shape.

The map of Delhi highlights all noteworthy places, rivers and boundary locations. Delhi's region is extended over a region of 1483 square kilometers and is amidst the mountain ranges of Himalayas and Aravallis. Delhi is bordered by Haryana on its three sides and Uttar Pradesh on its other side. Yamuna River runs across the city entering at the north eastern side and leaving south east towards Agra. From topography point of view, the city can be segmented into 3 distinguished parts, the ridge, Yamuna Flood plain and the plains. As per the topography, the city is based on western fringes of the well-known Gangetic Plains. Offering an impeccable opportunity of agriculture, the low height Yamuna Flood Plains are covered with rich and fertile alluvium soil that is brought by Yamuna river or at times gets deposited during the times of flood.

Delhi has its own rich culture and due to its magnificent location its offers the best environment to its residents. Being the capital of the country and majorly because of its rich resource system it serves an important zone in the nation. Though the city is landlocked but is well connected via air, rail and inland waterways that permit easy transportation of goods and services in both export and import terms. The map shows the prime location of Delhi which is surrounded via Himalayas on north and aravallis on the south west with indo gangetic plain bordering it on eastern part. Due to its prime location and being the national capital region of the country it serves as a home to millions of people all around.

More over people from different parts of the country and globe visit the city for its historical and cultural importance. It is also market and an industrial hub providing jobs to millions of people. The current population of Delhi is approx. 9.879 million which ranks second in the world. Delhi has thus become a home to a million of migrants because of its geographical and economical importance in the world.

Figure 1.1 Location of Delhi on the map of INDIA



(Source: www.googlemaps.co.in)

The study reveals that swift population augmentation continues to be a topic of apprehension as it has diverse effects, major being environmental pollution. Heavily colonized and hastily rising Delhi mega city is a place for settlement where the population continues to grow and diversify. The recent pollution control measures taken by central government reduced the environmental pollution up to some extent.

Thus Delhi also faces the universal problem of severe pollution due to urban and industrial environment. The city is over crowded with population density of 11300 people per square km. The pressure and disorganized expansion of the population is worsening the environment. There has been an extremely random and unplanned growth of industrial units and factories. Most of the industries are setup in commercial and residential areas thus violating the laws for their establishment. With a rapid boost in population Delhi faces a transport crisis characterized by levels of congestion, noise pollution, traffic fatalities and other problems. There has been a gigantic growth in the vehicular population infuriating traffic jamming and escalating air and noise pollution in the national capital region. Constant growth in the number of diesel vehicles adds up to the problem of air and noise pollution. Thus the level of air and noise pollution in Delhi has risen up to very alarming rates which discourage the inhabitants to dwell in the region.

In recent years noise has become a key area of research along with other form of pollution. This is quite clear from the studies carried out in the past. Therefore a thorough study of pollution level needs to be done to measure the status of contamination at each level. It is evident from the studies that vehicles serve a major source of noise causing problems to the passengers and people in the residential and commercial areas that lie in the vicinity of the traffic. It develops intrusion in health and communication. Noise primarily destroys one's ability to concentrate and creates tension and turmoil.

To trounce these tribulations many efforts have been made in the past. Development in noise control strategy has vividly grown at a rapid rate creating sophisticated techniques and modern methods. Basically, diminution in noise is the only way to control it. Noise control technique in contemporary time refers to optimization of noise level keeping efficient and outfitted considerations in mind. In orientation to the air and noise pollution tribulations Government of India has set up many autonomous regulatory bodies which along with other organizations monitors the pollution level and implies limits and standards to it. These, autonomous body include Central Pollution Control Board (CPCB), State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs) which are conscientious for implementing the legislation concerning to preclusion and control of pollution; they also develop policies and regulations which stipulates the standards for emission.

Recently the Delhi government had launched a program termed as odd-even vehicle rationing program that restricted the use of vehicles with reference to their number plates. The vehicles registered with odd or even number plates were allowed to run on alternate days. The program was launched as an immediate measure to settle the alarming air and noise pollution levels in Delhi. The program was carried out in 2 phases for 15 days each. After-effects of the program were analyzed by various researchers to predict the extent of success or failure of the program. Meanwhile, in this study a similar approach has been developed to assess the noise levels during the odd-even program so as to give a justified result to the steps taken. The study encircles on how the odd-even trial program was implemented with different measures. The benefits of the program has been discussed in detail like reduced congestion, reduced air and noise pollution levels, reduced fuel consumption and reduced energy loss. Efficiency of the transport system had also been improved and the management level had also increased. Overall it came up with positive attitude to combat pollution and a united effort was witnessed. The act of restricting the use of vehicles to minimize the pollution has been followed since the past. It is quite evident from the works of (de Grange and Troncoso, 2011), (Rouwendal and Verhoef, 2006), (Small and Gomez, 1998) that the restriction has earlier been witnessed in Beuno Aires in 1970, Caracas in 1980, Athens in 1985, Mexico in 1989.

1.2 Objectives of the Study

Keeping the effects of odd-even program in mind, the present study was carried out with the following objectives:

i. To study the characteristic of noise pollution.
ii. To study the problem of noise pollution at selected observation stations in Delhi.
iii. To study the effect of odd-even vehicle rationing program by measurement and statistical analysis of noise levels during its implementation.
iv. To discuss the significance of odd-even vehicle rationing program.

The objective of the study clearly states that a comprehensive approach has been build to identify the nature, source and effects of the noise pollution. A control measure strategy has also been discussed to manage and minimize noise pollution. The study is a small step in the direction of noise impact assessment so as to guide the researchers in their work. Efforts have been made to discuss the problem and control measures in detail for the improvement of information.

Figure 1.2 Congested view of main road in Delhi.

(Source: www.googlemaps.co.in)

CHAPTER II

LITERATURE REVIEW

2.1 Background

In this section sound and noise pollution has been discussed. Various basics of sound propagation and noise generation have been explored along with noise impact assessment studies and noise control techniques. Besides that Artificial neural networking and non-linear regression approach has been analyzed and reviewed to forecast and predict noise pollution level.

A wealth of literature exists in the area of road traffic noise and a lot of time and effort has been devoted to analysis of road traffic noise and prediction of certain mathematical models. From a long time, work is continued in this field. Some important literatures are as below:

Study was conducted in London which confirmed that traffic was the main source of noise in Central London, and details are given of two experiments on measuring the noise contributions made by different types of vehicle (Stephenson *et al.,* 1968). In the first investigation the noise levels due to 1100 vehicles were measured individually under similar conditions, and in the second case, traffic noise was measured at 140 sites, note being taken of traffic volume and composition. The importance of Lorries and buses in contributing to high noise levels is discussed, as are the effect of gradients and speed. Urban motorways will have a major influence on the noise environment of the future, and measurements near existing motorways are reported, both with respect to traffic volume and to distance from the motorway. In existing roads the effects of the introduction of one-way schemes, and of road widening programs are also described. Planning to mitigate the effect of traffic noise on the environment is discussed, with special reference to the use of barriers. The paper concludes with a summary of the Greater London Council's policy on traffic Noise.

Another study summarized that traffic noise needs to be described in physical terms such that measurements or predictions of noise exposure in these units are effectively measurements or predictions of nuisance (Scholes, 1971). Such units are developed by the means of social surveys, and typical survey techniques are briefly described. Of the three current proposals: Wilson Proposals, Traffic Noise index and Mean Energy Level; the Wilson Proposals fail the requirements of a physical unit intended to be the basis of traffic noise control because of the lack of demonstrated correlation of Noise levels with nuisance. Both Traffic Noise Index and Mean Energy Level have been shown to correlate well with nuisance but nevertheless the formulations of these two units are, in some respects, conflicting. The development and the relative merits of the two units are discussed, and the direction of further research into traffic noise is outlined.

Study by Harman D.M. and others in 1973 on traffic noise in an urban situation within Portsmouth city boundaries summarized the results of a noise survey made within the Portsmouth City boundaries are outlined. Measurements were made throughout the 18-hour day at 33 sites which covered a wide range of traffic conditions. Comparisons were made between the published noise prediction methods and the measured results for sites adjacent to roads carrying free-flowing traffic. A modification is introduced to allow the design parameter employed by traffic engineers to be used in the prediction formula. The fall-off of noise levels with distance was also examined. An area classification is suggested for situations where the prediction formulae are not able to be applied.

The data of noise spectra obtained in the cabs of new and in-service, heavy goods vehicles having gross vehicle weights up to 40 tons (Williams *et al.*, 1999). Comparisons are made between dB (A) and linear Sound pressure levels under motorway conditions at 30, 4O and 5O mile/h. The emphasis has been on the collection of data, particularly in the infrasonic region, which lies in the octave bands between 2-20 Hz. The results confirm that high levels of infrasound exist in the cabs and these levels are, possibly, influenced by the ventilation of the cab and the road speed. The data obtained are discussed from the points of view of hearing hazard, impaired vigilance, and possible dangers arising from infrasound. It is concluded that in the noisier vehicles there is certainly a danger to hearing, and from available data on the effects of noise in the laboratory and in industry, there is probably some effect on vigilance. The extent of the possible hazard of infrasound is less well established and a need for further research is pointed out.

A mathematical model described for the prediction of traffic noise levels in an urban or suburban situation (Clayden *et al,* 1975). At the present time, only noise levels produced by stationary Sound Sources have been considered. Any paint in a chosen area is described by its grid co-ordinates. A detailed plan of the buildings or other structures in the area and the position(s) of the Sound Source(s) are needed as input to the model. Noise levels at all grid positions in the area are then calculated on the basis of the attenuation of Sound due to direct propagation, diffraction and reflection. The results obtained, so far are given and since the model is in an early stage of development, and has yet to be proved against measurements in real situations, possible refinements and future developments are discussed in some detail.

Another study describes an objective traffic noise survey of Turin, an industrial town in north Italy (Benedetto *et al*., 1977). The main objects of the investigation were to determine the nature and level of outdoor traffic noise in an actual urban situation and to verify the relationships between level of traffic noise, traffic volume and traffic composition. Noise measurements were performed at 70 locations uniformly distributed over the town, in the autumn of 1974. A ten-minute record was made at each site ever), hour for 23 hours. The results are presented and compared with published data from previous surveys carried out in other European and North American towns.

A method for the prediction of the noise levels from road traffic, developed at the National Physical Laboratory (NPL), and has been used for comparison with measured values of road traffic noise in the Sydney Metropolitan Area (Burgess, 1977). As the comparison was not good, multiple regression analysis, using the basic format of the NPL formula, was performed. A better comparison was obtained from a formula in which the term relating to the average road speed of the vehicles was excluded. This new formula permits a simple graphical representation for the determination of L_{10} for urban traffic. A similar formula and graph for the determination of L_{eq} is also provided.

The extensive roadside noise measurements of 20 000vehicles in 100 measurement sites in the high-rise city, Hong Kong was done by classifying the vehicles into petrol-powered saloon, diesel-powered saloon, mini-bus and small lorry, and bus and big lorry, the survey was mainly concentrated in the urban areas (Ko *et. al.;* 2006). However, rural areas were also included in the investigation such that comparison with the urban areas could be made. The results obtained illustrate the effect of enclosed environment on the noise emitted by the vehicles and support the simple classification of the sites into closed, semi-closed and open environments. Distinct differences in the sound pressure levels observed in these environments have been found.

Responses were collected for a social survey from residents of 27 different sites in the Greater Manchester area (Yeow *et al*., 1977). The sites were exposed to noise emanating from (a) freely flowing traffic on urban roads, or (b) motorway traffic, or(c) congested or disturbed traffic flow on urban roads. Existing noise indices were tested on this general sample of traffic flow situations to determine their efficacy in the prediction of community dissatisfaction to traffic noise. No existing index could handle adequately all the traffic flow conditions. When the indices were combined with measures of traffic volume flow between midnight and 6 a.m. a marked improvement in their predictive capability was noted. In particular, extended indices based on L_{l0} (18 hour) and L_{eq} appeared to be useful predictors of community response to all of the traffic flow situations studied in this project.

An equation developed for predicting L_{10}noise levels for roads where interrupted flow traffic exits (Gilbert *et. al.*, 2002). This summarizes the initial work carried out at Imperial College to develop provisional prediction equation. It then describes how the equation was tested and modified by using data recently acquired at Sheffield and Rotherham. The provisional equation includes a variable, the index of dispersion, whose value cannot at present be predicted. But an alternative equation is described which uses only currently predictable variables. It is based on the data from Sheffield and Rotherham.

The development of means of using a scale model of road and its surrounding urban environment to predict L_{eq}, L_{10} and other measures of traffic noise was described and the model described was that of the Centre Scientific Technique du Batiment, Grenoble, France(Mulholland, 1971). The problems involved in the development include allowance for relative Sound absorption between real life and the model situation, the constraints on the accuracy of the results due to noise Source variations on the model and the effects of the finite size of the model.

The environmental noise level due to motor vehicle traffic to a first approximation is a function of traffic volume (Ramalingeswara e*t al*., 1991). The values of sound pressure level (L A_{10}) resulting from traffic noise measurements over one-hour periods have been correlated with the equivalent measured numbers of heavy light vehicles per hour (traffic density). A statistical analysis of the data has been made to enable LA_{10} be expressed in terms of the traffic density in the city of Visakhapatnam, India in 1986 and 1987. Plots of LA_{10} against logarithm N_h (equivalent heavy vehicle density) and logarithm N_1 (equivalent light vehicle density) for the different zones, as well as for the entire city have been made. The validity of these equations is tested by computing the values of the noise indices from these equations, using the traffic density data and comparing them with the measured values. The difference between the measured and calculated values is very small.

Principles of modeling traffic noise using anoptical scale model (Gabriela *et al.*, 1981). The main difference between this model and the widely used 'acoustical' scale model is that it makes use of light instead of sound. There were four phases to the study. The first of these involved the propagation of single vehicle noise over ground and its dependence upon distance and vehicle velocity. The second phase was concerned with light emitted by a small lamp, which imitated a single vehicle. The third part of the work dealt with the principles of the optical model, its construction and use in predicting the equivalent level, L_{eq}, of traffic noise. Finally, a model of a part of a residential area of Poznati, Poland, was built and values of L_{eq} computed. These results were compared with field measurements.

A survey was carried out of traffic noise in the city of Delhi inorder to examine the nature and levels of noise inside various types of vehicle (Kumar *et al*., 1994). The study involved measurements of average A-weighted levels and power spectra of noise inside buses, auto-rickshaws, cars and trucks from which L_{10}, L_{50}, L_{90} and L_{eq} levels were estimated. It is found that noise levels in auto-rickshaws are the highest, followed by trucks, buses and cars. The power spectra o fall four types of vehicle exhibit rather similar behavior.

A study was conducted to monitor and assess the road traffic noise in its spatial-temporal aspect in an urban area (Banerjee *et al*., 2008). Noise recordings from site, collected from April 2006 to March 2006, were used for statistical analysis and generation of various noise indices. The study reveals that present noise level in all the locations exceeds the limit prescribed by CPCB.

CHAPTER III

CHARACTERISTIC OF NOISE

3.1 Noise

3.1.1 Definition

Noise is described as an unacceptable level of sound that unfavorably affects the mental and physical peace of human being and when the intensity of noise increases it leads to noise pollution. The auditory and nervous system of humans can be destroyed if continuously exposed to loud level of sound (Craik & Stirling, 1980). As noise levels have rise due to growth in the population levels and number of vehicles owned by them the effects of noise has become more noticeable. For most of the people the relentless and rising sources of noise can often be considered an infuriation. This leads to illness and discomfort. Though, it is difficult to measure the cumulative exposure to noise but the standard limits can be set to increase factor of safety against noise via studies and research work. Previously many attempts have been made in this direction by the researchers and consequently different approaches have been set to combat noise pollution at own level (Battalwar *et al.*, 2012). Disclosure to disproportionate noise is a foremost cause of hearing disorders worldwide

The decibel is the paradigm for the quantification of noise. One consideration of the acoustic sound-wave propagation used to evaluate sound disclosure to humans is the sound pressure level (SPL) expressed in μPa or Pa (Singal, 2005). Human ear audible sound pressure levels range from 20 μPa (hearing threshold) till 20 Pa (pain threshold), resulting in the scale 1:10,000,000. Since using such a large scale is not practical, a logarithmic scale in decibels (dB) was introduced which is also in accordance with physiological and psychosomatic earshot vibrations. Sound is produced as result of some mechanical disturbance creating pressure variations in an environment such as air or water, or in fact any elastic medium which can transmit a pressure wave. To be able to hear the sound there must always be air or other elastic medium at the ear. The magnitude of the pressure variations (The amplitude of the pressure oscillation) is proportional to the loudness of the sound. The number of pressure cycles per second determines whether we hear a sound of high pitch or of low pitch, the higher the frequency the higher the pitch.

dB of sound pressure level (dB SPL) is defined as: $20 \log_{10} p1/p0$ where p1 is actually measured sound pressure level of a given sound, and p0 is a reference value of 20μPa, which corresponds to the lowest hearing threshold of the young, healthy ear. In the logarithmic scale the range of human ear's audible sounds is from 0 dB SPL (hearing threshold) to 120-140 dB SPL. The noise quantum of few cities in India indicate their pitch in decibel in the noisiest areas of corresponding cities, for example, Delhi-80db , Kolkata-87db, Mumbai- 85 db etc.

Increasing the demands of urbanizations and industrialization in India is causing major exposure of people to the unwanted sounds (Ali & Tamura, 2003). The sounds we make in our everyday life like loud music, unnecessary use of television, phone, traffic, dog barking and etc noise creating sources have become part of the urban culture as well as most disturbing things causing headache, sleep disturbances, stress, etc (Singal, 2005). Those things causing disturbance to the natural rhythm of life are called as dangerous pollutant. The urban areas of India have become highly populated in past few decades. In the last decade, it rose by 31.8%. This has led to certain environmental and health issues that also include environmental pollution. Some causes are unavoidable and are required to be followed for the developmental activities. So, it is not possible to completely avoid them.

3.1.2 Noise vs. Sound

Sound is a form of energy. It refers to disturbances in air, water or ground that creates hearing sensations. Sound wave energy consists of two parts mechanical kinetic energy and partly potential energy (Sandberg & Ejsmont, 2002). Acoustic sound waves travel as the disturbance travels from particle to particle. The medium particles vibrate in both longitudinal and transverse motion.

i. 0 to 20Hz – infrared
ii. 20Hz and above – ultrasound

The velocity of propagation can be specified as:

$$v = k\sqrt{(E/\rho)} \quad (3.1)$$

Where,

v = velocity of propagation,

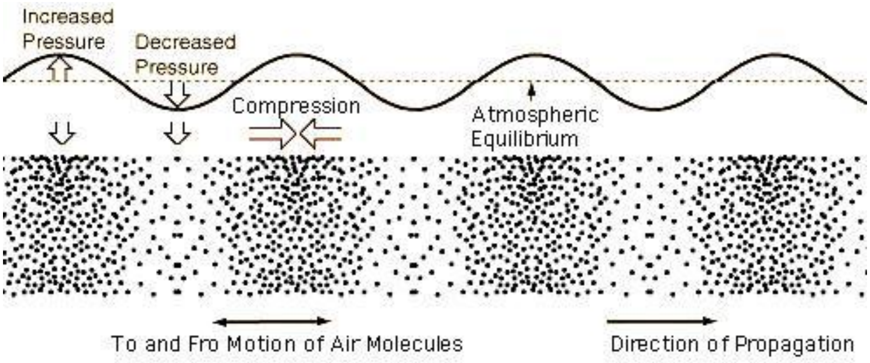
k= constant of proportionality,

E=young's modulus,

ρ= medium density.

Sound waves exhibit the phenomenon of diffraction, refraction, reflection and interference. Sound waves propagate in air as compression and rarefaction.

Figure 2.1 Formations of compression and rarefaction in elastic medium (Source: Singal, 2005).



Noise is a complex sound which is produced by non harmonic motion and is spontaneous in nature. Thus it is the undesired sound that happens at wrong place and wrong time. It is recognized as one of the major trepidations that impact the quality of human life (Hunashal *et.al.*, 2012). Presently noise is an outcome of modern civilization, industrial revolution and urbanization. Noise is a ubiquitous accessory of mechanical age in which we live; it is a by-product of the modern developments in technology which favors more mechanization, faster traffic and closer packing of the populations. The type of sound generally encountered by a person in normal living environment is either steady state or steady state mixed with impulsive sounds. Although the research in the field of the noise is very less, yet it is no less pollutant than the other unwanted pollutants in our environment. A vivid study of noise is therefore required to check its increasing level in day today life of human beings.

3.1.3 Noise Characterization

Noise waveform is commonly expressed as sinusoidal signal as shown in the figure. It can be characterized through its energy contents and frequency composition. RMS is the chief method of measuring the amplitude of noise.

$$A_{RMS} = \sqrt{[1/T \int_0^T a^2(t)dt]} \tag{3.2}$$

Where,

A_{RMS}= maximum amplitude reached by the signal,

T= time period,

a(t)= instantaneous amplitude,

Industrialization along with wealth and comfort brought pollution of the environment. In order to analyze the environmental impact of the industrial projects Environment Impact Assessment came into force. It examines the proposed action and the adverse effect on environment of the project. The procedure it follows:

i. Identifying the type of project activities that will be created by the project.
ii. The environment elements that will be harmed.
iii. Evaluation of the initial and subsequent outcomes.
iv. Management of the adverse impact generated by the project.

This assessment method was also introduced for noise; before starting the project the documents which describe the amount of noise that will be created, what changes will occur in the environment need to be mentioned. Various methods to overcome the adverse impact of noise due to the project should be taken (Ramanathan, 2001). The objective of the project should be made clear. It should contain all the information regarding the project. What all steps would be taken should be clearly written on paper with the signature of the authorities (EPA, 1973). Review of the impact is also necessary.

Changes which are for short term need not to be considered for documentation. The contour of the affected area is made which diagrammatically depicts the affected areas in the documents (Singal, 2005). Quick actions are taken for highly affected areas. The population which is affected by the noise is also taken into account. All the health welfare programs are being carried out.

The equation to calculate day-night average sound level is given below

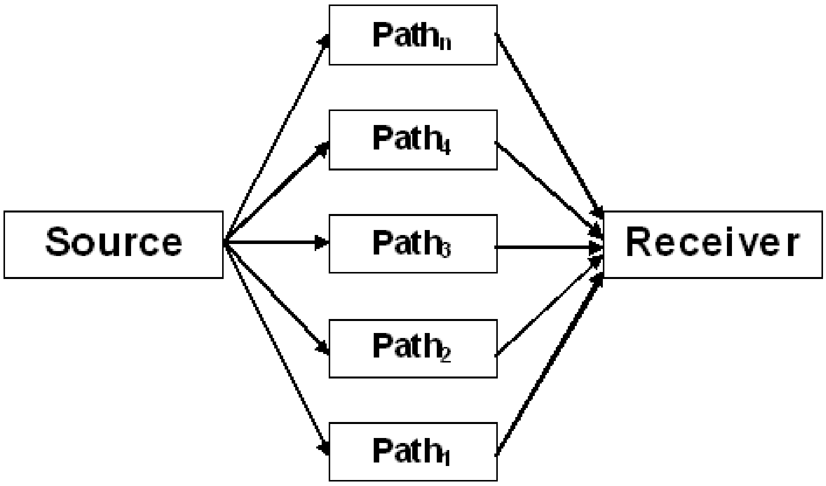
$$L_{DN} = 10 \log 2.56A + 22 \ dB \tag{3.3}$$

Where, A is refereed as the population density per square kilometer.

Exposure to the frequencies stated below for less than 1 minute do not cause harm, when the time duration becomes greater that 1 minute and less than 100 minutes, the non damaging level decreases by ‘ 10log t’, where t gives the time of exposure in minutes. Noise impact can either be intensive or extensive. The word intensive means the noise may affect few people severely while the term extensive means it may affect large population less severely. The moderate impact of noise on large population is around same as compared to greater noise on small population. Out of above three parameters, the source that affects the most is Traffic noise. In traffic noise, almost 70% of noise is contributing by vehicle noise. Vehicle noise, mainly, arises from two parameters i.e. Engine noise and Tire noise. The major concern is to study the vehicular traffic noise and its prediction.

It is seen that Equal Loudness Contours show human ear response as non-linear in relation to both frequency and SPL. Due to this behavior a rise of 10 dB in SPL corresponds only to a doubling of subjective loudness nearly. To represent this subjective behavior on a linear scale, Sone Scale was developed According to this scale one Sone is defined as the loudness of a Sound of 40 Phon, 50 Phon are equal to 2 Sone, 60 Phon are 4 Sone and so on.

Figure 3.2 Method of Sound Propagation. (Source: Singal, 2005).



The above figure shows the flowchart of noise in environment as to how it takes multiple paths to reach the receiver.

The reduction of noise is the major concern of the environmentalists. Reduction in noise can be done through the ways enlisted below:

i. Noise controlling at transmission path the noise follows,
ii. Controlling noise at the receiver and
iii. Noise control at the source

The part in which the noise is generated is known as the source. For example: fan, gear, compressor or any of the parts of machines. Attenuation or distortion of sound is caused during the transmission of sound waves. The disturbance generally affects the receiving end (Singh & Davar, 2004). Controlling noise at the source is considered as the best and the most advised method. This can be done by servicing of the machines, replacement of the older machines. Upgrading the machines will further improve its efficiency. Materials from which machines are made need to be of the best qualities. Controlling noise at the source becomes difficult at times (Singal, 2005). Therefore controlling noise during transmission was considered. Controlling noise was done through construction of barriers and insertion of devices which provide isolation, Controlling noise at the source is done through various activities enlisted below:

i. Balancing forces which act upon the system,
ii. Oiling, servicing the internal parts of the machines,
iii. Sound proof walls should be made,
iv. Close tolerance products must be made.
v. This reduces the vibration and harmful impact of the sound,
vi. Replacing old machines with the new and the efficient ones,
vii. Acoustic leakage should be avoided.
viii. Proper mounting of machines on vibration mounts to reduce vibrations.

Controlling noise along the transmission path is done by two ways:

i. Reactive devices and
ii. Dissipative devices.

Reactive devices are those devices which depend on tuned parts. Therefore these devices are widely used in tuned fixed speed machinery which consists of pure tones (Bies & Hansen, 2009). At low frequencies it is not considered as the results are not trustworthy. Along with dissipative devices they are made to attenuate noise of lower frequencies. When acoustic wave is incident on barrier, some of the energy is transmitted and some is absorbed by the material and rest is reflected back (Lai, 1998). Law of energy conversion can be mathematically expressed as:

$$E_i = E_t + E_a + E_r, \tag{3.4}$$

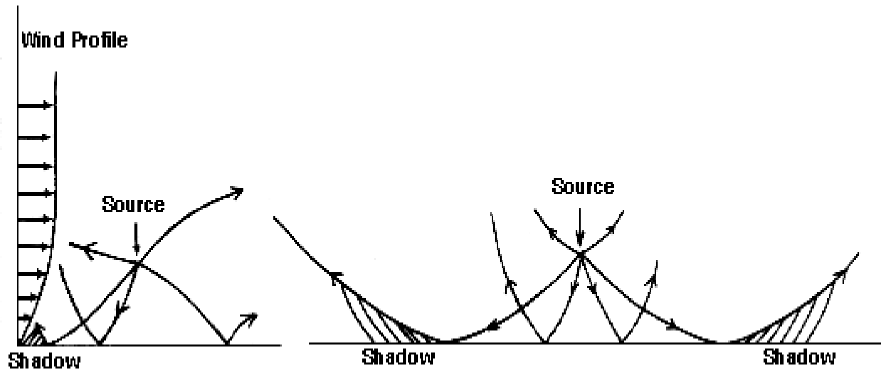
Where,

E_i = incident energy, E_t= transmitted energy, E_a= absorbed energy, E_r= reflected energy

It states that the incident energy is equal to the sum of the absorb energy, transmitted energy and reflected energy. Dissipative devices are those devices which are unturned and they convert the acoustic energy into the heat energy. They rely on the materials that absorb acoustic energy. They are basically used along with fans, gas moving devices and jet engines. Sound insulation is done using non porous rigid materials. Greater the thickness and weight of the material greater is the sound insulation. Insulators contain both damping as well as resilience (Delany & Bazley, 1970). Damping reduces resonance peak but decreases the efficiency of isolation above the resonant frequency. Above the resonance zone, the panels follow the mass law for transmission loss. When the frequency reaches above the projected wavelength of the sound incident on the panel called the coincidence effect the transmission loss is reduced due to coupling between the panel and the air. At critical frequency coincidence occurs depends on the panel material stiffness.

The overall noise is also dependent on the characteristics of the vehicle flow and the relative proportions of the vehicle types included in the flow. Knowledge of these factors is thus necessary to define the characteristics of highway noise and to subsequently predict the associated noise level in the surrounding area. The amount of information required depends on the degree of accuracy desired in the predictions, which in turn is a function of the method selected to characterize the temporal variation of the noise.

Figure 3.3 Transmission loss verses frequency plot (source : kumar and jain, 2000)



3.1.4 Weighting curves

The nonlinear response of ear has lead to the introduction of weighting filters, which correlate well with the response of the ear. The instrument used weight the different frequency components taking into account the frequency sensitivity of the ear and thereby gives a better indication of annoyance than the dB. The most commonly used of these curves is the A-weighting curve as it gives the best correlation between the measured values and the annoyance and the harmfulness of the sound signal. It follows approximately the 40 phons curve. The B and C weighting curves follow more or less the 70 phon and the 100 phon curve respectively. The D weighting curve follows a contour of perceived noisiness and is used for aircraft noise measurement. In addition to these weightings sound level meters usually also have a Linear or zero weighting.

Weighting filters can easily be built into portable Sound Level Meters, and the sound level measured is then given in dB (A) in case where an A-weighting filter has been used etc. Some sound level meters also have octave filters built in, or provision for connection of external filters.

Active noise control system is used to control the induction noise from the large fans used in the thermal power plants. The functioning principles of this system are interference and absorption (Singal, 2005).All the above mentioned control measures were either used for controlling noise at source or at the transmission path. Controlling noise at the receiver is also a method to control noise.

If a sound has components at one frequency only, it is said to be a pure tone. Such sounds are not very common in nature, however, and the only common example of a pure tone is the sound of a tuning fork. Most usually, Sounds have components at several frequencies and the character or timbre of a steady sound is determined by the pressure amplitudes at the different component frequencies. We can therefore describe a steady sound by a graph of frequency against amplitude, and such a graph is referred to as the Frequency spectrum of the sound. Sound measuring instruments are usually constructed to measure the frequency spectrum, but for measurement convenience and simplicity of the instrument in practice we measure the energy content in a particular range of frequencies. Some examples of the frequency spectra of particular sounds are given in next section. Sound has a unique characteristic of its own.

The part in which the noise is generated is known as the source. For example: fan, gear, compressor or any of the parts of machines. Attenuation or distortion of sound is caused during the transmission of sound waves. The disturbance generally affects the receiving end (Singh & Davar, 2004). Controlling noise at the source is considered as the best and the most advised method. This can be done by servicing of the machines, replacement of the older machines. Upgrading the machines will further improve its efficiency. Materials from which machines are made need to be of the best qualities. Controlling noise at the source becomes difficult at times (Singal, 2005). Therefore controlling noise during transmission was considered. Controlling noise was done through construction of barriers and insertion of devices which provide isolation,

Changes which are for short term need not to be considered for documentation. The contour of the affected area is made which diagrammatically depicts the affected areas in the documents (Singal, 2005).

This can be done by:

i. Shift of the workers should be there so that a particular worker is not exposed to noise for a longer period of time,
ii. Usage of earphones and other protective devices,
iii. Noise from the power-plant increases as engine speed increases
iv. Regular audiometric checkups of the workers to protect them from hearing loss.

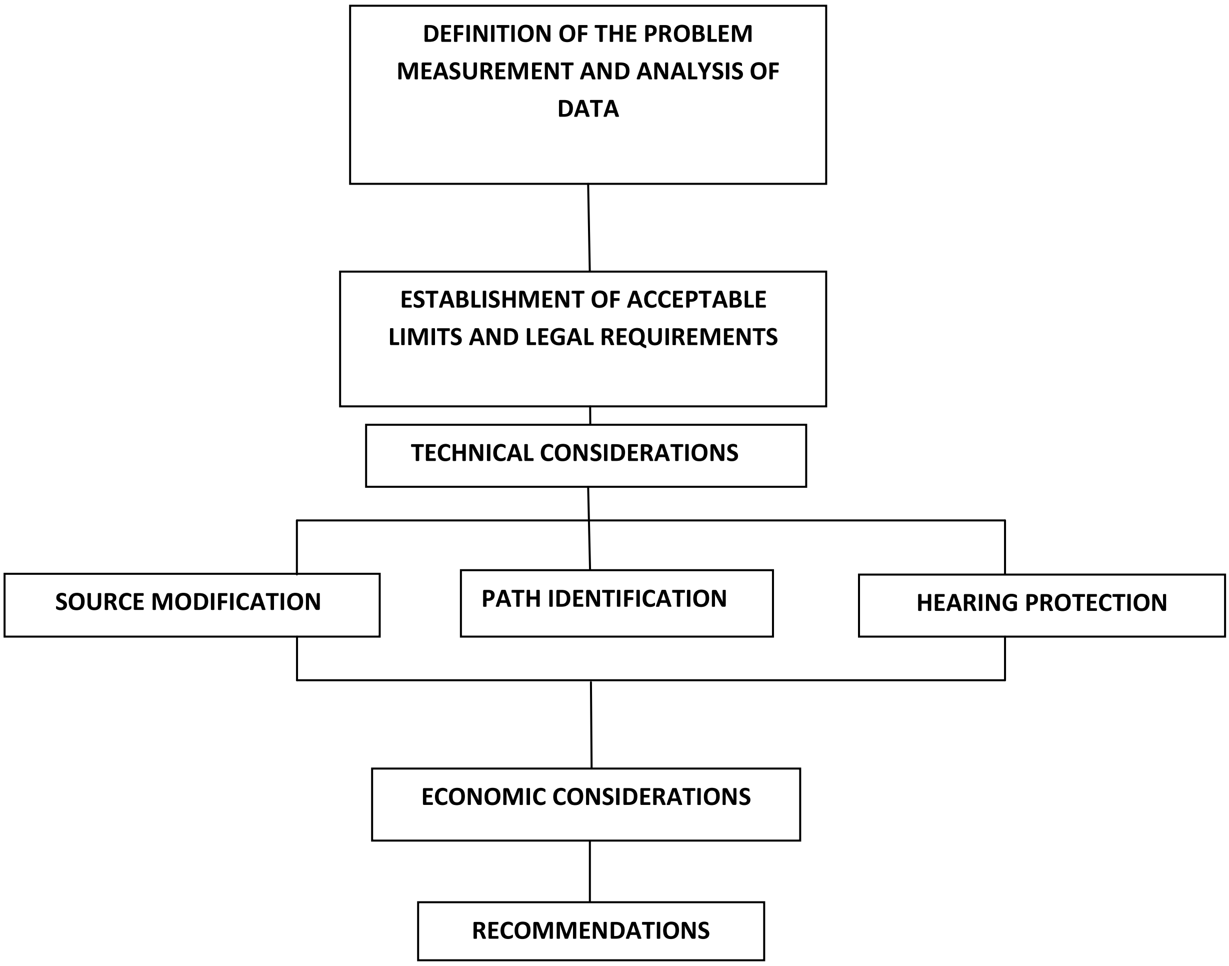


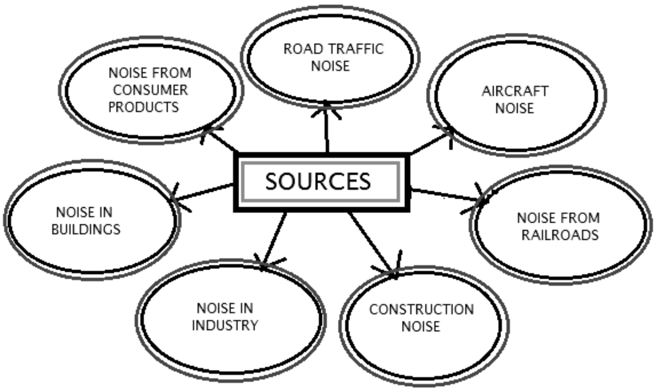
Figure 3.4 Flowchart of the stages of industrial noise control

3.1.5 Sources of Noise Pollution

Noise pollution like other pollutants is also a by- product of industrialization, urbanizations and modern civilization. Broadly speaking, the noise pollution has two sources, i.e. industrial and non- industrial (Zaidi, 1989). The industrial source includes the noise from various industries and big machines working at a very high speed and high noise intensity.

Non- industrial source of noise includes the noise created by transport/vehicular traffic and the vicinity noise generated by various noise pollution can also be divided in the categories , namely, natural and manmade. Most leading noise sources will fall into the following categories: roads traffic, aircraft, railroads, construction, industry, noise in buildings, and consumer products. The following have been identified as the Source of noise to which a man is exposed advertently or inadvertently on road, in the house, at work, in the factory, indoors or outdoors. Noise source, the path which the noise travels or the location where the noise is heard should be targeted first for controlling the noise. Absorption covers surrounding walls, benches and objects with material that absorbs sound such as foam, rubber, adhesive cork or fibre glass wool .Cover the machinery that is causing the noise. Separate the noise producing machinery from transmitting vibration to other equipment. For example, mounting a compressor on a rubber block. Vibration dampening helps in removing vibration as much by making the equipment stiffer. This is done by adding extra support frames to mounted equipment. Usage of sound absorbing obstacles between the noise source and the person hearing to noise reduces noise like barriers, screens, partitions and natural objects can all reduce noise heard outside the location. Heavy long curtains on window or room with no windows are best and keep the door shut. Noisy machinery should be as far away from the public as possible. Noise reduces naturally over distance.

Figure 3.5 Sources of noise pollution



a) Road Traffic Noise

In the city, the main sources of traffic noise are the motors and exhaust system of autos, smaller trucks, buses, and motorcycles. This type of noise can be augmented by narrow streets and tall buildings, which produce a canyon in which traffic noise reverberates (Anon, 1952). It is directly proportional to the volume of vehicles. Increasing of population is growing of vehicles and hence increasing of Noise pollution. The major sources of noise in automobiles are exhaust, intake, engine and fan, and tires at high speed.

The noise output of all components increases with speed. As an example keeping all the conditions same, an approximately 10 dB (A) increase with speed of a car from 30mph to 60mph. As a tire rolls over a road surface, it displaces macroscopic and microscopic volumes of air. The ‘macroscopic’ applies to volume displacements of the same order as the volume of the tire itself, and ‘microscopic’ applies to much smaller volumes.

This air displacement generated pressure disturbances in the surrounding air. Pressure disturbances in the audio frequency range and of sufficient amplitude are responsible for the production of noise along the roadway.

b) **Air Craft Noise**

Now-a-days, the problem of low flying military aircraft has added a new dimension to community irritation, as the nation seeks to improve its nap-of the- earth aircraft operations over national parks, rough areas, and other areas previously unaffected by aircraft noise has claimed national attention over recent years (Singh & Davar, 2004) more noise for the plight of persons who live near aerodromes. Taking off and landing of an aircraft produces intolerable noise. It has been observed that supersonic jet planes are one of the major irritants in today's noisy world. The noise of these planes may sometimes break windowpanes, crack on walls and shakes the buildings also. By these effects of noise one can very easily understand that what would be the effects of such noise on human body.

c) Noise from railroads

The noise from locomotive engines, horns and whistles, and switching and shunting operation in rail yards can impact neighboring communities and railroad workers (Peters, 1974). For example, rail car retarders can produce a high frequency, high level screech that can reach peak levels of 120 dB at a distance of 100 feet, which translates to levels as high as 138, or 140 dB at the railroad worker's ear. The noise generated in communities having long heave or rapid transit vehicles (like Metros) in their environment will depend primarily on track observer distance, frequency and train length and condition of track. Trains passing over bridges and other structures develop special resonating noise patterns. The rapid transit trains are short, so that their noise duration time is less than that of trains. Rapid transit vehicles produce lower level of noise than compare to lengthy trains.

d) Construction Noise

The noise from the construction of highways, city streets, and buildings is a major contributor to the urban scene (Singh & Davar, 2004). Construction noise sources include pneumatic hammers, air compressors, bulldozers, loaders, dump trucks (and their back-up signals), and pavement breakers.

e) Noise in Industry

Although industrial noise is one of the less prevalent, neighbor of noisy manufacturing plants can be disturbed by sources such as fans, motors, and compressors mounted on the outside of buildings (Zannin *et al.*, 2002). Interior noise can also be transmitted to the community through open windows and doors, and even through building walls. These interior noise sources have significant impacts on industrial workers, among whom noise- induced hearing loss is unfortunately common.

f) **Noise from appliances**

Apartment dwellers are often annoyed by noise in their homes, especially when the building is not well designed and constructed. In this case, internal building noise from plumbing, boilers, generators, air conditioners, and fans, can be audible and annoying (Singal, 2005). Improperly insulated walls and ceilings can reveal the sound of-amplified music, voices, footfalls and noisy activities from neighboring units. External noise from emergency vehicles, traffic, refuse collection, and other city noises can be a problem for urban residents, especially when windows are open or insufficiently glazed.

g) Noise from Consumer products

Certain household equipment, such as vacuum cleaners and some kitchen appliances have been and continue to be noisemakers, although their contribution to the daily noise dose is usually not very large.

3.2 Cause of noise pollution due to vehicles

The noise level in cities is rapidly increasing at an alarming rate. This is due to heavy traffic and more powerful engines. In India like many other developing countries traffic noise is major continents of environmental pollution and now it has become a permanent part of urban and sub-urban life. It is very harmful to human beings. In the new millennium, for protection environmental degradation it is vital to pay greater attention towards measuring noise pollution, enforcing regulation for noise emission limits, elimination and control noise pollution.

3.3 Factors that affect traffic noise

There are various factors that affect the traffic noise

a) The speed of the traffic flow, as there is increase in the traffic flow, the noise level increases. Higher the speed higher noise levels. At lower speeds, the influence of engine transmission of noise is predominant where as at higher speed the tyre surface interaction assumes importance. Noise level increases during acceleration.

b) Interaction of tyre-road surface: It is a major generator of noise Grooved cement concrete pavement is found to be source of annoying noise to neighborhood.
c) Road surface condition: Smooth surface generally produce less noise. Rough surface and poorly maintained road with pot-holes produce more noise.
d) Due to various parts of vehicle: Important Sources are , Engine Inlet Exhaust , propulsion & transmission including gears, brakes, horns, chaises body structure, Load in vehicle, door slamming etc. Further as the vehicle grow older and their mechanical condition degrades the noise generated in more.
e) Motor cycles, scooter, tempos, and minibuses are generally noisier as compared to passenger cars.
f) Large H.P. Diesel engine vehicle, Commercial truck, Tractor-trolley, transport vehicle is the main source of noise.

3.4 Effect of noise pollution

There is various adverse effect of noise on human health and on the environment.

Physiological effects: Noise pollution has inference for health as serious as air or water pollution. Noise can change people physiological state by speeding up pulse and respiratory rates (Stansfeld & Matheson, 2003). It can impair hearing either permanently or temporarily, people working at the industries are threatened with hearing damage. Medical fact suggests that noise can cause heart attacks. Noise can cause chronic effects as hypertension or ulcers. Noise can cause deafness. Some experimental research conducted on pregnant female mice reveals that air craft taking off which bring 120 to 160 dB caused miscarriages in them, if the findings on mice are made applicable on human being.

Table 3.1 Effect of exposure to noise which is greater than its max limit by WHO (Singhal, 2005)

Environment Type	Recommended 8 hr Max. L_{eq} in dBA	Effects in case the limit exceeds recommended values
Industrial/ Occupational Commercial Urban	75	Risk of Hearing Impairment
Day Time	55	Annoyance increases
Night Time	45	Difficulty in Falling Asleep
Indoor Domestic Day Time	45	Speech Communication Deteriorates
Night Time	35	Increased Awakening

The effect of these categories includes, anger, tensions in muscles, nervous irritability and strain. It creates annoyance to the receptors due to sound level fluctuations. The non periodic sound due to its irregular occurrences causes displeasure to hearing and causes annoyance. The physiological features like breathing amplitude, blood pressure, heart-beat rate, pulse rate, blood cholesterol are affected.

Behavioral effects: By experimental results performance of school going children is poor in comprehension, when schools are in the busy / traffic area. Noise can cause irritation, which results in learning disabilities (Stansfeld & Matheson, 2003). Lack of concentration on work occurs when people are in traffic area and lot of noisy area. People become restless lose concentration power and presence of mind due to noise prone areas.

Personal effects: If the adverse effects of noise tend to persist for longer duration they may cause mal adaptive reactions in the individuals, disturbing his total personality build up. Insomnia, fatigue, hypertension, blood pressure and deafness are the symptoms shown by the people living in the noise pain, ringing in the ears, feeling of tiredness, thereby effecting the functioning of human system.

Noise pollution effects on wildlife: According to the reports noise pollution has serious adverse effects on wildlife as well. There is turn down in migratory birds to a habitat if it becomes noisy (Francis *et. al.,* 2009). The vibrations caused due to high noise level may cause even death to the birds. Deer and lions affected from the traffic noise as observed in some zoo. Physiological and environmental consequences of noise could be serious to the survival of wildlife.

Effects of noise on non-living things: The high intensity of noise such as vibrations emanating from heavy machinery cause shattering of window glasses, losing the plaster of house walls, cracks in walls, cracks in household equipments and breaking down the hanging in the house. The buildings and materials get adversely affected by exposure to infrasonic or ultrasonic waves and even get malformed (Ridker & Henning, 1967). When sound measurement on for instance a machine is carried out, it is important that the background noise level is so low, that it does not have any influence on the result.

3.5 Adverse health effects of noise pollution

The World Health Organization (WHO) has documented seven categories of adverse health effects of noise pollution on humans

Loss of hearing: Hearing damage is related to duration and intensity of noise exposure and occurs at levels of 80 dB i.e. above the threshold level or greater, which is comparable to the noise of heavy truck traffic (EPA, 1973). Children are affected more than adults. Long exposure to high sound levels cause loss of hearing. This is mostly unnoticed but has an adverse impact on hearing function. Recreational activities that can put you at risk for NIHL include target shooting and hunting, snowmobile riding, listening to MP3 players at high volume through headphones, playing in a band, and attending loud concerts. Harmful noises at home may come from sources including lawnmowers, leaf blowers, and woodworking tools.

The louder the sound, the shorter the amount of time it takes for NIHL to happen. Here are the average decibel ratings of some familiar sounds:

a) The humming of a refrigerator: 45 decibels
b) Normal conversation: 60 decibels
c) Noise from heavy city traffic: 85 decibels
d) Motorcycles: 95 decibels
e) An MP3 player at maximum volume: 105 decibels
f) Sirens: 120 decibels
g) Firecrackers and firearms: 150 decibels

Your distance from the source of the sound and the length of time you are exposed to the sound are also important factors in protecting your hearing. A good rule of thumb is to avoid noises that are too loud, too close, or last too long.

Effect on heart: Noise harms heart by elevating stress hormones such as cortisol, adrenaline, and noradrenalin, which, over time, can lead to high blood pressure, stroke and heart failure (EPA, 1974). One review of research showed that "arousal associated with night time noise exposure increased blood and saliva concentrations of these hormones even during sleep. Deepak Prasher, a professor of audiology at University College in London and a member of the WHO Noise Environmental Burden on Disease working group, states "Many people become habituated to noise over time.

The biological effects are imperceptible, so that even as you become accustomed to the noise, adverse physiological changes are nevertheless taking place, with potentially serious consequences to human health Taken together, recent epidemiologic data show us that noise is a major stressor that can influence health through the endocrine, immune, and cardiovascular systems." Among women the impact can be significant who critic themselves to be receptive to noise, chronic noise exposure increased the risk of cardiovascular mortality by 80 percent, Chronic noise exposure further leads to health risks beyond your heart, such as diminished productivity, sleep disruption, impaired learning.

Interference with spoken communication: Noise pollution interferes with the ability to figure out normal speech and may lead to a number of personal disabilities, handicaps and behavioral changes (Singal, 2005). Problems like lack of concentration, fatigue, uncertainty, lack of self confidence, irritation, misunderstandings, decreased working capacity, disturbed interpersonal relationships and stress reactions.

Sleep disturbances: Continuous sleep is known to be a requirement for good physiological and mental functioning in healthy persons. Noise pollution is a chief cause of sleep disturbances. Apart from various effects on sleep itself, noise pollution during sleep causes increased blood pressure, increased heart rate, increased pulse amplitude, vasoconstriction and increased body movement. These effects do not decrease over time. Secondary effects include fatigue, depressed mood and well-being and decreased performance. Combinations of noise and vibration have a significant detrimental effect on health, even at low sound pressure levels.

Mental health disturbances: It accelerates and intensifies the enlargement of latent mental disorders. Noise pollution may cause or contribute to the following adverse effects: Anxiety, stress, nervousness, nausea, headache, emotional instability and argumentativeness, changes in mood, increase in social conflicts, neurosis, hysteria and psychosis. Children, the elderly and those with underlying depression are particularly susceptible to these effects.

Impaired task performance: The effects of noise pollution on task performance have been well-studied. Noise pollution impairs task performance, increases errors and decreases motivation noise. Noise produces negative after-effects on performance, especially in children it appears that the longer the exposure, the greater the damage.

Negative social behavior and irritation reactions: Irritation is defined as a feeling of displeasure associated with any agent or condition believed by an individual to adversely effects on him or her. Irritation increases significantly when noise is accompanied by vibration or by low frequency components. The term irritation does not begin to cover the wide range of negative reactions associated with noise pollution these include anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion.

Social and behavioral effects are complex, subtle and indirect. These effects include changes in everyday behavior, changes in social behavior and changes in social indicators and changes in mood. The road surface and the road gradient at any inspection point hence need to be considered.

CHAPTER IV

NOISE POLLUTION IN DELHI

4.1 Noise Problem in Delhi

The rapid increase in motorization and urbanization in Delhi to meet the demands has resulted in a increased level of pollution. Previous researches show that the city is under severe state of pollution.

Figure 4.1 Congestion on roads of Delhi during peak traffic hours.

Noise problem persists at areas with heavy, medium or light traffic in Delhi and the problem worsens at peak hours when there is heavy rush on roads (Figure:6). Table:2 shows the community response in Delhi. More critical the problem more is the complaint level but at the same time immediate measures have also been taken.

Table 4.1 Estimated community response to noise (ISO: R 1971-1996, IS: 1981-1989)

Rating Sound Exceeding Noise Criterion dB(A)	Category	Estimated Community Response Description
0	None	No observed reaction
5	Little	Sporadic complaints
10	Medium	Wide spread complaints
15	Strong	Threat of community action
20	Very Strong	Vigorous community action

Table 4.2 Measured vehicular noise level parameters in DELHI (Kumar and Jain, 1991).

Modes of Transport	L_{10} dB(A) at Levels of Confidence		L_{90} dB(A) at Levels of Confidence		Leq dB(A) at Levels of Confidence		Spectral Levels in dB at Octave Bands (Hz)		
	5%	1%	5%	1%	5%	1%	31.5	1000	16 k
DTC Buses	85.98 + 1.29	85.98 + 1.88	75.39 + 0.97	75.39 + 1.41	83.95 + 1.39	83.95 + 2.02	102	79	50
Private Buses	83.75 ± 0.87	83.75 ± 1.27	73.88 ± 1.08	73.88 ± 1.08	81.29 ± 0.96	81.29 ± 1.40	99	76	44
Auto Rickshaw	90.42 ± 0.96	90.42 ± 1.40	82.37 ± 0.75	82.37 ± 1.09	88.89 ± 1.12	88.89 ± 1.64	91.5	82	55

4.2 Measures for Controlling Noise Pollution in DELHI

Public education programs and government plays a vital role in controlling the noise-level. The police and civil administration could also make possible checking of noise-levels. However, the data suggests need for a multi-dimensional approach i.e. a single measure cannot achieve the goal of noise-reduction. In terms of age, significant proportion persons between 20-40 years and 40-60 years feel that civil authorities should be empowered along with other measures. It strengthens the belief that public education is needed because people are not aware of legislation/rules of environment ministry of Delhi. The youth need to be educated with the rules. Each of age groups feels that a combination model could work better for a public cause.

Table 1.3 Upper limits of noise for desirable and prohibitive levels of traffic noise (Rao and rao, 1992).

Noise Index	Upper limits for noise levels in dB(A)		
	Desirable		Prohibitive
	Dissatisfaction	Dissatisfaction	Dissatisfaction
	Score 2	Score 3	Score 5
L_{10}	64	74	93
L_{50}	58	67	85
L_{90}	52	61	79
L_{eq}	58	68	89
L_{NP}	69	82	111

Eliminating noisy activities: Eliminate noisy activities and equipment from wherever possible. Off site location can be preferred for noisy equipment. Older noisy equipments can be replaced by the newer one and quieter one. If possible remove the noisy equipments which are idle for many days.

Minimize noisy activities: Minimize noisy activities during receptive times of the day. Perform noisy activities such as drilling, grinding or hammering during the middle of the day rather than early morning or late afternoon. If you are loading a truck first thing in the morning then reverse the truck into place the afternoon before.

Controlling the produced noise: In India noise figured incidentally in general legislation of the Government of India as a component in Indian Penal Code, Motor Vehicles Act (1939)and Industries Act (1951). Some of the states also had noise limits incorporated in certain manner in their legislation. In 1986, the Environment (Protection) Act was legislated.

A review of the status report indicates that noise Surveys were made in India in the sixties by the National Physical Laboratory, New Delhi. The findings of this survey clearly established the existence of high noise levels in Delhi, Bombay and Calcutta. An expert committee on noise Pollution was set up by the Ministry of Environment, Govt. of India, in early 1986 to look into the present status of Noise pollution in India Expert Committee submitted its report in June 1987.

4.3 Standards

Various sections of the act empower a state to frame rules for the upkeep of motor vehicles and control of noise produced by them in its jurisdiction. Rules framed by the states are mostly concerned with horns and silencers**.** Section 11 of the Factories Act, 1948 provides protection from nuisance which reads: Sec. 11(1): "Every factory shall be kept clean and free from any drain, privy or other nuisance". The use of word nuisance in the section may include noise. Under Section 35 of the Act protection to eyes of an employee is given but protection to ears is nowhere industries crossing permissible levels it is high time that the government cares to give a look to these ancient legislations. It states that who so ever commits a public nuisance in any case not otherwise punishable by this code will be punished with fine which may extend to two hundred rupees. The fine should possibly be increased to an exorbitant amount that may in a way help in preventing people from indulging in activities leading to production of high noise levels. Empowering magistrates will only help when the authorities care about enforcement which seems to be totally lacking. Under section 119 the subject of concern is horns. The law states "That every motor vehicle shall be fitted with an electric horn and any multi toned horns that produce shrill, loud or alarming noises are not permissible under law." In India, Noise figured only incidentally in general legislation of the Govt. of India as a Component in Indian Penal Code, Motor Vehicles Act (1939), and Industries Act (1951). Some of the states also had noise limits incorporated in certain manner in their legislation. In 1986, the Environment (Protection) Act was legislated.

Table 4.4 Outdoor and indoor limits of noise for desirable and prohibitive levels of traffic.

Outdoor noise levels in residential areas	
Type of Residential Area	**Acceptable Noise Levels in dB(A)**
Rural	25 – 35
Suburban	30 – 40
Residential Urban	35 – 45
Residential & Business Urban	40 – 50
City	45 – 55
Industrial Area	50 – 60
Indoor noise levels in public / private places	
Type of Place / Building	**Acceptable noise levels in dB(A)**
Radio and TV Studios	25 – 30
Music Room	30 – 35
Hospital, Class Room, Auditorium	35 – 40
Apartment, Hotel, Home, Conference Room, Small Office	35 – 40
Concert Room, Private Office, Libraries	40 – 45
Large Public Office, Banks, Stores	45 – 50
Restaurants	50 – 55

Table 4.5 Upper limits of noise for desirable and prohibitive levels of traffic noise (CPCB noise rules, 2000).

Type of the Area	**Environmental Noise Standards (L_{eq}) in dB(A)**	
	Day Time	**Night Time**
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45
Silence Zone	50	40

A review of the status report indicates that noise Surveys were made in India in the sixties by the National Physical Laboratory, New Delhi. The findings of this survey clearly established the existence of high noise levels in Delhi, Bombay and Calcutta. An expert committee on noise Pollution was set up by the Ministry of Environment, Govt. of India, in early 1986 to look into the present status of Noise pollution in India Expert Committee submitted its report in June 1987.

CHAPTER V

ODD-EVEN VEHICLE RATIONING PROGRAMME

5.1 ODD-EVEN Vehicle Rationing Programme

The odd and even program in DELHI had been administered as an emergency stroke to seize the elevated emergency peak of the risen pollution level which had been registered 2-3 times more than the standards (Environment Pollution (Prevention and Control) Authority for NCR report, 2016). The mounting motor vehicle population raises uncontrolled noise pollution with a short and long term impact on physiological and psychological well being of humans. Thus a precautionary action has been taken by the government to immediately lower down the rising pollution levels. Though, the basic aim of ODD-EVEN vehicle rationing program was to instantly lower the rising air quality levels in the city by restricting the number of vehicles on the road which in turn served a lead to decrease the noise pollution level. Thus a check on both air and noise pollution was maintained. An additional significant advantage of the program is the enhanced effectiveness of the civic transport coordination and emancipation up of space in the city. Car pooling concept was also witnessed at the same pace. However, even as such domination and management measures are complex to uphold, the benefits made from these trial actions will only diminish over time. Long-term actions with strong monetary impetus to ensure beneficial results are crucial for superior quality of environment. Although, this is also not the only action that has been taken in the capital to restrict noise pollution, various other former laws and rules had been imposed.

Number of acts and regulations that had been formerly planned and executed by the Indian government is

i. Environment (Protection) Act, 1986
ii. Noise Pollution, Control and Regulation Rules, 2000
iii. Noise Pollution, Control and Regulation Rules, 1999

Ambient laws and norms in respect of noise for various categories have been notified under the Environment (Protection) Act, 1986. Noise restrictions have been prescribed for automobiles, domestic appliances and manufacturer apparatus at the built-up stage. Authoritarian agencies have been setup to implement the standards for management and normalization of noise pollution. The Ministry of science and technology is currently implementing laws and norms to standardize the growing levels. These standards and norms have been put into action since 2003. Noise standard for diesel were standardized and implemented in 1998 but currently the Government is working to amend these laws and regulation and bring some changes. For firecrackers the laws were implemented in 1999. Central Pollution Control Board had approved out a conformity testing of the fire crackers accessible in the marketplace and also taken up with the Department of Explosives for acquiescence with these values. Noise standards for petrol and kerosene generator sets have been effective since September, 2002. The sale of the products will be seized if the norms are not fulfilled. The Noise Rules, 2000, implements the laws for the sound from the loudspeaker. Aircraft noise monitoring at Indira Gandhi international airport has been done by the central pollution control board and revision of these norms is still being carried out.

The odd-even scheme is intended for instantaneous aid as the number of private cars on roads were almost halved, which add up to pollution level and create congestion and jams amidst the city (Environment Pollution (Prevention and Control) Authority for NCR report, 2016). Under ODD-EVEN vehicle rationing program number plates with odd and even digits would run date wise as in odd dates for odd number plate vehicles and even dates for even number plate's vehicle. The restriction had been effective for 12 hours that is 8:00 am to 8:00 pm and Sunday was exempted from this rationing program. The first phase of this program was in January and second one was in April each for 15 days. The course of action depends upon the type and location of zones where the noise level is really high. The guidelines visualize dropping the number of automobiles on Delhi roads by about 50% . The policy has captivated admiration from quite a few justified statements of improvement in environmental quality. On the other hand it raised several other consequent problems such as the passengers travelling in these vehicles were restricted to accommodate in public conveyance system such as metros plus buses creating havoc and fuzz in the city. Noise levels in the megacity have exceeded the standard limits (Gurjar *et. al.*, 2004) and automobiles are the main cause of metropolitan noise production (Banerjee *et. al.*, 2008)

5.2 Case Study on Odd-Even Vehicle Rationing Program in Beijing (China)

Due to fast economic growth and the increasing number of residents, Beijing now suffers from massive traffic congestion. In 2009, the net increase of vehicles reached 515,000 in the city, close to the 580,000 total vehicle populations in Hong Kong, China. The Beijing government estimated that the vehicle population exceeded 4.7 million in 2010, with an average daily gain of about 2,000 vehicles. In December 2010, the Beijing government instituted a combination of policy measures to control private vehicle use and improve public transport. This involved a six-step plan, with 28 specific measures aimed at controlling the motorized vehicles (in line with the national Twelfth Five-Year Plan). The city planned to use both regulatory and economic instruments to control the number of motorized vehicles and to reduce the traffic volume. Beijing introduced a quota system for license plates to regulate the increasing number of private cars. Under the quota system, only 240,000 license plates were issued through a lottery system in 2011, compared with 700,000 the previous year. The license plates will be issued only for permanent residents of Beijing. Additionally, the Beijing government imposed an odd-even license plate system to reduce the number of the cars on the roads during special events and extreme weather conditions. The system allows cars to drive on alternate days, based on the license plate number. This measure is already in place a few other cities around the world, such as Bogota and Mexico City. However, the scheme is a temporary solution because it encourages owners to buy a second car. Cars registered outside of Beijing will not be allowed into the city during peak hours. Check points are set up to prevent motorists to enter the fifth ring road from 7 a.m. to 9 a.m. and from 5 p.m. to 8 p.m. This encourages people to commute by train or bus to the city. The Beijing municipal government launched a special campaign to restrict official motor vehicles, which covers various organizations, political advisory bodies, government-funded institutions among others. The growth in official vehicles is also one of the reasons for the traffic congestion – they contribute 15 per cent of the city's car ownership. Restrictions will be applied on the purchase and operation of official vehicles.

Figure 5.1 Aerial view of traffic jam in China.

Since 2002, the Beijing government gradually increased parking fees to discourage vehicle use. Parking fees in non-residential areas have increased to discourage driving to work. Based on the level of congestion, the non-residential areas have been divided into three zones. The parking fees were raised from 2 Yuan to 10 Yuan in April 2010; the fee is also as high as 15 Yuan in the highly congested zones.

CHAPTER VI

MATERIALS AND METHOD

6.1 General

This section discusses the methodology adopted for the project development and the material used for the same. The study aims to determine the noise levels at various locations in DELHI. Different parameters were selected based on the previous works of Kumar & Jain (1994); Singhal (1986); Parbat & Nagarnaik (2003). The mean values of these measured parameters were analyzed and relatively compared to standard noise levels provided by CPCB (2001) and WHO. In order to develop the database for the project, a structured framework was established. The framework addressed the type and the size of the data required to accomplish the research objectives as well as to facilitate the processing of the data for the analysis. Additionally the noise parameters were mathematically evaluated to estimate the mean, the standard deviation, the minimum and the maximum values of equivalent noise level (Leq). Previous works of Pandharipande & Badhe, (2002); Parbat & Nagarnaik (2003) suggests the application and feasibility of statistical approach in noise data analysis and forecasting. Following is the basic structure of the study:

i. Selection of noise affected sites for the information valuation.
ii. Sampling and tabulation of noise data.
iii. Statistical scrutiny and relative observations.
iv. Results and discussion.
v. Conclusion.

Flowchart outlining the basics of the study has been shown in the Figure 6.1

The study entitles to present an outlook vision in the area of noise pollution measurement, assessment and forecasting so as to conflict the crisis of noise at its production point without tormenting any losses. The object of the research is to study the significance of odd-even plan launched by the Delhi Government and discuss precautionary control actions for reducing it. This in turn would give the idea for future study and actions and it would help the future research workers as a guiding platform in formulating newer action plans and strategies. Scope for future work is also discussed because the problem of noise pollution is at its peak and better action plans need to be implemented.

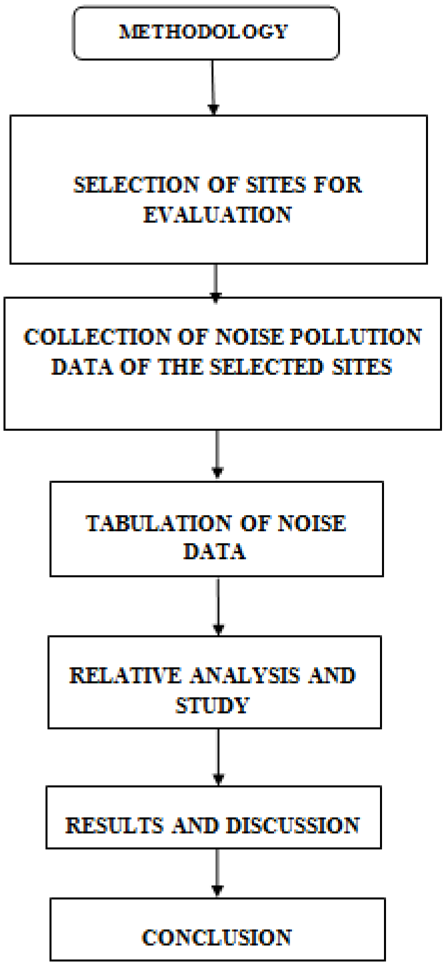


Figure 6.1 Flowchart showing the methodology adopted for the study.

6.2 Selection of Sites

For the collection of Traffic noise data 3 sites were selected at different points in Delhi. The sites covered entire zones of Delhi giving an estimate of relative noise pollution level in adjoining areas. The sites selected were

i. Punjabi Bagh
ii. Anand Vihar
iii. R.K.Puram

The sites have been selected as per the locations undertaken by CPCB in their real time ambient noise monitoring network. The sites are well connected with the other parts of the city through transportations and metro rail network. They form a commercial and residential hub and therefore need to be monitored for noise levels. They also form a triangular zone diving Delhi into 3 halves giving more or less brief idea about the adjoining prevailing noise conditions. Geographical locations of these sites have been mentioned in Table 3.1 which illustrates the latitude and longitude of the place from where the study was carried out. Chhapgar & Mohanan (1984) measured noise levels in Delhi covering residential, commercial, industrial and semi rural areas. Kumar & Jain (1994); Singhal (1986) analyzed the noise levels at Kashmere Gate and Madhuban Chowk categorizing it under commercial and residential zones respectively.

Table 6.1 Geographical location of the selected sites along with the noise zone they fall in.(CPCB real time noise monitoring network).

Sr. No.	Sampling Station	Location		Noise zone
		Latitude	Longitude	
1.	PUNJABI BAGH	28°40'12.0N	77°13'51.1E	Commercial and residential (mixed)
2.	ANAND VIHAR	28°38'54.7N	77°19'05.8E	Commercial and residential(mixed)
3.	R.K.PURAM	28°33'50.4N	77°10'46.2E	Residential

6.3 Map showing locations of sampling sites

a) PUNJABI BAGH

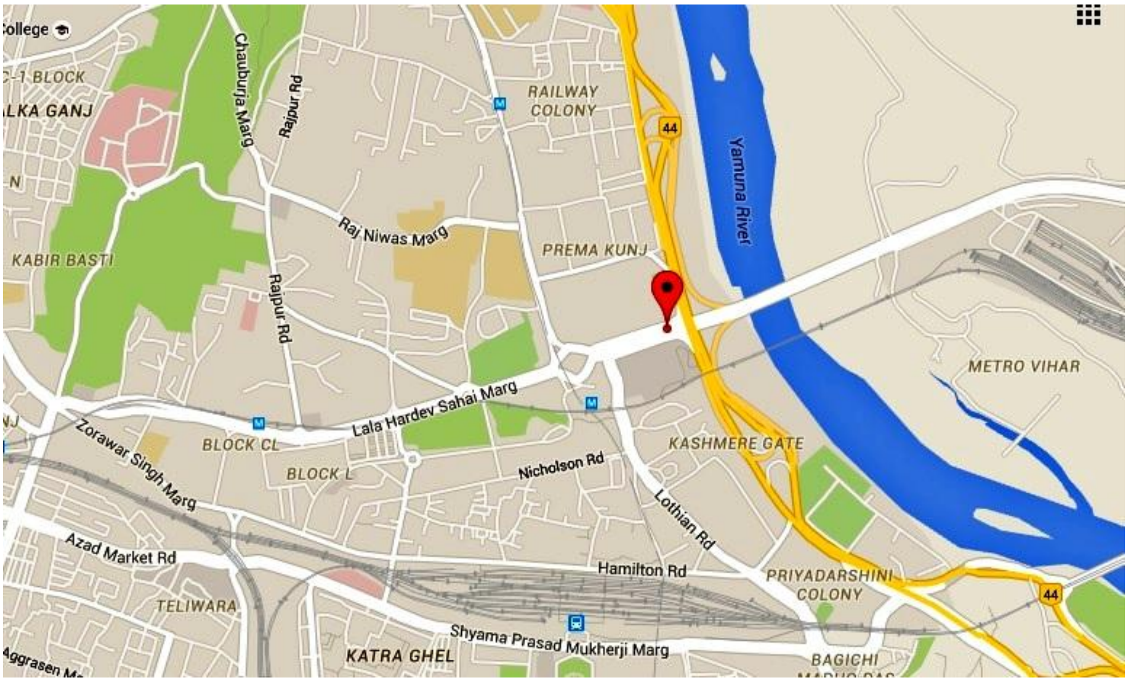


Figure 6.2 Location of sampling sites at PUNJABI BAGH.

b) ANAND VIHAR

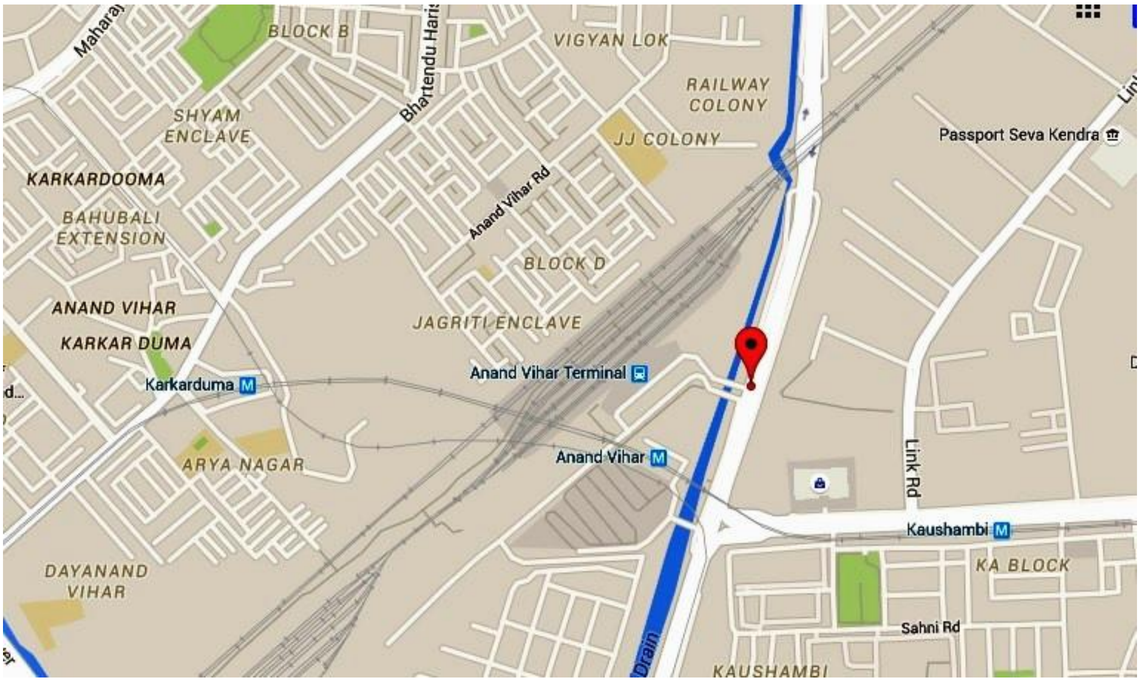


Figure 6.3 Location of sampling sites at ANAND VIHAR.

c) R.K.PURAM

Figure 6.4 Location of sampling sites at R.K.PURAM

These sites are monitored by central pollution control board as well as state pollution control board.

6.4 Data Sampling

The odd-even period marked one month noise level study collecting daily hourly average of the peak hour noise parameters as prescribed further in this section.

The noise level data for these 3 sites was collected from both primary and secondary sources out of which only one of the relatively accurate data set was analyzed. These sources were Central Pollution Control Board real time ambient noise monitoring network, Delhi Pollution Control Committee reports, and self-assessed real time data. But, since the prime objective of the project study is to statistically analyze large sample of noise datasets for precise and meticulous inference of odd-even program, a relatively more emphasis was given on examination and inspection rather than collection and survey. Thus, the CPCB real time ambient noise monitoring network was chosen for this which provides noise survey data samples both from office and internet site. The CPCB provides a real time noise survey data for multiple places recording parallel datasets at different installed locations which is shown in figure 11. The following datasets as monitored by CPCB, New Delhi has been tabulated and shown in next chapter.

For the measurement and analysis of relative noise levels at the selected sites four parameters ie, L_{10}, L_{50} , L_{90} and L_{eq} were considered from the source, figure 12, 13, 14 and 15. As monitored by CPCB, A-weighted hourly average of peak hours for L_{10}, L_{50} and L_{90} during day was taken and A-weighted daily average of L_{eq} was taken for study (figure 16, 17). The noise levels were undertaken for 30 days intervals from 1st April'16 to 30th April'16. This period marked the beginning of second phase of odd-even vehicle rationing program in New Delhi which started from 16th April'16. The noise level data for 15 days pre odd-even vehicle rationing program was also taken to analyze the relative change in noise levels during odd-even phase. Furthermore, Noise Pollution level (NPL) and Traffic Noise Index (TNI) has been calculated from L_{10}, L_{50} and L_{90} percentile noise levels to estimate the noise pollution at survey sites from the equations given in section 3.6. These indices illustrate the level of noise and we can analyze them to check it. A linear trend line with equation y= mx+c shows the gradient of the graph of these indices. Furthermore, mean values of Leq has been compared for normal vs. odd-even days which gives a clear status of pollution change. Time series analysis (figure.19) along with curve smoothening has been done to compare the actual Leq vs. Leq forecasted for odd-even program which has been shown in next chapter along with other statistical analysis.

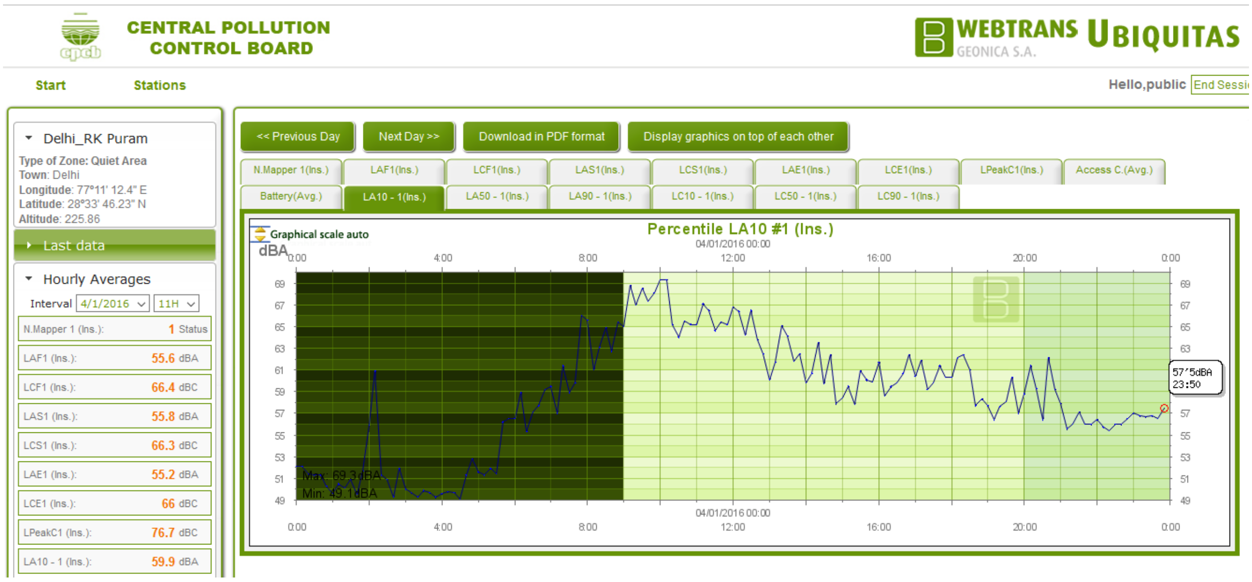


Figure 6.5 Screenshot of the CPCB noise monitoring network home page.

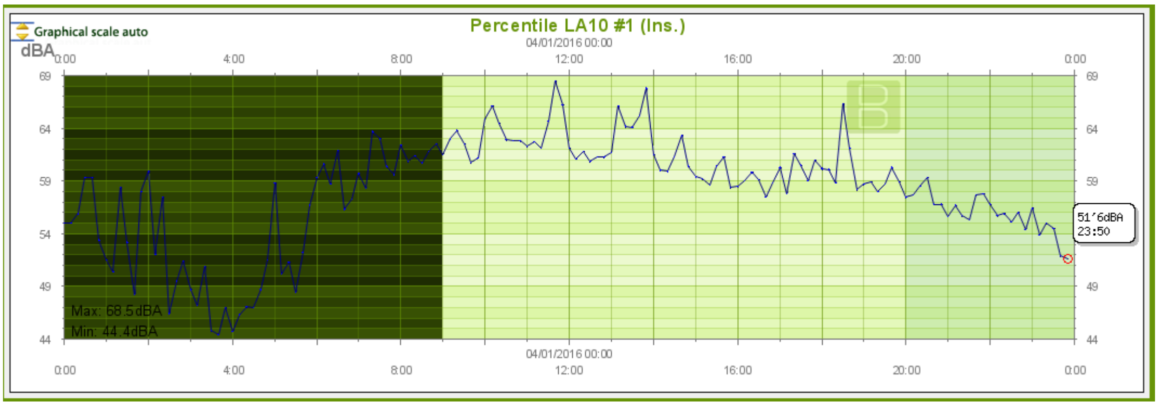


Figure 6.6 Screenshot of the L_{10} noise mapper from CPCB real time noise monitoring web page.

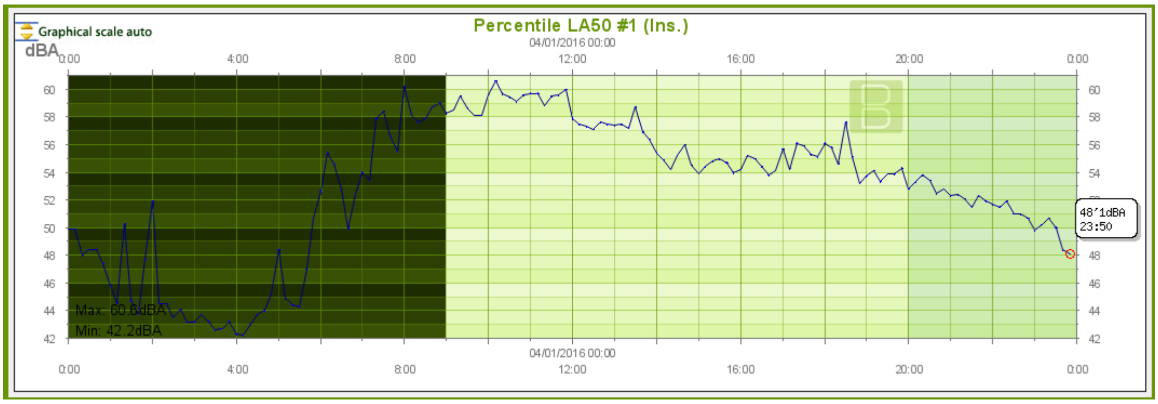


Figure 6.7 Screenshot of the L_{50} noise mapper from CPCB real time noise monitoring web page.

These screenshots show how the noise parameters were extracted. The data thus obtained has been tabulated using excel sheets and multiple software were used to carry the analysis. Various tabs are shown in figure.11 giving the detailed view of the site.

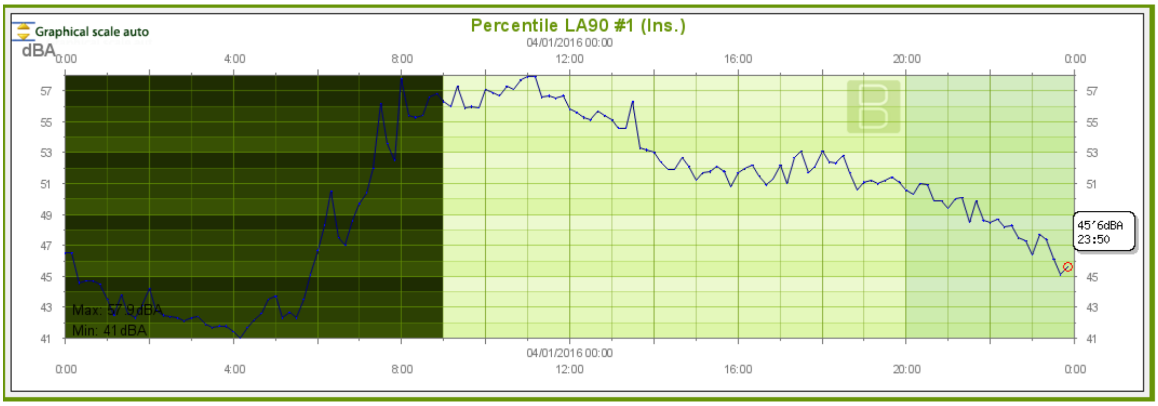


Figure 6.8 Screenshot of the L_{90} noise mapper from CPCB real time noise monitoring web page.

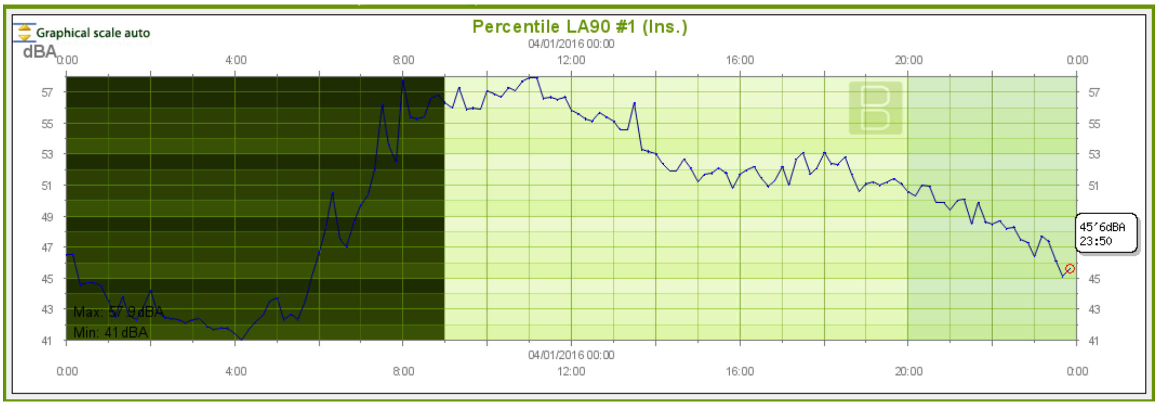
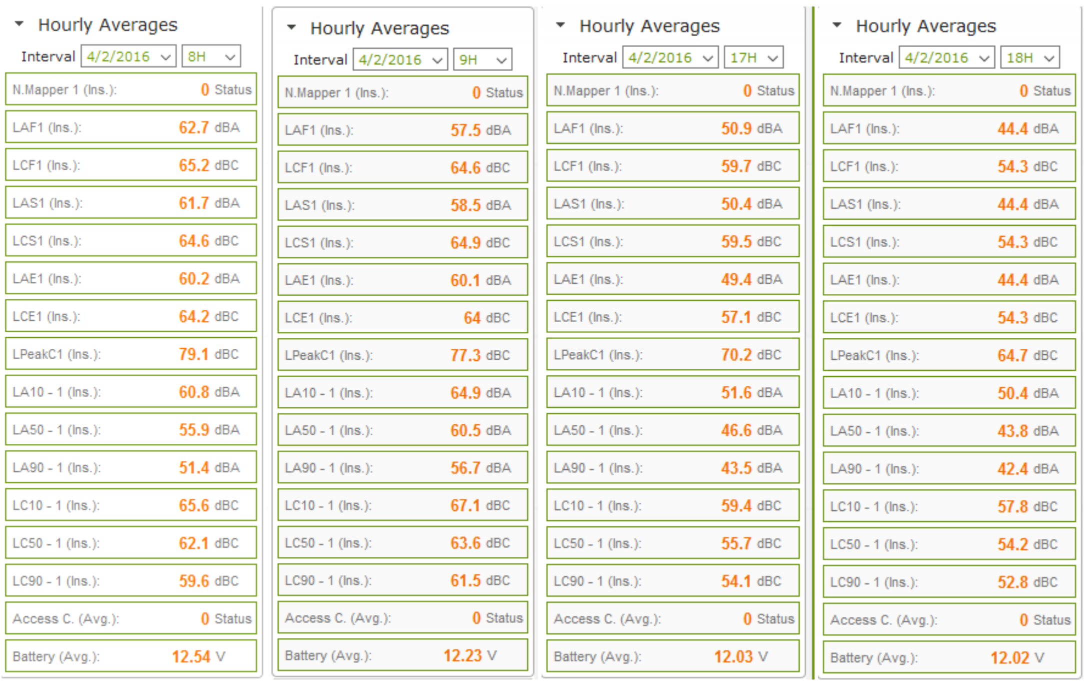


Figure 6.9 Screenshot of the Leq noise mapper from CPCB real time noise monitoring web page.



Hourly Averages	Interval 4/2/2016 8H	Interval 4/2/2016 9H	Interval 4/2/2016 17H	Interval 4/2/2016 18H
N.Mapper 1 (Ins.):	0 Status	0 Status	0 Status	0 Status
LAF1 (Ins.):	62.7 dBA	57.5 dBA	50.9 dBA	44.4 dBA
LCF1 (Ins.):	65.2 dBC	64.6 dBC	59.7 dBC	54.3 dBC
LAS1 (Ins.):	61.7 dBA	58.5 dBA	50.4 dBA	44.4 dBA
LCS1 (Ins.):	64.6 dBC	64.9 dBC	59.5 dBC	54.3 dBC
LAE1 (Ins.):	60.2 dBA	60.1 dBA	49.4 dBA	44.4 dBA
LCE1 (Ins.):	64.2 dBC	64 dBC	57.1 dBC	54.3 dBC
LPeakC1 (Ins.):	79.1 dBC	77.3 dBC	70.2 dBC	64.7 dBC
LA10 - 1 (Ins.):	60.8 dBA	64.9 dBA	51.6 dBA	50.4 dBA
LA50 - 1 (Ins.):	55.9 dBA	60.5 dBA	46.6 dBA	43.8 dBA
LA90 - 1 (Ins.):	51.4 dBA	56.7 dBA	43.5 dBA	42.4 dBA
LC10 - 1 (Ins.):	65.6 dBC	67.1 dBC	59.4 dBC	57.8 dBC
LC50 - 1 (Ins.):	62.1 dBC	63.6 dBC	55.7 dBC	54.2 dBC
LC90 - 1 (Ins.):	59.6 dBC	61.5 dBC	54.1 dBC	52.8 dBC
Access C. (Avg.):	0 Status	0 Status	0 Status	0 Status
Battery (Avg.):	12.54 V	12.23 V	12.03 V	12.02 V

Figure 6.10 Screenshot of the hourly percentile noise levels from CPCB real time noise monitoring web page.

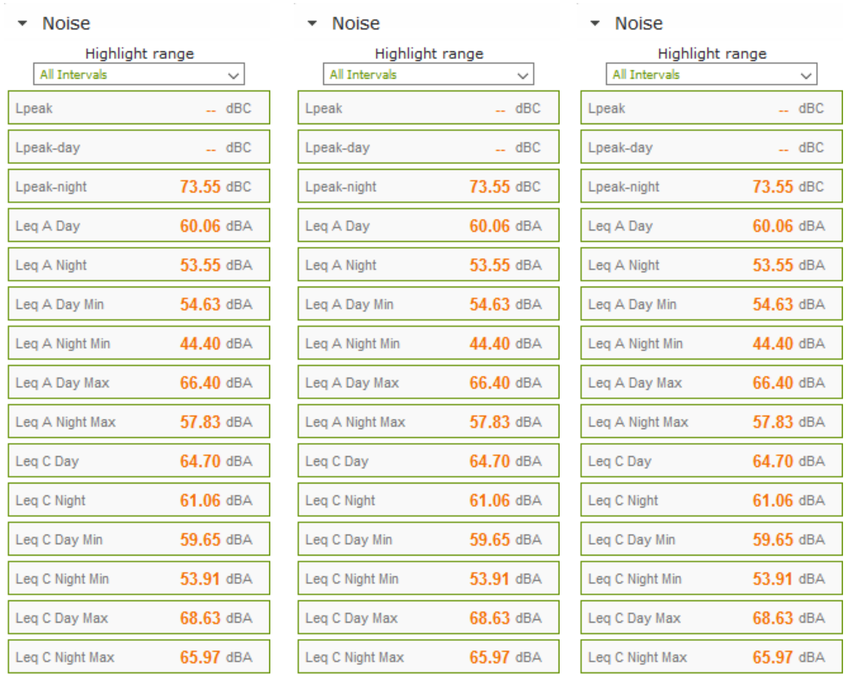


Figure 6.11 Screenshot of daily mean of Leq for day time during April'16.

6.5 Statistical study of noise parameters using Empirical equations

These are the empirical equations used for the statistical calculation of noise pollution level. These equations have been widely used by the research workers in their study (Scoles and Vulkan, 1969). For measurement and analysis the whole traffic is considered a line source. The problem of variability of noise with time, due to the passage of of different types of vehicle and their physical state is overcome by statistical analysis of noise level defining different parameters like maximum, minimum, and average noise levels. Other parameters taken to check the level of noise pollution are TNI (traffic noise index), NPL (noise pollution level) and NC (noise climate).

Equation Used:

1) Equivalent noise level:

$$L_{eq} = 10 \log 10 1/T \int (P/Pref)^2 \, dto \qquad (6.1)$$

2) TNI (Traffic Noise Index):

$$TNI = 4 (L_{10} - L_{90}) + L_{90} - 30 \text{ dB (A)} \qquad (6.2)$$

3) NPL (Noise Pollution Level):

$$NPL = L_{50} + (L_{10} - L_{90})^2 / 56 + (L_{10} - L_{90}) \qquad (6.3)$$

Percentile Exceeded Sound Levels:

$L_{10=}$ percentile noise level exceeding for the 10% of the time duration,

$L_{50=}$ percentile noise level exceeding for the 50% of the time duration,

$L_{90=}$ percentile noise level exceeding for the 90% of the time duration.

This defines the sound level that has been exceeded "X" percent of time in a measurement period. The value of the sound level history over a given period of time is presented in the form of a cumulative distribution. The percentile exceeded sound levels most commonly used are L_{10} and L_{50}.

Equivalent Continuous (A-Weighted) Sound Level, L_{eq}

Continuous steady noise level which would have the same total A-weighted acoustic energy as the real fluctuating Noise measured over the same period of time.

Day Night Average Sound level, L_{dn}

This is an average sound level taken over a 24 hours period, 10 dB is added to account for the increased undesirable effect of noise at night. This is used to indicate the tolerance of peoples to noise at various times of the day.

Traffic Noise Index (TNI)

The traffic Noise index is used to describe community noise. The TNI takes into account the amount of variability in observed sound levels, in an attempt to improve the correlation between traffic noise measurements and subjective response to Noise.

Noise Pollution Level (NPL)

Noise pollution level is sometimes used to describe community noise which employs the equivalent continuous (A-weighted) sound level and the magnitude of the time fluctuations in levels. It also improves the correlation between traffic noise measurements and subjective response to Noise. Other parameters taken to check the level of noise pollution are TNI (traffic noise index) and NC (noise climate).

$$L_{NP} = L_{eq} + 2.56\,\sigma \text{ dB} \qquad (6.4)$$

Where,

σ = standard deviation of the instantaneous Sound level

L_{eq} = equivalent continuous Sound level

Out of the above, the two noise descriptors which have been mostly used in many countries to describe highway noise are L_{10} and L_{eq} levels.

6.6 Use of XLSTAT software in statistical analysis

The software used for statistical analysis of data is XLSTAT (Version 2016.02.28451) which is available as a plugin add-on in MICROSOFT EXCEL software. It has been used for the tabulation, processing, analysis and display of data. Figure.18 shows the screenshots of the home page of the software where the plugin XLSTAT is available.

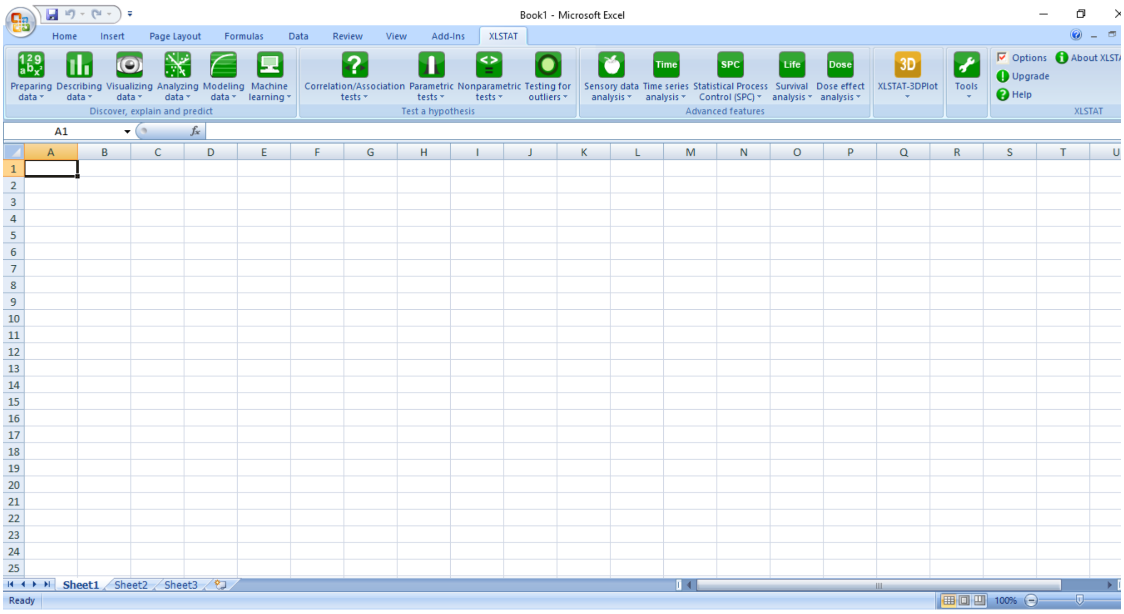


Figure 6.12 Excel software with XLSTAT plug-in.

Along with XLSTAT various other software were used for secondary purpose SPSS statistics (version 23) and Sigmaplot (version 12.0) and DATAFIT (version 8.0) for statistical calculations and results display.

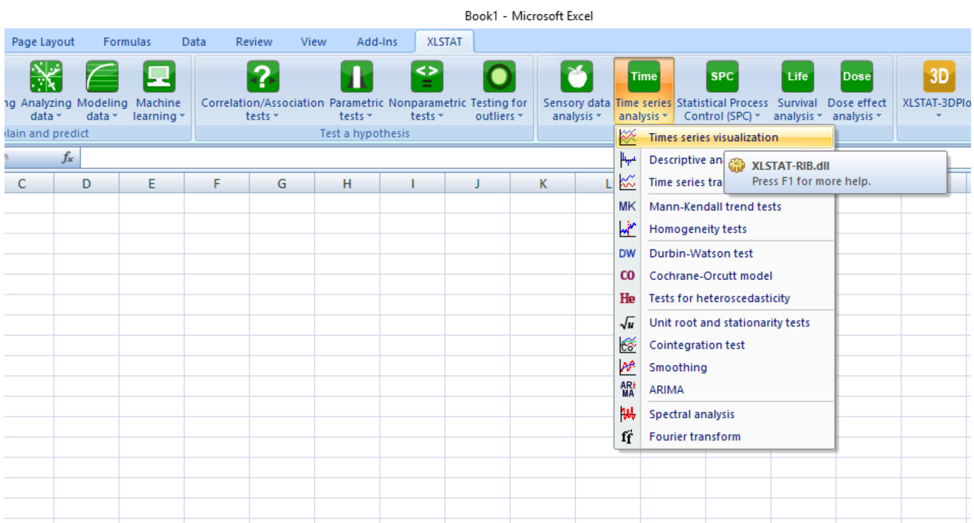


Figure 6.13 Time series analysis in XLSTAT for data forecasting and curve smoothening.

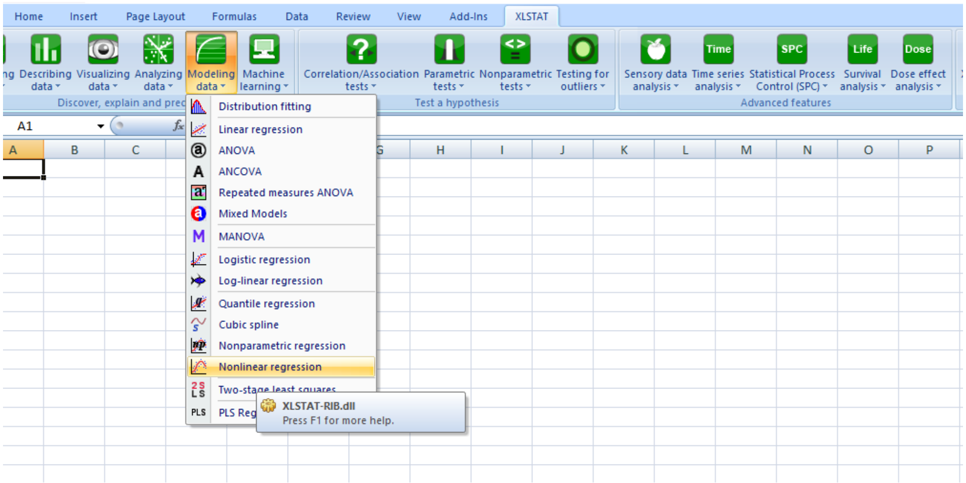


Figure 6.14 Non linear regression analysis for data modeling in XLSTAT.

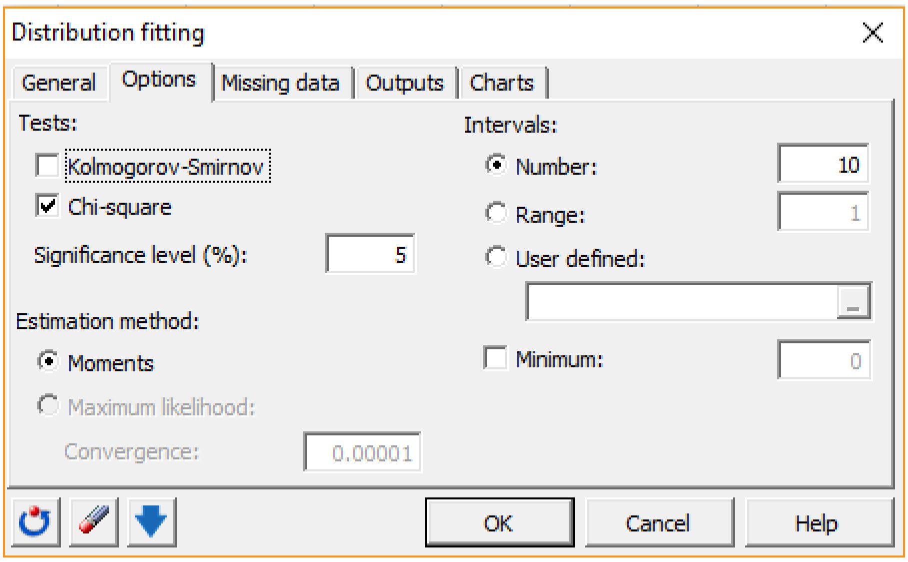


Figure 6.15 Distribution fitting window in XLSTAT for data plotting.

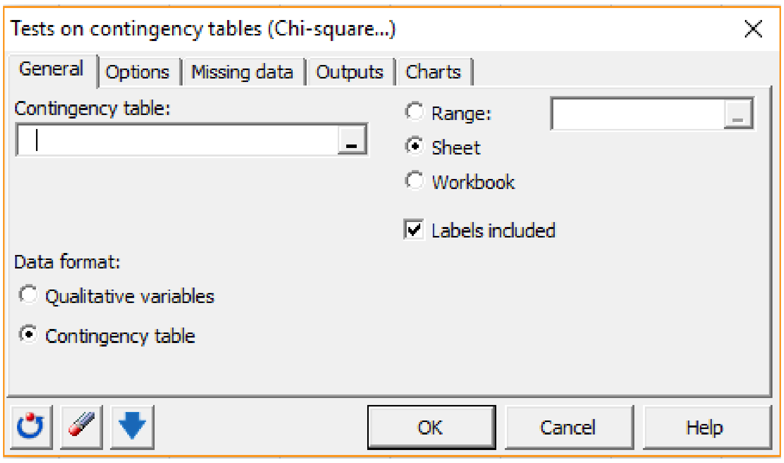


Figure 6.16 Chi square test in XLSTAT to check the goodness of fit the model.

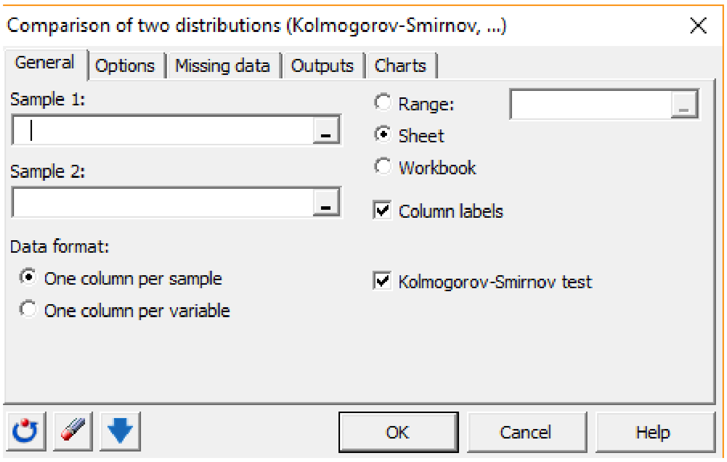


Figure 6.18 Cumulative frequency comparison for Leq actual vs. Leq forecasted.

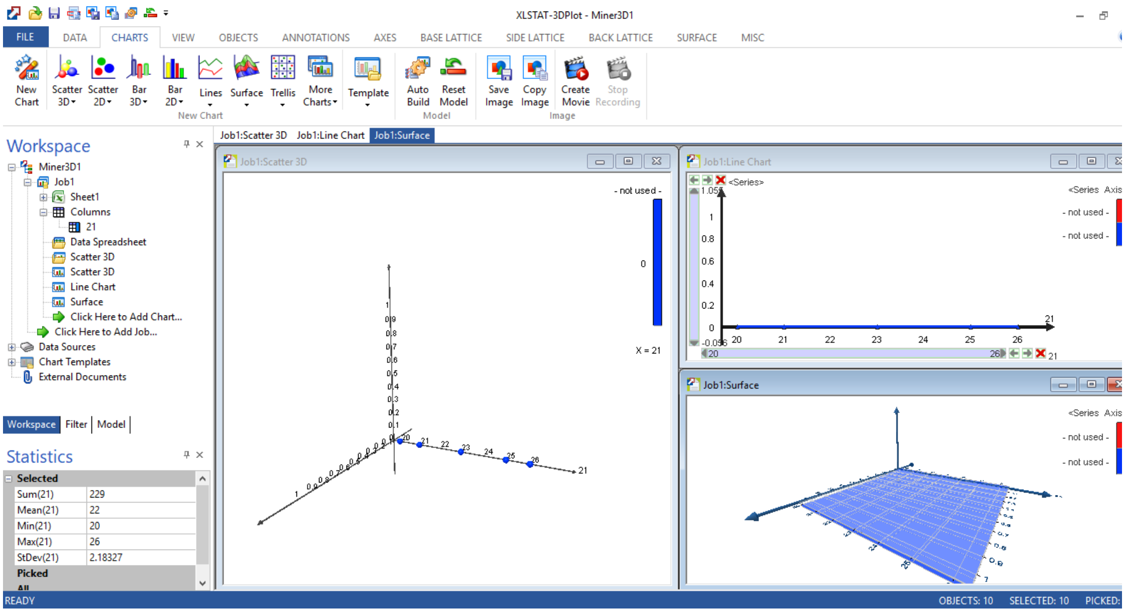


Figure 6.19 Screenshot showing plotting of results in XLSTAT-3D.

The various tests and analysis done using the XLSTAT software have been shown with the help of screenshots. The software was used for analytical study of time series forecasting where the noise data was forecasted for a certain period of time depending on its past trend. Equation of the trend line has been modeled through XLSTAT based upon various dependent and independent variables.

To check the relative change in data, cumulative frequency analysis and RMSE (root mean square error) test has been done. Furthermore, regression tests (R^2) and chi-square test has been done to check the goodness of fit of the observed noise sample from the calculated noise sample.

6.7 Noise Modeling

6.7.1 Definition

Environmental noise modeling refers to the estimation of noise levels within a certain set of conditions under a region of interest. Environmental noise modeling may b mathematical, software, artificial neural modeling or hybrid modeling. In our present study, mathematical modeling has been done using empirical equations to estimate the noise levels.

As discussed that environmental noise modeling is associated with certain set of restrictions and conditions, the noise level thus estimated is a fixed representation of particular interest. But here to avoid ambiguity the approximations are kept constant and are used as corrections in our mathematical equations. Thus it is important to know that the output of a model is just a prototype of the actual conditions.

Since the approach to environment noise modeling varies in every condition depending upon the complexity of the scenario. However, certain logistic and systematic approach is followed irrespective of the type and conditions available like the noise sources details and the technical study of the physical environment.

6.7.2 Application

Environmental noise predictions are applied in the decision making process where the decision involves a future change, technical challenges, or noise measurement strategies. Predictions often complement the measurement for a perfect development of a noise assessment procedure. Environmental noise modeling is used in:

i. Forecasting
ii. Assessment of existing paradigms
iii. Investigating the result of measurement and management strategy
Complementing the results of measurement

However methods differ broadly in their complexity and extent of relevance so as to suggest a significant fact. Therefore it is important to know the limitations of these models and the reliability it offers.

Providing the pre modeling studies and survey the output of the model is self judgment based. The goodness of a model depends upon the flexibility of choices and abundance of parameters which are used in input conditions so as to provide an appropriate prediction.

6.7.3 Input data

The accuracy a model depends upon the amount of continuous input data. Several variables and equations are used to construct a flexible model under a given set of conditions and approximations.

The prediction of noise level was computed by using the general statistical equations

$$\text{i.e} \quad L_{eq} = L_{90} + 0.018\ (L_{10} - L_{90})\text{^}2 \quad (6.5)$$

Where, the statistical percentile indicators were calculated with the following formulas:

$$L_{10} = 61.1 + 8.4\ \text{Log}\ (A) + 0.15B – 11.5\ \text{Log}\ (C) \quad (6.6)$$

$$L_{50} = 44.9 + 10.8\ \text{Log}\ (A) + 0.12B – 9.6\ \text{Log}\ (C) \quad (6.7)$$

$$L_{90} = 39.2 + 10.5\ \text{Log}\ (A) + 0.06B – 9.3\ \text{Log}\ (C) \quad (6.8)$$

where, 'A' is the vehicles flow, 'B' is the percentage of heavy vehicles and 'C' is the distance from the observer to the midway lane which can be kept as constant.

Therefore with the help of above (1), (2), (3) equations we can calculate the real time vehicle flow rate (A) and percentage of heavy vehicles (B) for peak hours during odd-even vehicle rationing program.

Now for mathematical noise modeling we use regression models based on previous works of other researchers (Lam and Tam, 1998), (Rawat *et. al.*, 2009) from CoRTN model. For Indian conditions the main equation used for predicting noise level is

$$L_{eq} = 10\log\ (A) + 33\log\ (V+40+(500/V)) + 10\log\ (1+5B/V) – 26.6 \quad (6.9)$$

Where A= traffic flow rate,

B= percentage of heavy vehicles,

V= average speed of vehicles.

Now to keep the simplicity of the equation there are certain adjustments made in the parameters to avoid calculation errors. Average speed of vehicle is kept constant (V=30 km/hr) for uninterrupted traffic flow. Distance'd' can also be kept constant for simpler calculations. Now the accuracy of the equation depends upon the number of parameters used in the empirical equation but for simplicity only important parameters are taken. Factors are like gradient, ground cover, angle of view, and barriers can be neglected or might be added as corrections. Rest is adjusted as corrections in the final equation.

6.7.4 Goodness of fit of the model

The goodness of fit of a statistical model describes how well it fits a set of observations. Measures of goodness of fit typically summarize the discrepancy between observed values and the values expected under the model in question.

In our study the goodness of fit of the model has been done using R^2(R-squared) regression test or simply coefficient of determination test and Kolmogrov-Smirnov test which gives the cumulative frequency curve of the predicted and actual noise data. In R^2 test the output varies from 0 to 1 ie, 0 to 100% level of confidence limit. Any value close to 1 is described as good and the model is applicable.

The above tests define the degree of accuracy of the model while comparing the observed sample with the expected probability distribution. Thus they can be used as a reliable check for the goodness of fit of the model.

CHAPTER VII

RESULTS AND DISCUSSION

7.1 General Discussion

In this section the data under study has been tabulated, statistically analyzed and displayed graphically. This section discusses the data obtained from the primary and secondary sources. Primary data collection has been done via site survey and field measurements while secondary data has been taken from the real time noise monitoring by CPCB (Central Pollution Control Board), New Delhi. For the measurement and analysis of relative noise levels at the selected sites four parameters ie, L_{10}, L_{50}, L_{90} and L_{eq} were considered from the source (CPCB ambient real time noise monitoring network). As monitored by CPCB, A-weighted hourly average of peak hours for L_{10}, L_{50} and L_{90} during day was taken and A-weighted daily average of L_{eq} was taken for study. The noise levels were undertaken for 30 days intervals from 1st April’16 to 30th April’16. This period marked the beginning of second phase of odd-even vehicle rationing program in New Delhi which started from 16th April’16. The noise level data for 15 days pre odd-even vehicle rationing program was also taken to analyze the relative change in noise levels during odd-even phase.

Percentile noise level L_{10}, L_{50}, L_{90} dB(A) at all the three sites are shown in table 4.1-4.12. These are the percentile levels for the peak hours ie, 8:00am-10:00am, 5:00pm-7:00pm for the month of April’16. The graph of each percentile noise level for each site has been plotted in figure 4.1 which depicts the two point moving average of the peak hourly noise level. For processing of percentile noise levels equations given in section has been used. From that daily mean of TNI and NPL has been obtained. The values obtained of TNI and NPL are processed under curve smoothening before data fitting. The smoothened data has been plotted for the month of april'16 against the 30 days interval. A linear regression trend line has been drawn along the NPL and TNI which gives the gradient of the graph and its deviation from the mean. The negative (-ve) slope of the regression line and the negative (-ve) standard deviation for every index indicates that the values of indices has decreased from starting to end of April'16. This is clear for all the three sites and it is clear that the NPL and TNI have reduced. Further analysis has been discussed later in this chapter which includes noise data forecasting and modeling.

7.2 Percentile Noise Levels at selected sites in Delhi

Table 7.1 Mean percentile noise level L_{10} at R.K.Puram during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	58.9	53.4	52.7	52.7	DAY 16	60.2	55.1	52.7	53.2
DAY 2	58.2	52.3	51.9	51.9	DAY 17	62.3	53.9	49.8	50.3
DAY 3	58.8	51.5	50.2	50.2	DAY 18	59.5	57.4	52.8	53.3
DAY 4	59.5	53.6	52.5	52.5	DAY 19	59.9	57.4	52.3	52.8
DAY 5	58.8	56.1	53.4	53	DAY 20	58.4	54.6	50.2	50.7
DAY 6	64.1	58.8	55.5	55.5	DAY 21	59.7	57.2	52.4	52.9
DAY 7	57.7	57.1	53.3	53.3	DAY 22	59.7	56.9	52.3	52.8
DAY 8	58.9	53.4	52.7	53.4	DAY 23	59.2	56.4	51.7	52.2
DAY 9	53.3	55.9	52.3	52.3	DAY 24	60.9	58.8	50.1	50.6
DAY 10	57.2	53.3	51.5	51.5	DAY 25	59.1	56.9	52.3	52.8
DAY 11	56.1	57.2	53.6	53.6	DAY 26	61.3	58.2	53.5	54.2
DAY 12	58.8	56.1	53.1	53.2	DAY 27	59.5	57.4	53.4	53.4
DAY 13	64.2	58.8	55.5	55.5	DAY 28	59.9	57.6	53.2	53.7
DAY 14	58.1	54.6	52.7	52.7	DAY 29	59.3	57.6	53.2	53.7
DAY 15	57.1	53.6	51.7	51.7	DAY 30	61.2	58.1	53.2	53.5

Table 7.2 Mean Percentile noise level L_{50} at R.K.Puram during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	58.4	54.6	52.9	53.7	DAY 16	60.3	55.2	55.1	54.7
DAY 2	57.7	54.1	52.1	52.2	DAY 17	56.1	51.8	52.1	50.8
DAY 3	58.3	53.6	50.4	50.5	DAY 18	59.2	55.1	55.1	53.8
DAY 4	59.2	54.9	52.7	52.8	DAY 19	59.6	54.8	54.6	53.3
DAY 5	58.1	54.1	52.3	52.4	DAY 20	58.1	52.4	52.5	51.2
DAY 6	62.8	59.2	56.4	56.5	DAY 21	59.4	54.8	54.7	53.4
DAY 7	62.1	56.7	53.5	53.6	DAY 22	59.4	54.6	54.6	53.3
DAY 8	65.6	57.3	53.6	53.7	DAY 23	58.7	54.1	54.2	52.7
DAY 9	64.4	55.5	52.5	52.6	DAY 24	60.6	54.4	52.4	51.1
DAY 10	57.5	52.9	51.7	51.8	DAY 25	58.8	54.6	54.6	53.3
DAY 11	62.4	56.8	53.8	53.9	DAY 26	59.5	55.8	55.8	54.5
DAY 12	61.1	55.7	53.2	53.3	DAY 27	59.2	55.1	55.2	53.9
DAY 13	63.5	58.4	55.7	55.8	DAY 28	59.6	55.4	55.5	55.3
DAY 14	57.6	54.2	52.9	53.2	DAY 29	59.6	55.4	55.5	54.1
DAY 15	56.6	53.2	51.9	52.2	DAY 30	60.9	55.5	55.3	52.2

Table 7.3 Mean percentile noise level L_{90} at R.K.Puram during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	60.1	56.2	53.9	53.9	DAY 16	61.8	58.6	54.9	55.3
DAY 2	59.4	53.2	50.6	50.6	DAY 17	57.6	54.8	52.2	52.4
DAY 3	60.2	52.7	48.9	53.2	DAY 18	60.7	58.3	56.3	55.4
DAY 4	60.7	54.0	51.2	52.3	DAY 19	61.1	58.3	54.5	54.9
DAY 5	59.7	53.2	53.3	56.2	DAY 20	59.6	55.5	52.4	52.8
DAY 6	64.5	58.3	57.4	57.3	DAY 21	60.9	58.1	54.6	55.3
DAY 7	63.8	55.8	54.5	54.4	DAY 22	60.9	57.8	54.5	54.9
DAY 8	67.3	56.4	54.6	54.5	DAY 23	60.2	57.3	53.9	54.3
DAY 9	66.1	54.6	53.5	53.4	DAY 24	62.1	59.7	52.3	52.7
DAY 10	59.2	52.0	52.7	52.6	DAY 25	60.3	57.8	54.5	54.9
DAY 11	64.1	55.9	54.8	54.7	DAY 26	62.5	59.1	55.7	56.1
DAY 12	62.8	54.8	54.2	54.1	DAY 27	60.7	58.3	55.1	55.5
DAY 13	65.2	57.5	56.7	56.6	DAY 28	61.1	58.5	55.4	55.8
DAY 14	59.3	53.3	53.9	53.8	DAY 29	60.5	58.5	55.4	55.8
DAY 15	58.3	52.3	52.9	52.8	DAY 30	62.4	58.9	55.2	55.6

Table 7.4 Daily mean percentile noise level for peak hours at R.K.Puram during April'16.

	L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)		L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)
DAY 1	58.9	55	52.7	DAY 16	60.6	56.5	53.8
DAY 2	58.2	54.5	51.9	DAY 17	56.4	52.7	50.9
DAY 3	58.8	54	50.2	DAY 18	59.5	56.2	53.9
DAY 4	59.5	55.3	52.5	DAY 19	59.9	56.2	53.4
DAY 5	58.5	54.5	52.1	DAY 20	58.4	53.4	51.3
DAY 6	63.3	59.6	56.2	DAY 21	59.7	56	53.5
DAY 7	62.6	57.1	53.3	DAY 22	59.7	55.7	53.4
DAY 8	66.1	57.7	53.4	DAY 23	59.1	55.2	52.8
DAY 9	64.9	55.9	52.3	DAY 24	60.9	57.6	51.2
DAY 10	58	53.3	51.5	DAY 25	59.1	55.7	53.4
DAY 11	62.9	57.2	53.6	DAY 26	61.3	57.2	54.6
DAY 12	61.6	56.1	53.1	DAY 27	59.5	56.2	54.1
DAY 13	64	58.8	55.5	DAY 28	59.9	56.4	54.3
DAY 14	58.1	54.6	52.7	DAY 29	59.3	56.4	54.3
DAY 15	57.1	53.6	51.7	DAY 30	61.2	56.8	54.1

Table 7.5 Mean percentile noise level L_{10} at Anand Vihar during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	65.7	64.3	63.3	61.8	DAY 16	60.4	60.5	60.9	60.8
DAY 2	66.2	63.8	62.2	61.2	DAY 17	59.7	61.2	60.1	62.2
DAY 3	65.7	63.3	60.5	59.3	DAY 18	60.3	59.5	58.4	58.3
DAY 4	66.4	64.6	62.8	61.6	DAY 19	60.2	60.8	60.7	60.6
DAY 5	65.4	63.8	62.4	61.3	DAY 20	61.2	61.8	60.3	60.2
DAY 6	70.2	68.9	66.5	65.5	DAY 21	64.8	65.1	64.4	64.3
DAY 7	69.5	66.4	63.6	62.4	DAY 22	64.1	62.6	61.5	61.4
DAY 8	69.2	67.1	63.7	62.5	DAY 23	67.6	63.2	61.6	61.5
DAY 9	71.8	65.4	62.6	61.4	DAY 24	66.4	61.4	60.5	60.4
DAY 10	64.9	62.6	61.8	60.6	DAY 25	59.5	58.8	59.7	59.6
DAY 11	69.8	66.5	63.9	62.7	DAY 26	64.4	62.7	61.8	61.7
DAY 12	68.5	65.4	63.3	62.1	DAY 27	63.1	61.6	61.2	61.1
DAY 13	70.9	68.1	65.8	64.6	DAY 28	65.5	64.3	63.7	63.6
DAY 14	69.3	63.9	63.2	61.8	DAY 29	59.6	60.1	60.9	60.8
DAY 15	67.1	62.9	62.2	60.8	DAY 30	58.6	59.1	59.9	59.8

Table 7.6 Mean percentile noise level L_{50} at Anand Vihar during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	57.4	56.3	54.1	54.6	DAY 16	59.5	57.7	55.3	55.4
DAY 2	56.7	55.8	53.3	53.8	DAY 17	55.3	53.9	52.1	52.5
DAY 3	57.3	55.3	51.6	52.1	DAY 18	58.4	57.4	55.1	55.5
DAY 4	58.1	56.6	53.9	54.4	DAY 19	58.8	57.4	54.6	55.3
DAY 5	57.2	55.8	53.5	54.2	DAY 20	57.3	54.6	52.5	52.9
DAY 6	61.8	60.9	57.6	58.1	DAY 21	58.6	57.2	54.7	55.1
DAY 7	61.1	58.4	54.7	55.2	DAY 22	58.6	56.9	54.6	56.3
DAY 8	64.6	59.6	54.8	55.3	DAY 23	57.9	56.4	54.6	54.4
DAY 9	63.4	57.2	53.7	54.2	DAY 24	59.8	58.8	52.4	52.8
DAY 10	56.5	54.6	52.9	53.4	DAY 25	58.2	56.9	54.6	54.1
DAY 11	61.4	58.5	55	55.5	DAY 26	60.2	58.2	55.8	56.2
DAY 12	60.1	57.4	54.4	54.9	DAY 27	58.4	57.4	55.2	55.6
DAY 13	62.5	60.1	56.9	57.4	DAY 28	58.8	57.6	56.3	55.9
DAY 14	56.6	55.9	54.1	54.6	DAY 29	58.2	57.6	56.1	55.9
DAY 15	55.6	54.9	53.1	53.6	DAY 30	60.1	58.3	52.3	55.7

Table 7.7 Mean percentile noise level L_{90} at Anand Vihar during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	55.7	56.1	53.9	51.6	DAY 16	56.3	54.2	55.3	57.1
DAY 2	55	55.6	53.1	50.8	DAY 17	58.7	52.6	52.4	53.1
DAY 3	55.6	55.1	51.4	49.1	DAY 18	56.8	54.8	55.4	53.1
DAY 4	56.3	56.4	53.7	51.4	DAY 19	58.1	56.2	54.9	55.3
DAY 5	55.3	55.6	53.3	51.1	DAY 20	57.3	55.4	52.8	54.5
DAY 6	60.1	60.7	57.4	55.3	DAY 21	60.8	57.4	55.5	59.6
DAY 7	59.4	58.2	54.5	52.2	DAY 22	60.8	57.1	54.9	57.1
DAY 8	62.9	58.8	54.6	52.3	DAY 23	60.1	56.6	54.3	57.7
DAY 9	61.7	57.2	53.5	51.2	DAY 24	56.3	54.2	55.3	55
DAY 10	54.8	54.4	52.7	50.4	DAY 25	60.2	57.1	54.9	53.3
DAY 11	59.7	58.3	54.8	52.5	DAY 26	62.4	58.4	56.1	57.2
DAY 12	58.4	57.2	54.2	51.9	DAY 27	60.6	57.6	55.5	56.1
DAY 13	60.8	59.9	56.7	54.4	DAY 28	61.2	57.8	55.8	58.8
DAY 14	54.9	55.7	53.9	51.6	DAY 29	60.4	57.8	55.8	54.6
DAY 15	53.9	54.7	52.9	50.6	DAY 30	62.3	58.2	55.6	53.6

Table 7.8 Daily mean percentile noise level for peak hours at Anand Vihar during April'16.

	L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)		L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)
DAY 1	67.9	62.2	60.8	DAY 16	69.6	65.3	62.6
DAY 2	67.2	61.8	58.9	DAY 17	68.2	63.5	60.4
DAY 3	68.4	63.1	60.2	DAY 18	68.6	63.1	60.1
DAY 4	67.7	62.5	59.5	DAY 19	68.3	63.2	60.4
DAY 5	68.3	64.1	61.9	DAY 20	69.1	62.8	59.2
DAY 6	69.4	64.5	61.8	DAY 21	68.7	62.7	59.6
DAY 7	68.2	64.1	60.7	DAY 22	68.7	63.3	59.9
DAY 8	68.1	62.8	60.3	DAY 23	68.1	62.3	59.1
DAY 9	68.4	63.3	61.2	DAY 24	68.4	63.6	61.3
DAY 10	68.5	63.8	61.3	DAY 25	68.4	64.1	61.5
DAY 11	69.1	63.2	61.2	DAY 26	68.3	64.6	62.4
DAY 12	68.6	62.6	59.8	DAY 27	70.3	64.6	62.1
DAY 13	68.3	63.2	60.5	DAY 28	68.3	63.3	61.1
DAY 14	70.1	63.9	61.1	DAY 29	68.2	64.2	61.7
DAY 15	69.9	64.5	61.8	DAY 30	68.2	63.9	61.7

Table 7.9 Mean percentile noise level L_{10} at Punjabi Bagh during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	58.9	55	52.7	52.7	DAY 16	60.6	56.5	53.8	53.8
DAY 2	58.2	54.5	51.9	51.9	DAY 17	56.4	52.7	50.9	50.9
DAY 3	58.8	54	50.2	50.2	DAY 18	59.5	56.2	53.9	53.9
DAY 4	59.5	55.3	52.5	52.5	DAY 19	59.9	56.2	53.4	53.4
DAY 5	58.5	54.5	52.1	52.1	DAY 20	58.4	53.4	51.3	51.3
DAY 6	63.3	59.6	56.2	56.2	DAY 21	59.7	56	53.5	53.5
DAY 7	62.6	57.1	53.3	53.3	DAY 22	59.7	55.7	53.4	53.4
DAY 8	66.1	57.7	53.4	53.4	DAY 23	59	55.2	52.8	52.8
DAY 9	64.9	55.9	52.3	52.3	DAY 24	60.9	57.6	51.2	51.2
DAY 10	58	53.3	51.5	51.5	DAY 25	59.1	55.7	53.4	53.4
DAY 11	62.9	57.2	53.6	53.6	DAY 26	61.3	57	54.6	54.6
DAY 12	61.6	56.1	53	53	DAY 27	59.5	56.2	54	54
DAY 13	64	58.8	55.5	55.5	DAY 28	59.9	56.4	54.3	54.3
DAY 14	58.1	54.6	52.7	52.7	DAY 29	59.3	56.4	54.3	54.3
DAY 15	57.1	53.6	51.7	51.7	DAY 30	61.2	56.8	54.1	54.1

Table 7.10 Mean percentile noise level L_{50} at Punjabi Bagh during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	58.9	55	52.7	52.7	DAY 16	60.6	56.5	53.8	53.8
DAY 2	58.2	54.5	51.9	51.9	DAY 17	56.4	52.7	50.9	50.9
DAY 3	58.8	54	50.2	50.2	DAY 18	59.5	56.2	53.9	53.9
DAY 4	59.5	55.3	52.5	52.5	DAY 19	59.9	56.2	53.4	53.4
DAY 5	58.5	54.5	52.1	52.1	DAY 20	58.4	53.4	51.3	51.3
DAY 6	63.3	59.6	56.2	56.2	DAY 21	59.7	56	53.5	53.5
DAY 7	62.6	57.1	53.3	53.3	DAY 22	59.7	55.7	53.4	53.4
DAY 8	66.1	57.7	53.4	53.4	DAY 23	59	55.2	52.8	52.8
DAY 9	64.9	55.9	52.3	52.3	DAY 24	60.9	57.6	51.2	51.2
DAY 10	58	53.3	51.5	51.5	DAY 25	59.1	55.7	53.4	53.4
DAY 11	62.9	57.2	53.6	53.6	DAY 26	61.3	57	54.6	54.6
DAY 12	61.6	56.1	53	53	DAY 27	59.5	56.2	54	54
DAY 13	64	58.8	55.5	55.5	DAY 28	59.9	56.4	54.3	54.3
DAY 14	58.1	54.6	52.7	52.7	DAY 29	59.3	56.4	54.3	54.3
DAY 15	57.1	53.6	51.7	51.7	DAY 30	61.2	56.8	54.1	54.1

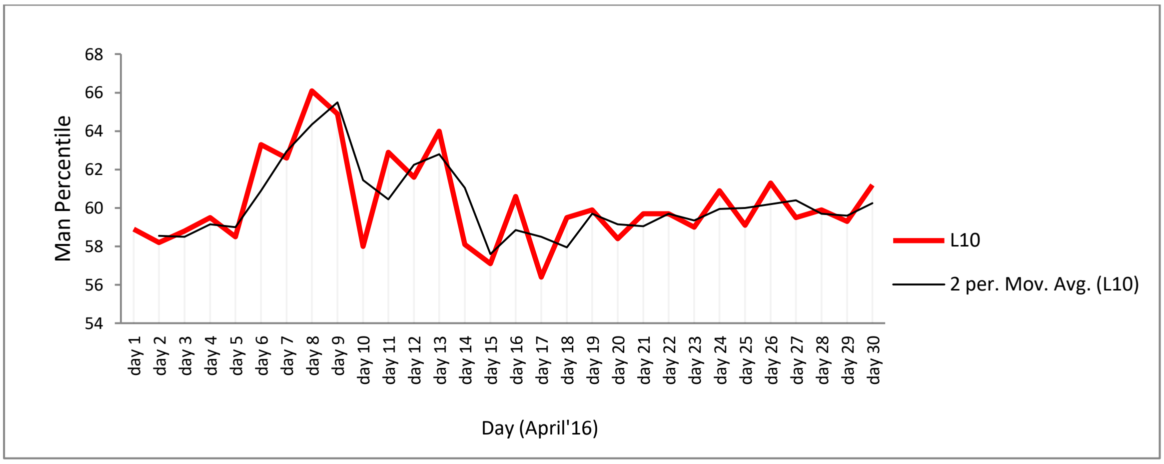
Table 7.11 Mean percentile noise level L_{90} at Punjabi Bagh during April'16 for peak hours.

	8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm		8:00am-9:00am	9:00am-10:00am	5:00pm-6:00pm	6:00pm-7:00pm
DAY 1	58.9	55	52.7	52.7	DAY 16	60.6	56.5	53.8	53.8
DAY 2	58.2	54.5	51.9	51.9	DAY 17	56.4	52.7	50.9	50.9
DAY 3	58.8	54	50.2	50.2	DAY 18	59.5	56.2	53.9	53.9
DAY 4	59.5	55.3	52.5	52.5	DAY 19	59.9	56.2	53.4	53.4
DAY 5	58.5	54.5	52.1	52.1	DAY 20	58.4	53.4	51.3	51.3
DAY 6	63.3	59.6	56.2	56.2	DAY 21	59.7	56	53.5	53.5
DAY 7	62.6	57.1	53.3	53.3	DAY 22	59.7	55.7	53.4	53.4
DAY 8	66.1	57.7	53.4	53.4	DAY 23	59	55.2	52.8	52.8
DAY 9	64.9	55.9	52.3	52.3	DAY 24	60.9	57.6	51.2	51.2
DAY 10	58	53.3	51.5	51.5	DAY 25	59.1	55.7	53.4	53.4
DAY 11	62.9	57.2	53.6	53.6	DAY 26	61.3	57	54.6	54.6
DAY 12	61.6	56.1	53	53	DAY 27	59.5	56.2	54	54
DAY 13	64	58.8	55.5	55.5	DAY 28	59.9	56.4	54.3	54.3
DAY 14	58.1	54.6	52.7	52.7	DAY 29	59.3	56.4	54.3	54.3
DAY 15	57.1	53.6	51.7	51.7	DAY 30	61.2	56.8	54.1	54.1

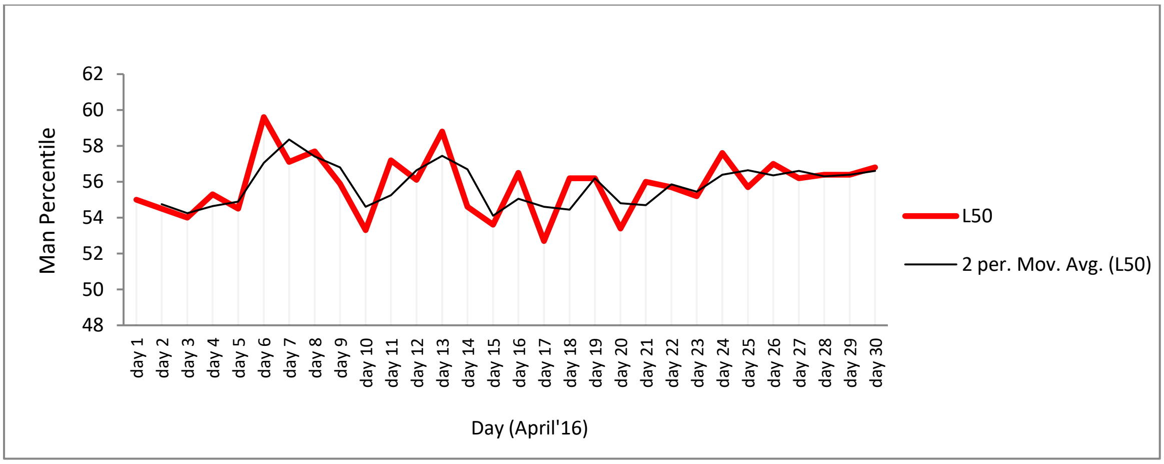
Table 7.12 Daily mean percentile noise level for peak hours at Punjabi Bagh during April'16.

	L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)		L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)
DAY 1	64.75	59.99	59.37	DAY 16	57.1	50.9	47
DAY 2	70.81	58.42	58.4	DAY 17	57.8	52.6	46.8
DAY 3	65.5	56.86	59.7	DAY 18	56.2	51.6	47.2
DAY 4	66.45	57.62	65.34	DAY 19	57.2	50.7	45.7
DAY 5	63.7	58.94	58.1	DAY 20	57.1	51.5	46.5
DAY 6	62.36	57.93	56.7	DAY 21	58.3	53.5	48.8
DAY 7	68.38	59.22	66.3	DAY 22	59.2	53.1	48.7
DAY 8	61.24	58.71	53.6	DAY 23	59.5	52.1	48.2
DAY 9	61.84	56.27	52.3	DAY 24	62	54.8	48
DAY 10	63.97	56.38	59.7	DAY 25	60.6	55.6	50.8
DAY 11	67.17	62.42	68.1	DAY 26	58.5	51.4	48.3
DAY 12	64.25	63.75	59.9	DAY 27	58.6	52.1	49
DAY 13	63.67	64.06	58	DAY 28	57.5	52.6	47.3
DAY 14	63.37	60.63	55.1	DAY 29	57.5	51.2	48.1
DAY 15	63.75	59.9	59.4	DAY 30	56.2	51.4	47.6

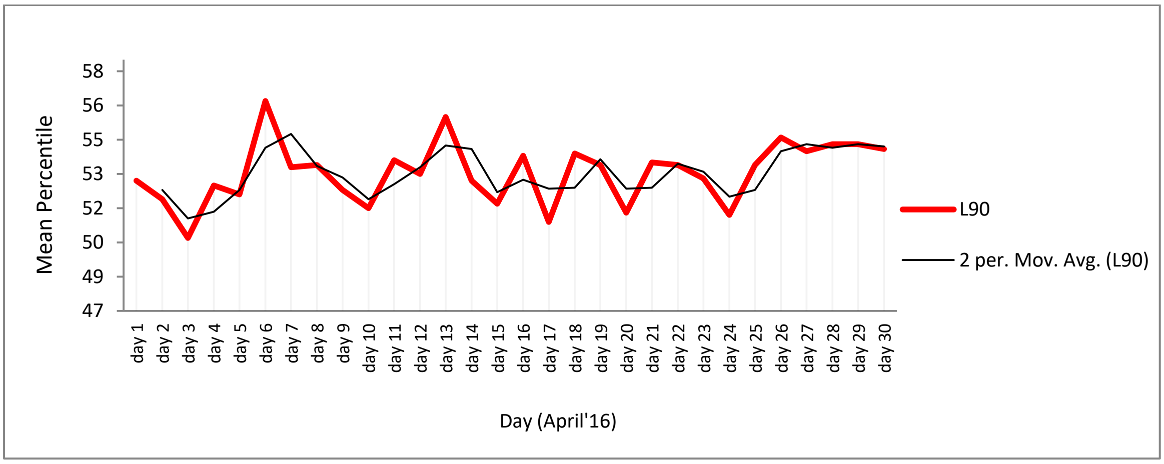
Figure 7.1 Two point moving average of percentile noise levels for R.K.Puram during April'16.



(i) L_{10}



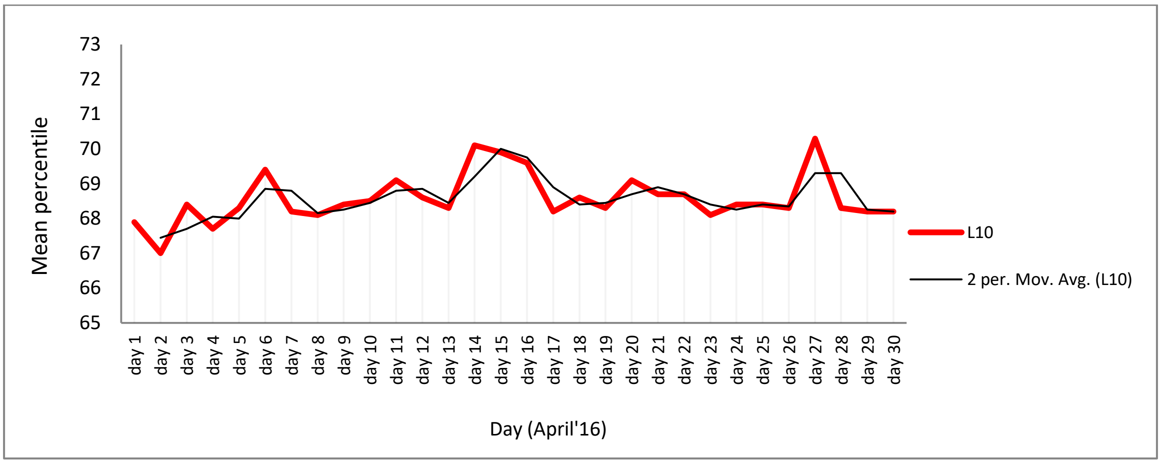
(ii) L_{50}



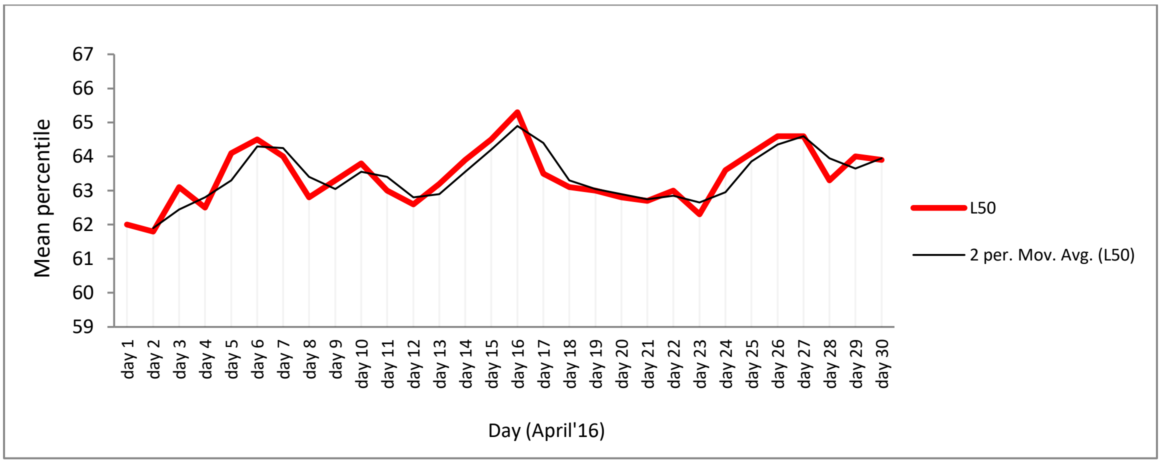
(iii) L_{90}

The above figure shows how the value of percentile noise level fluctuates along with 2 point moving average for R.K.Puram.

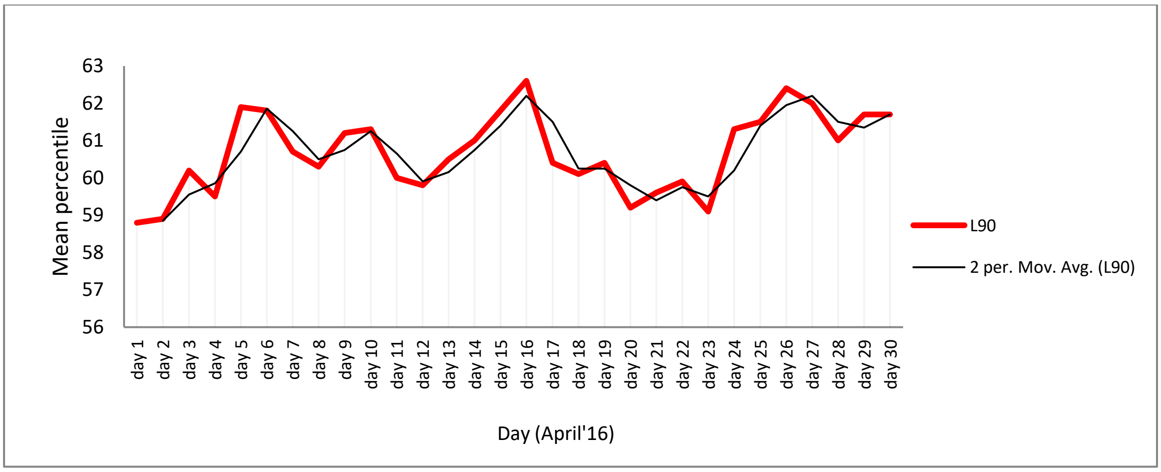
Figure 7.2 Two point moving average of percentile noise levels for Anand Vihar during April'16.



(i) L_{10}



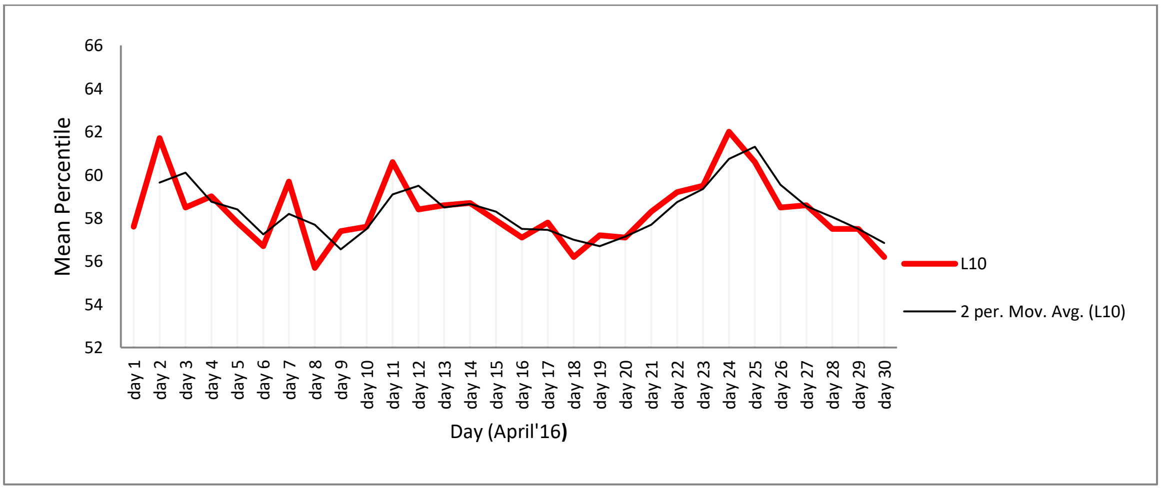
(ii) L_{50}



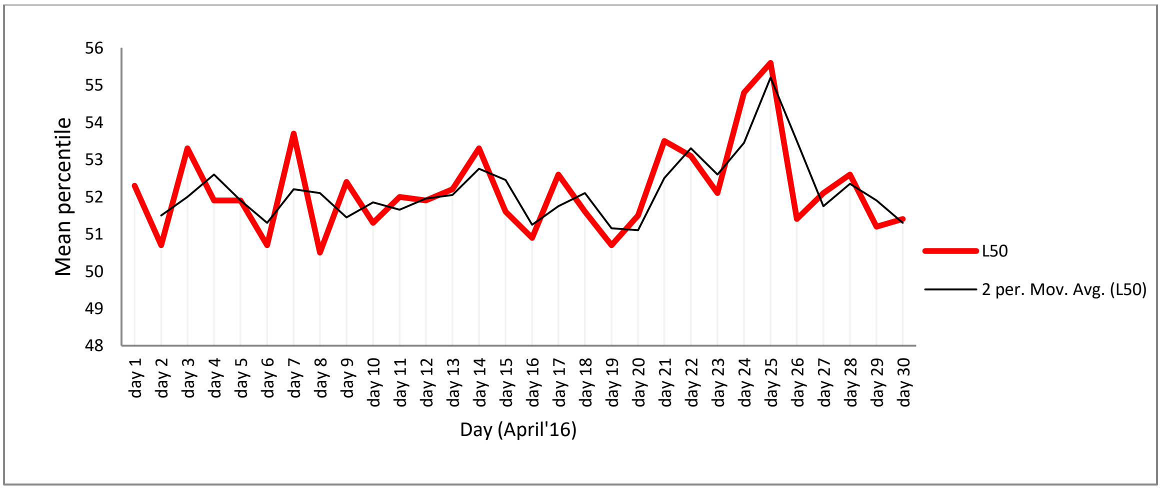
(iii) L_{90}

The above figure shows how the value of percentile noise level fluctuates along with 2 point moving average for Anand Vihar.

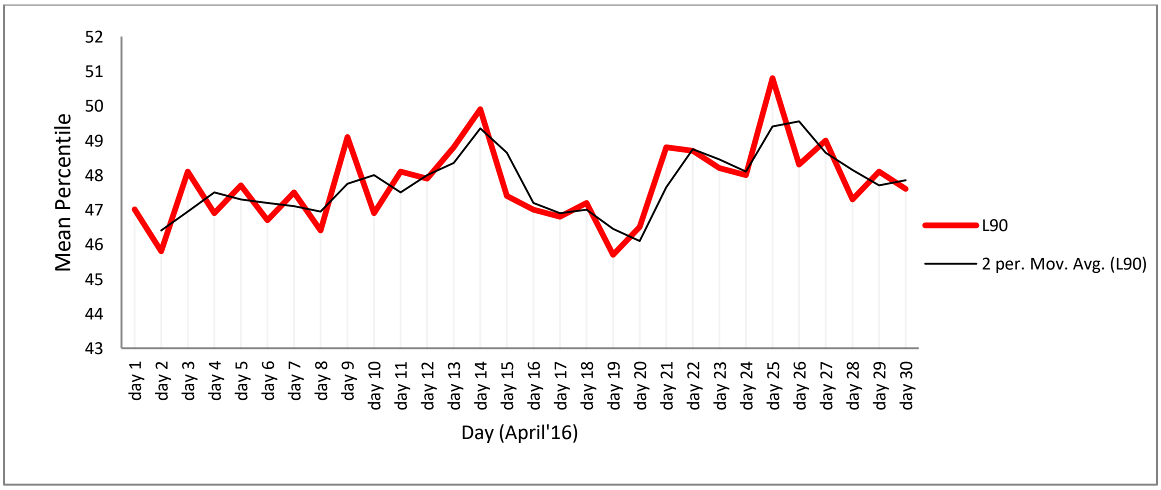
Figure 7.2 Two point moving average of percentile noise levels for Punjabi Bagh during April'16.



(i) L_{10}



(ii) L_{50}



(iii) L_{90}

Table 7.13 Equivalent Noise Level (Leq) and Noise Indices at R.K.Puram during April'16.

	Leq dB(A)	NPL dB(A)	TNI dB(A)		Leq dB(A)	NPL dB(A)	TNI dB(A)
DAY 1	61.79	61.84	47.5	DAY 16	61.44	64.07	51.0
DAY 2	60.16	61.46	47.1	DAY 17	58.43	58.70	42.9
DAY 3	58.18	63.83	54.6	DAY 18	60.69	62.32	46.3
DAY 4	61.07	63.12	50.5	DAY 19	60.57	63.40	49.4
DAY 5	61.09	61.58	47.7	DAY 20	58.84	61.34	49.7
DAY 6	61.58	67.54	54.6	DAY 21	62.69	62.84	48.3
DAY 7	62.66	67.84	60.5	DAY 22	60.35	62.66	48.6
DAY 8	62.34	73.09	74.2	DAY 23	60.71	62.04	47.6
DAY 9	59.01	71.15	72.7	DAY 24	59.18	68.87	60.1
DAY 10	57.34	60.50	47.5	DAY 25	59.72	61.94	46.2
DAY 11	63.11	67.94	60.8	DAY 26	60.27	64.45	51.4
DAY 12	63.84	65.93	57.4	DAY 27	63.85	62.20	46.1
DAY 13	64.54	68.50	59.5	DAY 28	61.49	62.52	46.7
DAY 14	63.26	60.49	44.3	DAY 29	61.51	61.82	44.3
DAY 15	59.28	59.49	43.3	DAY 30	57.99	64.74	52.5

Table 7.14 Equivalent Noise Level (Leq) and Noise Indices at Anand Vihar during April'16.

	Leq dB(A)	NPL dB(A)	TNI dB(A)		Leq dB(A)	NPL dB(A)	TNI dB(A)
DAY 1	67.07	61.11	65.2	DAY 16	67.46	73.11	60.6
DAY 2	66.71	70.99	61.3	DAY 17	67.24	72.31	61.6
DAY 3	66.70	72.42	63.1	DAY 18	67.24	72.80	64.1
DAY 4	67.75	60.75	62.3	DAY 19	67.59	71.94	62.2
DAY 5	67.18	71.18	57.5	DAY 20	67.62	74.33	68.8
DAY 6	67.56	73.06	62.2	DAY 21	67.82	73.18	66.1
DAY 7	67.60	72.43	60.7	DAY 22	67.81	73.09	65.1
DAY 8	67.02	71.61	61.5	DAY 23	68.58	72.65	65.1
DAY 9	66.81	71.36	60.2	DAY 24	67.49	71.54	59.7
DAY 10	67.74	71.86	60.1	DAY 25	67.21	71.79	59.1
DAY 11	67.70	73.48	66.4	DAY 26	67.22	71.08	56.2
DAY 12	67.89	72.69	65.3	DAY 27	67.67	74.04	65.2
DAY 13	68.44	72.01	61.7	DAY 28	67.39	71.48	60.2
DAY 14	67.47	74.38	67.4	DAY 29	67.65	71.20	57.7
DAY 15	67.88	73.69	64.2	DAY 30	67.72	71.10	57.7

Table 7.15 Equivalent Noise Level (Leq) and Noise Indices at Punjabi Bagh during April'16.

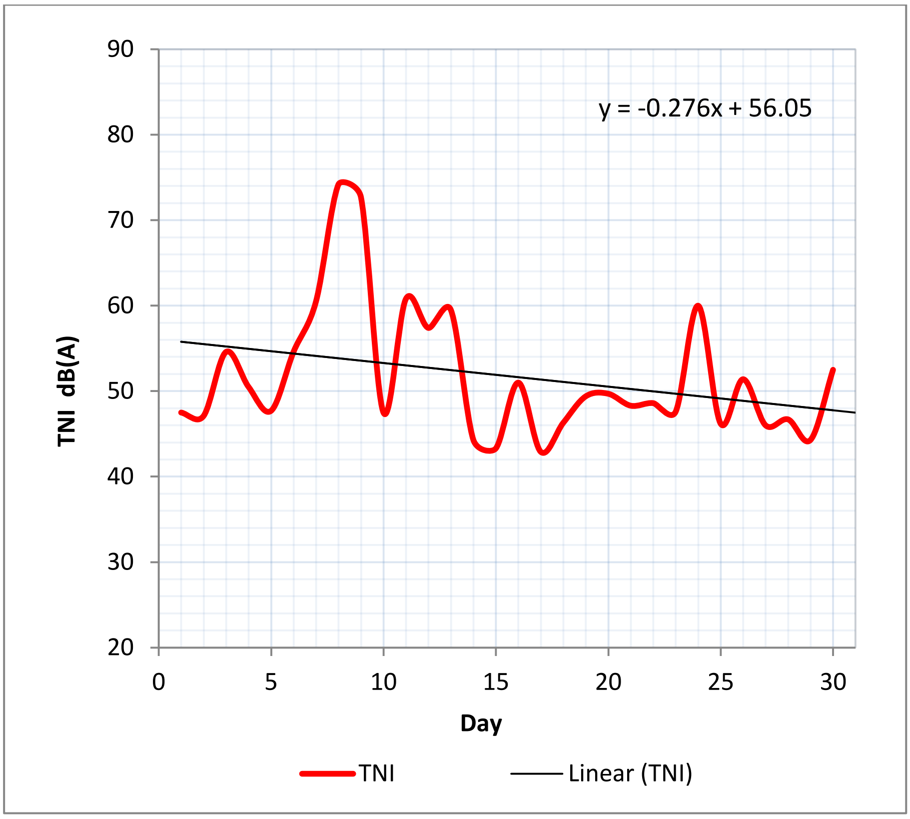
	Leq dB(A)	NPL dB(A)	TNI dB(A)		Leq dB(A)	NPL dB(A)	TNI dB(A)
DAY 1	59.99	64.75	59.3	DAY 16	60.07	62.71	57.4
DAY 2	58.42	70.81	79.4	DAY 17	56.87	65.67	60.8
DAY 3	56.86	65.50	59.7	DAY 18	57.93	61.95	53.2
DAY 4	57.62	66.45	65.3	DAY 19	58.16	64.47	61.7
DAY 5	58.94	63.70	58.1	DAY 20	59.53	63.97	58.9
DAY 6	57.93	62.36	56.7	DAY 21	63.56	64.57	56.8
DAY 7	59.22	68.38	66.3	DAY 22	59.11	65.45	60.7
DAY 8	58.71	61.24	53.6	DAY 23	60.47	65.57	63.4
DAY 9	56.27	61.84	52.3	DAY 24	57.64	72.07	74.1
DAY 10	56.38	63.97	59.7	DAY 25	57.75	67.07	60.1
DAY 11	62.42	67.17	68.1	DAY 26	57.25	63.34	59.1
DAY 12	63.75	64.25	59.9	DAY 27	57.16	63.23	57.4
DAY 13	64.06	63.67	58.1	DAY 28	59.59	64.53	58.1
DAY 14	60.63	63.37	55.1	DAY 29	59.31	62.07	55.7
DAY 15	58.91	63.75	59.4	DAY 30	57.14	61.27	52.1

The index calculated above in Table 20, 21, 22 is hence used to estimate the level of noise pollution. It is clear from the observation that the index rises on weekends which is due to the fact that there is heavy traffic rush on weekends and people use personal vehicle rather than using public transport. But relative observation in Figure.28 shows that there is fall in the level of NPL and TNI which is clear from the negative (-ve) slope obtained in Figure.29. A negative slope (m) indicates that the value of index falls with time. Thus during the latter half of the month when odd-even program had been launched it is clear that there slight decrease in pollution level.

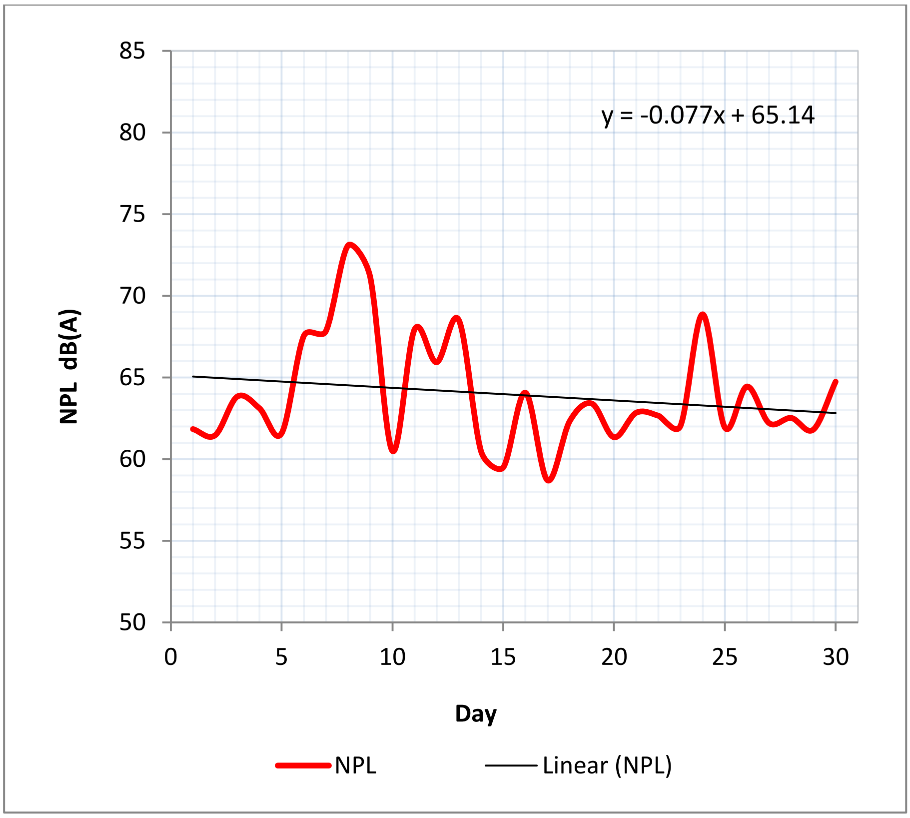
Table 7.16 Equation of the linear regression line along with standard deviation.

Site	Noise Indices	Equation of line	r_{xy}
R.K.Puram	TNI	y = -0.276x + 56.05	-0.096
	NPL	y = -0.077x + 65.14	-0.038
Anand Vihar	TNI	y = -0.056x + 63.15	-0.024
	NPL	y = -0.002x + 72.35	-0.005
Punjabi Bagh	TNI	y = -0.159x + 62.47	-0.055
	NPL	y = -0.045x + 65.33	-0.025

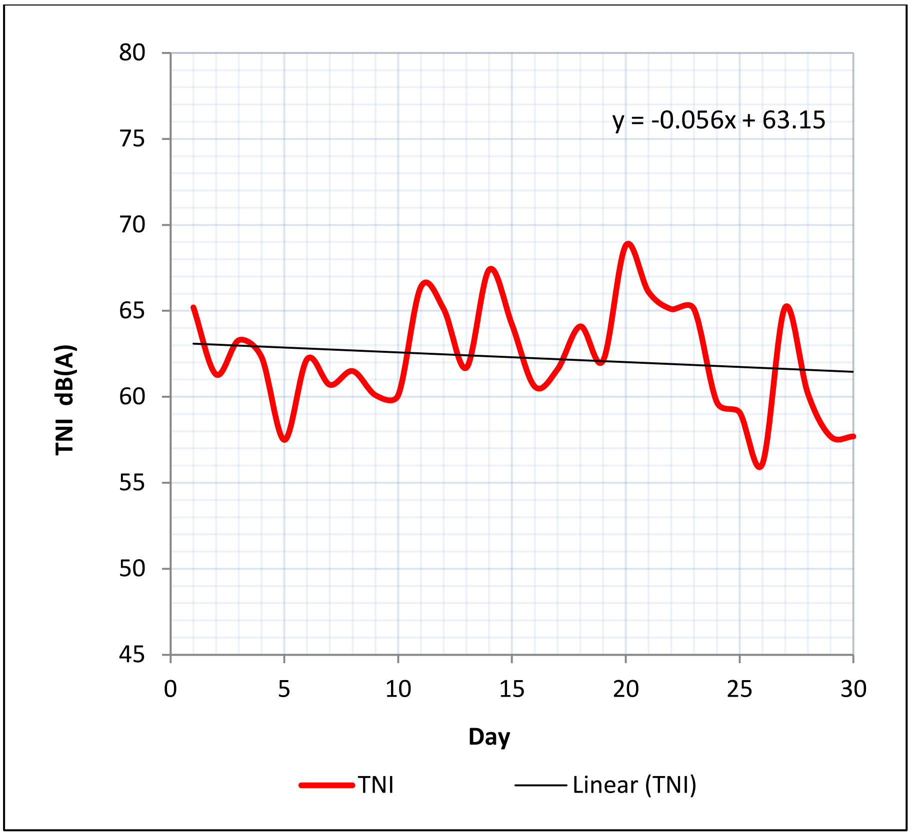
Figure 7.4 Noise Indices showing the linear regression line and standard deviation from the mean.



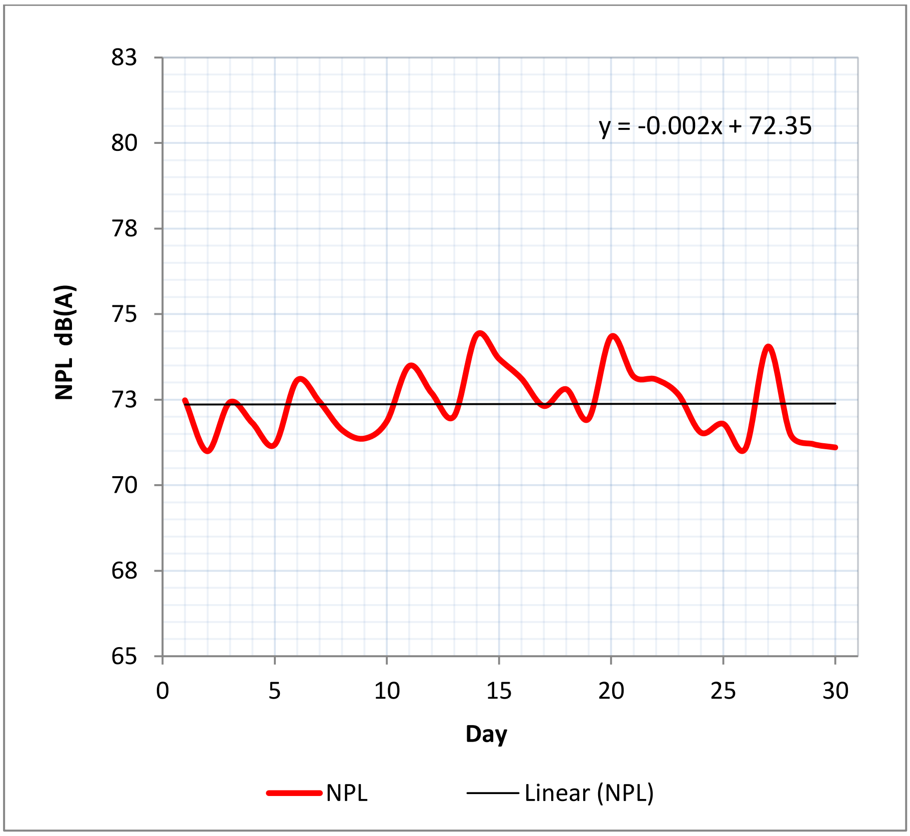
(i) TNI of R.K.Puram



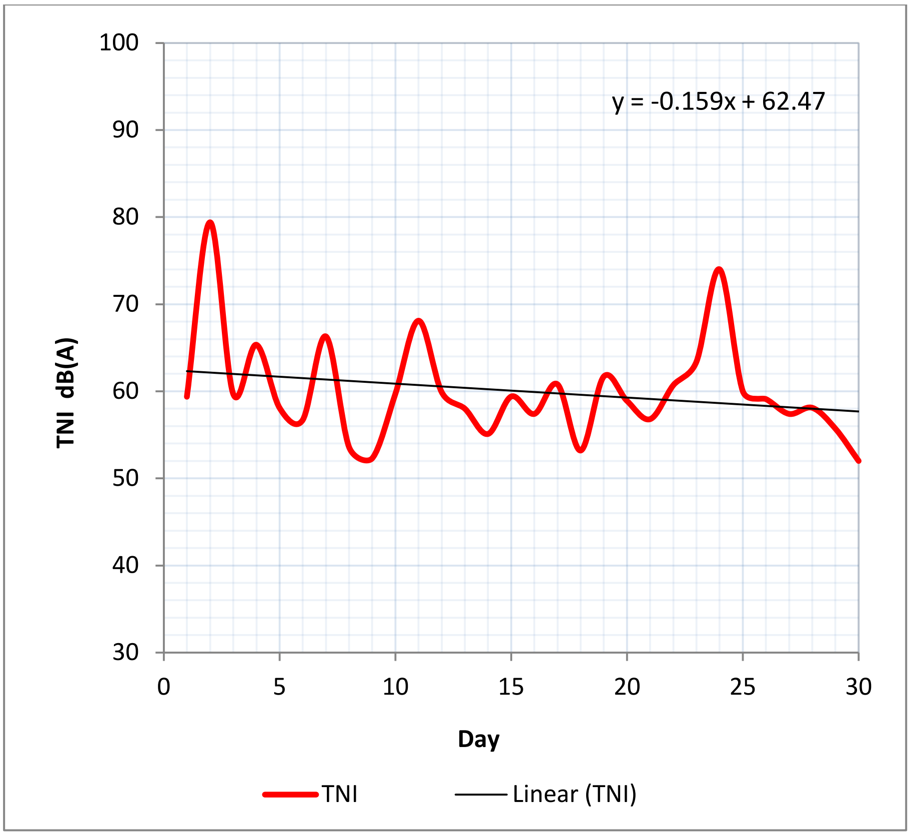
(ii) NPL of R.K.Puram



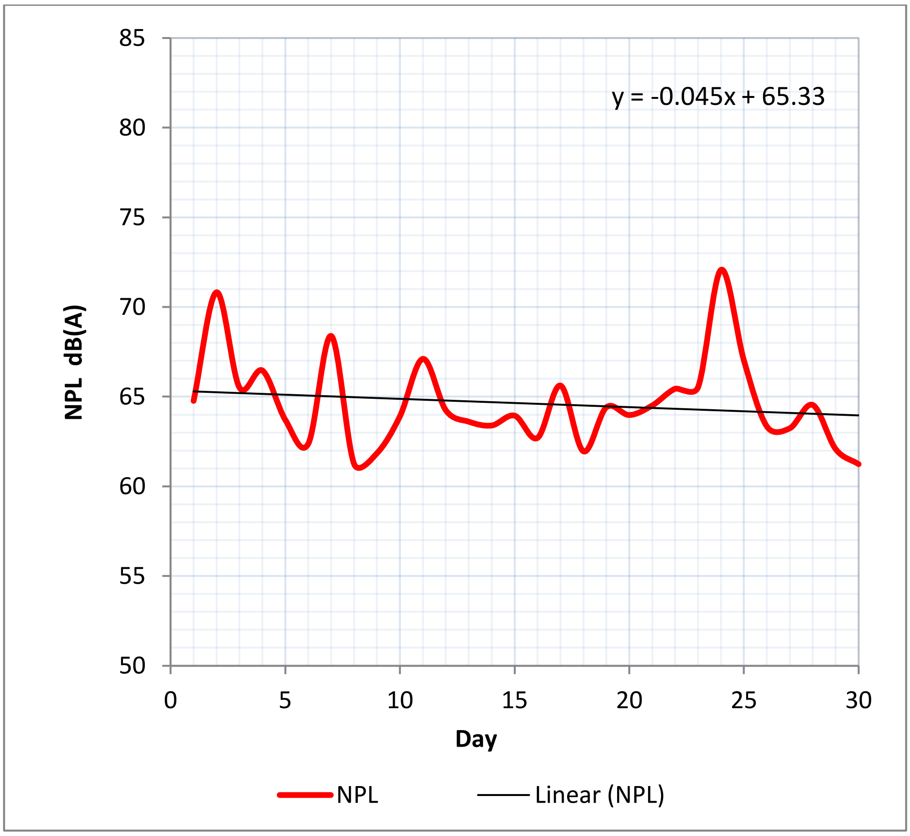
(iii) TNI of Anand Vihar



(iv) NPL of Anand Vihar



(v) TNI of Punjabi Bagh



(vi) NPL of Punjabi Bagh

7.3 Descriptive Statistics of Equivalent noise level (Leq) and Noise Indices

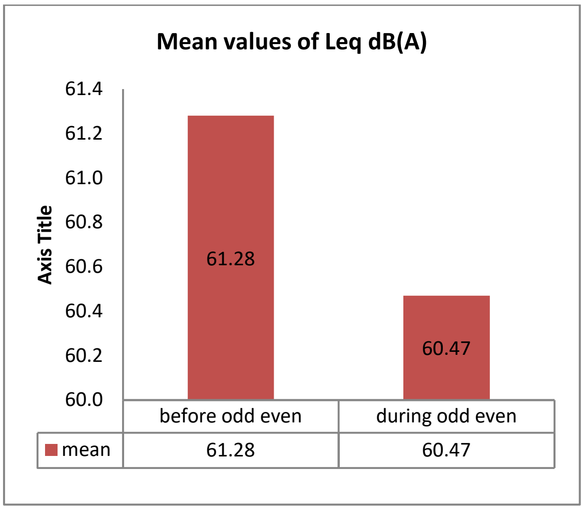
Table 7.1 Descriptive results of the statistical analysis of equivalent noise level (Leq) for all sites.

	R.K.Puram		Anand Vihar		Punjabi Bagh	
	Before odd-even (1^{st}-15^{th} April'16)	During odd-even (16^{th}-30^{th} April'16)	Before odd-even (1^{st}-15^{th} April'16)	During odd-even (16^{th}-30^{th} April'16)	Before odd-even (1^{st}-15^{th} April'16)	During odd-even (16^{th}-30^{th} April'16)
Mean	61.28	60.47	68.43	67.53	59.38	58.73
Standard Error	0.549713	0.440426	0.128538	0.090082	0.620469	0.469799
Median	61.58	60.57	68.56	67.59	58.9	58.16
Standard Deviation	2.129028	1.705763	0.497827	0.348885	2.403066	1.819525
Sample Variance	4.53276	2.909627	0.247831	0.121721	5.774729	3.31067
Kurtosis	-0.74474	0.537274	-0.64486	0.199059	-0.11615	0.396171
Skewness	-0.37078	-0.03746	0.025342	1.63472	0.876195	1.272067
Range	7.2	6.86	1.7	1.38	7.68	7.29
Minimum	57.34	56.99	67.72	67.25	56.38	56.27
Maximum	64.54	63.85	69.42	68.58	64.06	63.56
Sum	919.23	906.73	1026.48	1013.69	890.7	880.93
Count	15	15	15	15	15	15
Total Number of observations	**60**	**60**	**60**	**60**	**60**	**60**
Total Number of Exceedence from Standard limit	**60**	**60**	**60**	**60**	**60**	**60**
Exceeded percentage	**100**	**100**	**100**	**100**	**100**	**100**

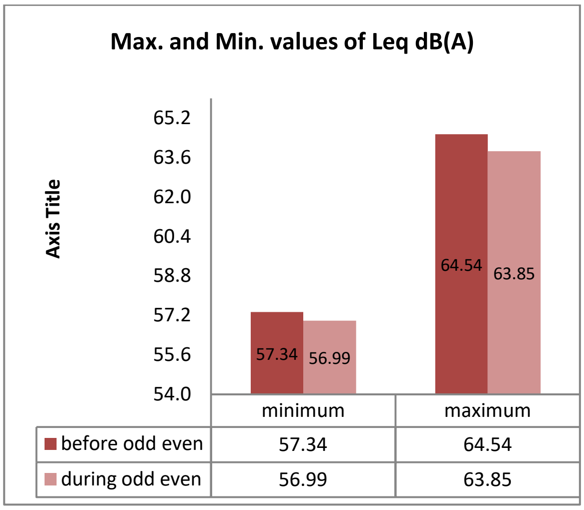
The mean value of L_{eq} for R.K.Puram has reduced from 61.28 dB(A) to 60.47 dB(A) but it still above the prescribed limit of 50 dB(A) for the silence zone. For Anand Vihar the mean value of L_{eq} has reduced from 68.43 dB(A) to 67.53 dB(A) but it is still above the prescribed limit of 65 dB(A). And for Punjabi Bagh the mean value of L_{eq} has reduced from 59.38 dB(A) to 58.73 dB(A) which is also above the prescribed limit of 55 dB(A). The relative mean L_{eq} values have been shown in Figure.29.

The descriptive results of statistical analysis has been shown in Figure.30 which shows the mean values of equivalent noise level has fallen in each site. Every set of result show a slight decrease in level indicating the performance of odd-even program. But at the same time the decreased level are still above the limits set by the government therefore the success of the program is not worthy.

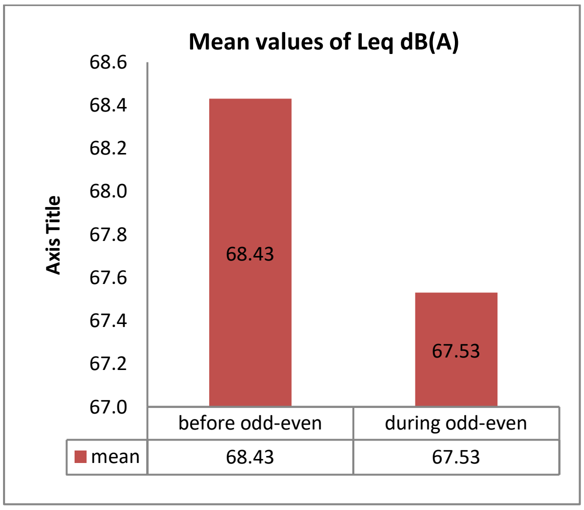
Figure 7.5 Graphical comparison of Mean Leq, Max. and Min. Leq for April'16.



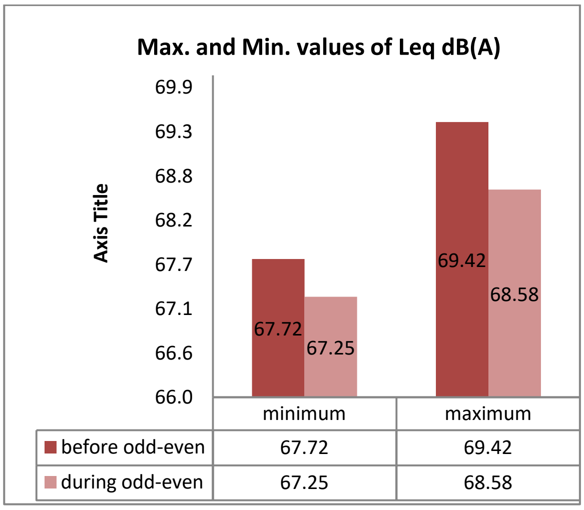
(i) Mean Leq (R.K.Puram)



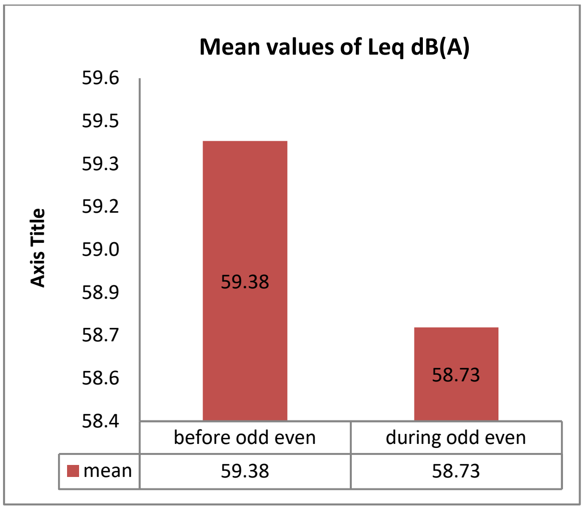
(ii) Max. and Min. Leq (R.K.Puram)



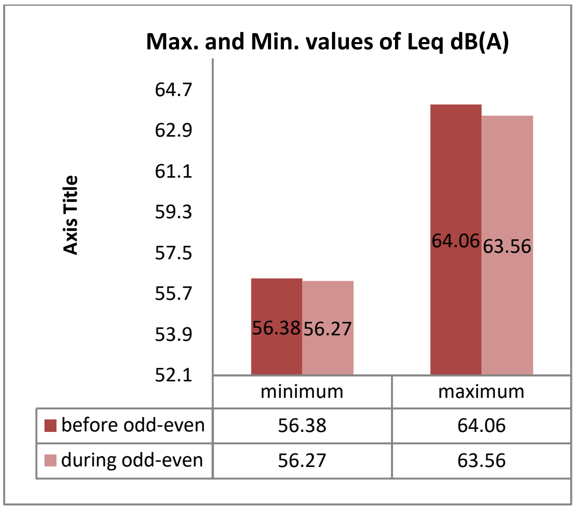
(iii) Mean Leq (Anand Vihar)



(iv) Max. and Min. Leq (Anand Vihar)



(v) Mean Leq (Punjabi Bagh)



(vi) Max. and Min. Leq (Punjabi Bagh)

Table 7.18 Forecasted Leq vs. Actual Leq for odd-even program (15th to 30th April'16)

	Leq dB(A) (actual)	Leq dB(A) (forecasted)	Residuals	Leq dB(A) (actual)	Leq dB(A) (forecasted)	Residuals	Leq dB(A) (actual)	Leq dB(A) (forecasted)	Residuals
Day 16	61.44	63.18	1.74	67.46	68.66	1.20	60.07	60.69	0.62
Day 17	58.43	63.18	4.75	67.24	68.08	0.84	56.27	62.08	5.81
Day 18	60.69	63.67	2.98	67.24	68.45	1.21	57.93	61.01	3.08
Day 19	60.57	64.77	4.20	67.59	68.48	0.89	58.16	62.37	4.21
Day 20	58.84	64.42	5.58	67.62	67.89	0.27	59.53	61.84	2.31
Day 21	62.69	60.96	-1.73	67.82	67.67	-0.15	63.56	59.9	-3.66
Day 22	60.35	59.22	-1.13	67.8	68.60	0.80	59.11	59.38	0.27
Day 23	60.71	65.16	4.45	68.58	68.55	-0.03	60.47	65.74	5.27
Day 24	59.18	66.22	7.04	67.49	69.01	1.52	57.64	66.66	9.02
Day 25	59.72	66.56	6.84	67.2	69.27	2.07	57.75	66.82	9.07
Day 26	60.27	65.00	4.73	67.22	68.60	1.38	57.25	64.15	6.90
Day 27	63.85	61.86	-1.99	67.67	68.79	1.12	57.16	62.39	5.23
Day 28	61.49	65.30	3.81	67.39	69.61	2.22	59.59	63.79	4.20
Day 29	61.51	65.30	3.79	67.65	69.01	1.36	59.30	65.25	5.95
Day 30	56.99	65.81	8.82	67.72	69.39	1.67	57.14	64.13	6.99

With the help of time series forecasting the equivalent noise levels for odd-even program has been predicted and the relative change is tested through Kolmogrov-Smirnov test.

Figure 7.6 Cumulative Distribution of Leq actual vs. Leq forecasted for R.K.Puram during odd-even program (15th – 30th April'16).

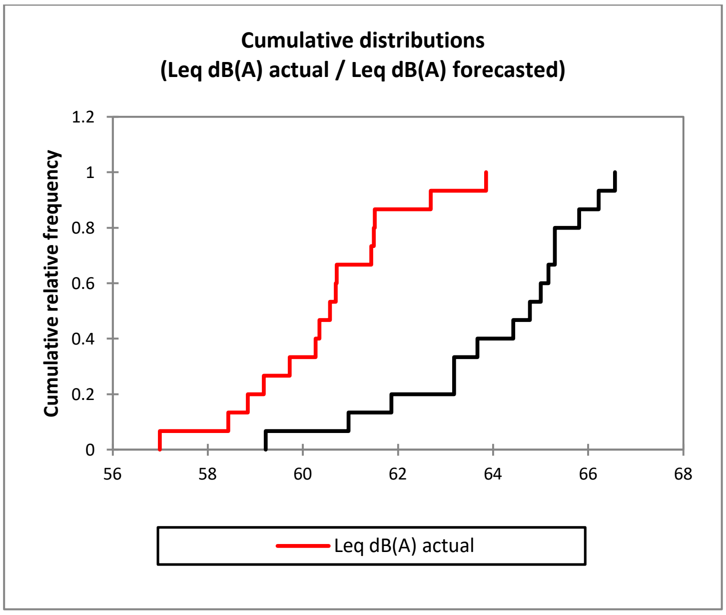


Figure 7.7 Cumulative Distribution of Leq actual vs. Leq forecasted for Anand Vihar during odd-even program (15th – 30th April'16).

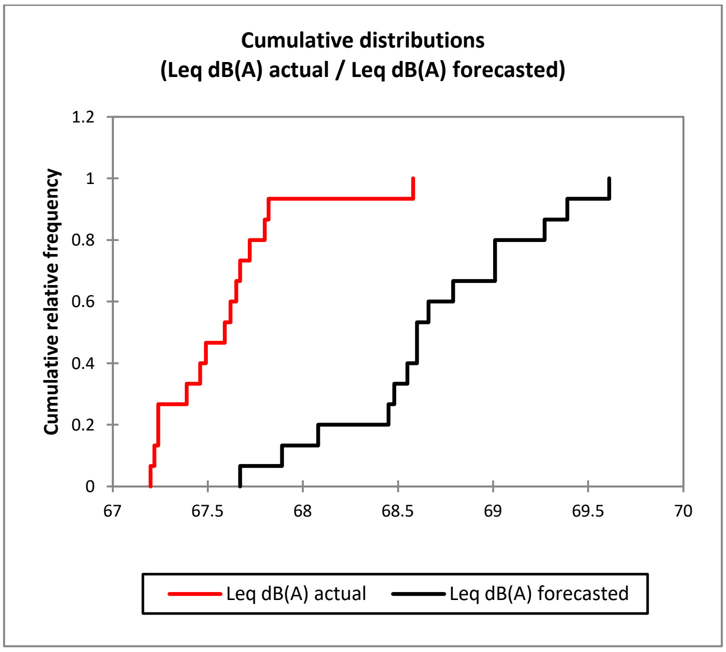
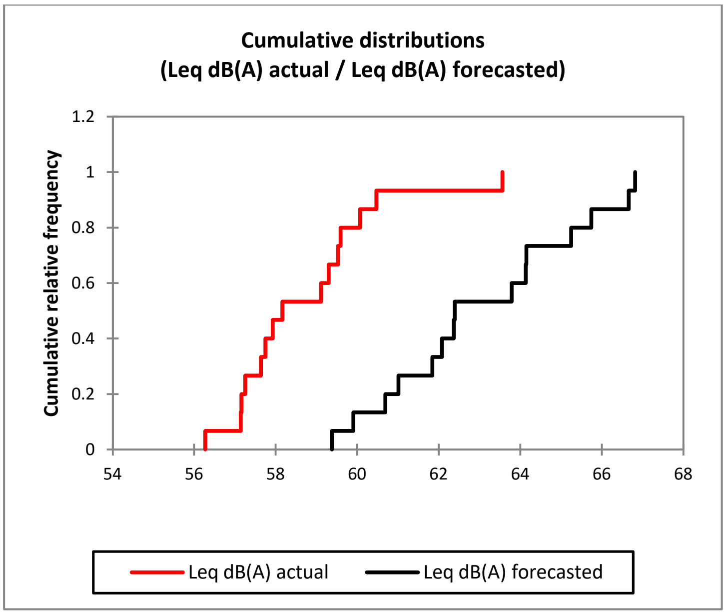


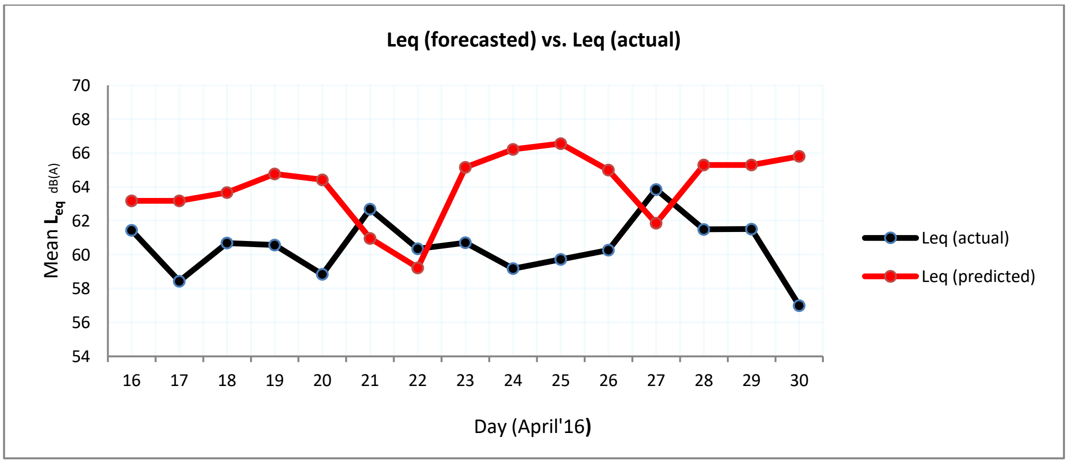
Figure 7.8 Cumulative Distribution of Leq actual vs. Leq forecasted for Punjabi Bagh during odd-even program (15th – 30th April'16).



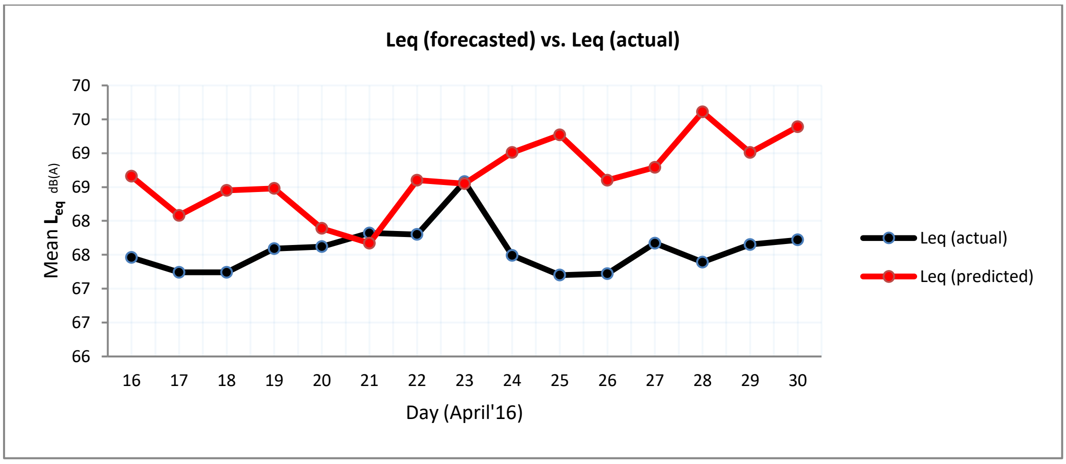
Forecasting for 16th-30th April'16 (15 days) has been done using the time series regression analysis of previous 90 days daily mean of L_{eq} dB(A) using the XLSTAT plugin in Microsoft Excel software. Daily mean values of L_{eq} dB(A) for the peak hours has been taken from the month of Jan'16, Feb'16, Mar'16 and then the forecasted L_{eq} has been compared to the actual L_{eq} that has been shown in figure 3.2. The graph clearly indicates that the actual L_{eq} is lesser than the forecasted

L_{eq} and therefore it assists the previous conclusion of the study that the noise pollution has reduced to a certain level.

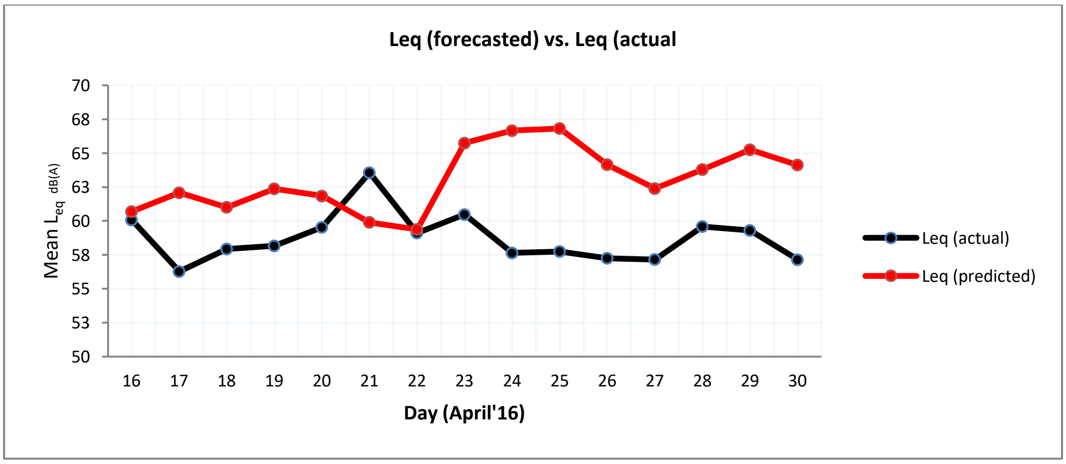
Figure 7.9 Leq (forecasted) vs. Leq (actual) during odd-even program.



(i) R.K.PURAM



(ii) ANAND VIHAR



(iii) PUNJABI BAGH

7.4 Mathematical Noise Modeling for odd-even (15^{th} – 30^{th} April'16) program.

The following equations were used to create the model for the odd-even program. These equations have been adopted from the previous studies of research workers. The variables used in the equations have been defined in earlier chapters. Since modeling is to be done in a restricted environment therefore by inspection it was observed that the value of 'c' ie, distance of instrument from half of the lane is 15m. Using these values we can calculate the values of 'A' and 'B'

$$L_{10} = 61.1 + 8.4 \text{ Log (A)} + 0.15B – 11.5 \text{ Log (C)} \quad (7.1)$$

$$L_{50} = 44.9 + 10.8 \text{ Log (A)} + 0.12B – 9.6 \text{ Log (C)} \quad (7.2)$$

$$L_{90} = 39.2 + 10.5 \text{ Log (A)} + 0.06B – 9.3 \text{ Log (C)} \quad (7.3)$$

From the above (1), (2), (3) equation when the A (vehicle flow rate), B (percentage of heavy vehicles) and C (15m in our case) is known we can calculate the value of L_{eq} for 15 days interval. Rest assumptions are made through site survey are ignored in the calculation but will be added in the main equation as corrections.

$$L_{eq}=10\log A + 33\log (V+40+500/V) + 10\log (1+5B/V) – 26.6 \quad (7.4)$$

Table 7.19 Equivalent noise level obtained from the equation of mathematical model for R.K.Puram.

	L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)	Q	P	Leq dB(A) (calculated)	Leq dB(A) (actual)
DAY 16	60.6	56.5	53.8	125	10.2	60.42	61.44
DAY 17	56.4	52.7	50.9	134	11.4	58.13	58.43
DAY 18	59.5	56.2	53.9	152	9.6	61.29	60.69
DAY 19	59.9	56.2	53.4	141	12.1	60.53	60.57
DAY 20	58.4	53.4	51.3	163	11.3	57.54	58.84
DAY 21	59.7	56	53.5	165	10.3	62.61	62.69
DAY 22	59.7	55.7	53.4	152	10.6	61.35	60.35
DAY 23	59	55.2	52.8	145	15.4	60.71	60.71
DAY 24	60.9	57.6	51.2	165	14.2	58.24	59.18
DAY 25	59.1	55.7	53.4	166	13.4	59.21	59.72
DAY 26	61.3	57	54.6	170	12.1	61.21	60.27
DAY 27	59.5	56.2	54	162	12.6	63.81	63.85
DAY 28	59.9	56.4	54.3	155	10.2	60.42	61.49
DAY 29	59.3	56.4	54.3	145	13.4	62.42	61.51
DAY 30	61.2	56.8	54.1	136	11.2	56.21	57.99

Figure 7.10 Relative Cumulative frequency distribution of Leq predicted vs Leq actual of R.K.Puram.

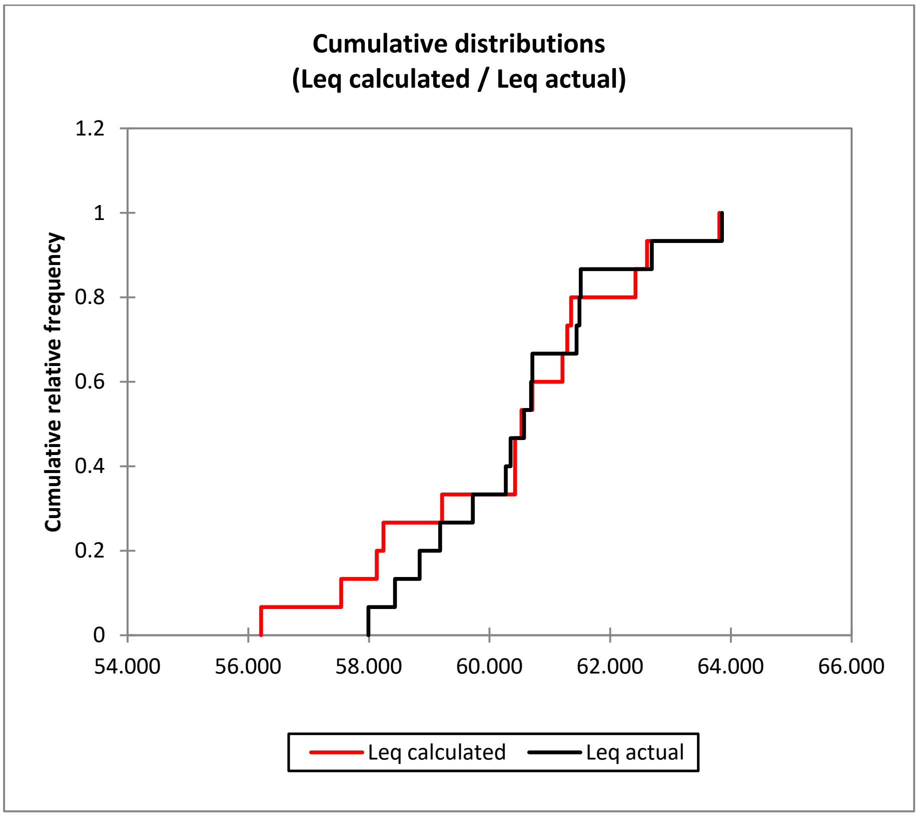


Figure 7.11 Nonlinear regression analysis showing goodness of fit for Leq (calculated) vs. Leq (actual) for R.K.Puram.

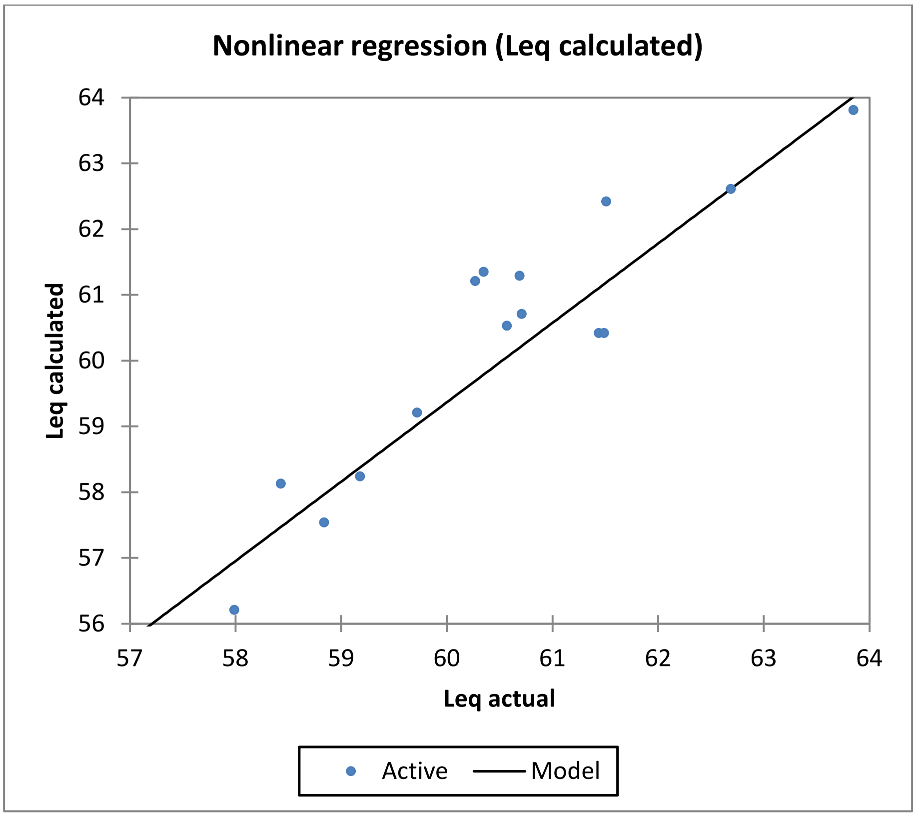


Figure 7.12 Regression test to check the validation of the model for R.K.Puram.

Nonlinear regression of variable Leq calculated:

Goodness of fit statistics:

Observati	15.000
DF	13.000
R²	0.850
SSE	10.171
MSE	0.782
RMSE	0.885
Iterations	200.000

Model parameters:

Parameter	Value
pr1	1.207
pr2	-13.043

Equation of the model:

Leq calculated = 1.20683311392681*Leq actual+-13.0431468167678

Table 7.20 Equivalent noise level obtained from the equation of mathematical model of Anand Vihar.

	L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)	Q	P	Leq dB(A) (calculated)	Leq dB(A) (actual)
DAY 16	69.6	65.3	62.6	143	12.2	67.42	67.46
DAY 17	68.2	63.5	60.4	123	11.2	67.12	67.24
DAY 18	68.6	63.1	60.1	127	11.8	67.02	67.24
DAY 19	68.3	63	60.4	167	14.6	67.05	67.59
DAY 20	69.1	62.8	59.2	145	13.4	67.11	67.62
DAY 21	68.7	62.7	59.6	164	15.2	67.55	67.82
DAY 22	68.7	63	59.9	132	12.6	67.51	67.81
DAY 23	68.1	62.3	59.1	111	17.3	68.52	68.58
DAY 24	68.4	63.6	61.3	121	16.9	67.36	67.49
DAY 25	68.4	64.1	61.5	139	14.1	67.13	67.21
DAY 26	68.3	64.6	62.4	164	14.2	67.02	67.22
DAY 27	70.3	64.6	62	162	13.9	67.52	67.67
DAY 28	68.3	63.3	61	132	11.1	67.11	67.39
DAY 29	68.2	64	61.7	122	11.3	67.51	67.65
DAY 30	68.2	63.9	61.7	110	10.3	67.72	67.72

Figure 7.13 Relative Cumulative frequency distribution of Leq predicted vs Leq actual for Anand Vihar.

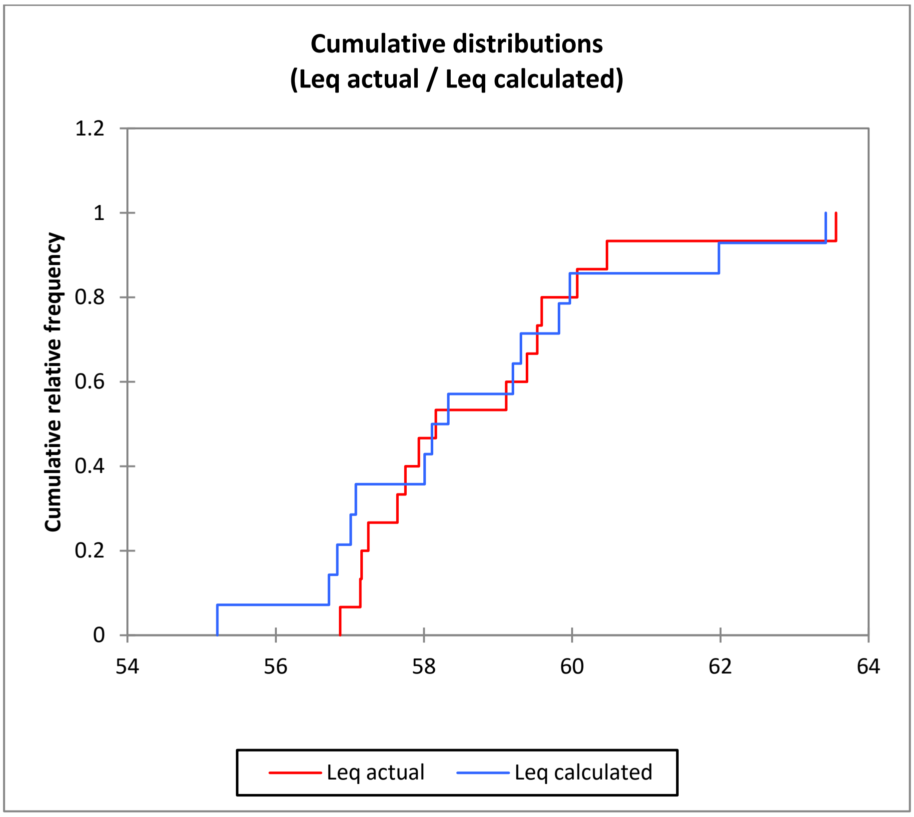


Figure 7.14 Nonlinear regression analysis showing goodness of fit for Leq (calculated) vs. Leq (actual) for Anand Vihar.

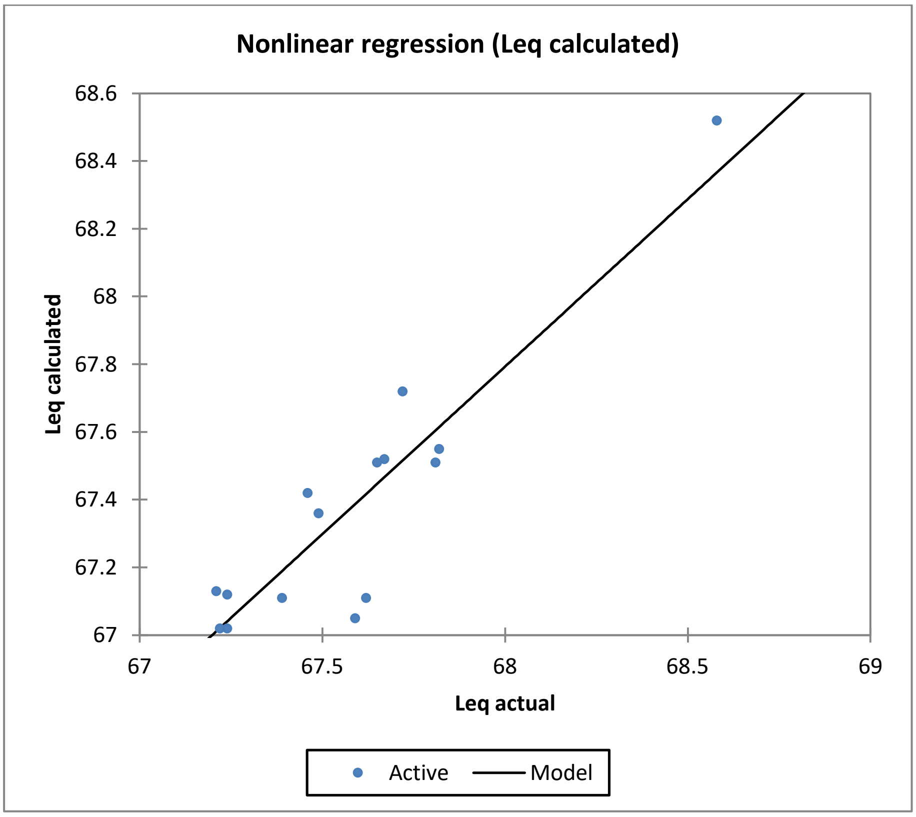


Figure 7.15 Regression test to check the validation of the model for Anand Vihar.

Nonlinear regression of variable Leq calculated:

Goodness of fit statistics:

Observati	15.000
DF	13.000
R²	0.837
SSE	0.351
MSE	0.027
RMSE	0.164
Iterations	2.000

Model parameters:

Parameter	Value
pr1	0.989
pr2	0.529

Equation of the model:

Leq calculated = 0.989179427510251*Leq actual+0.528658396890352

Table 7.21 Equivalent noise level obtained from equation of mathematical model of Punjabi Bagh.

	L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)	Q	P	Leq dB(A) (calculated)	Leq dB(A) (actual)
DAY 16	57.1	50.9	47	114	13.2	61.98	60.07
DAY 17	57.8	52.6	46.8	123	12.2	55.21	56.87
DAY 18	56.2	51.6	47.2	132	11.0	56.83	57.93
DAY 19	57.2	50.7	45.7	145	16.5	57.01	58.16
DAY 20	57.1	51.5	46.5	144	15.4	58.33	59.53
DAY 21	58.3	53.5	48.8	165	15.2	63.42	63.56
DAY 22	59.2	53.1	48.7	164	12.3	59.20	59.11
DAY 23	59.5	52.1	48.2	168	13.2	59.97	60.47
DAY 24	62	54.8	48	141	16.1	58.01	57.64
DAY 25	60.6	55.6	50.8	123	18.4	56.72	57.75
DAY 26	58.5	51.4	48.3	112	15.2	58.11	57.25
DAY 27	58.6	52.1	49	102	12.7	57.08	57.16
DAY 28	57.5	52.6	47.3	103	13.7	59.82	59.59
DAY 29	57.5	51.2	48.1	120	13.2	59.31	59.39
DAY 30	56.2	51.4	47.6	131	11.7	58.97	57.14

Figure 7.16 Relative Cumulative frequency distribution of Leq predicted vs Leq actual for Punjabi Bagh.

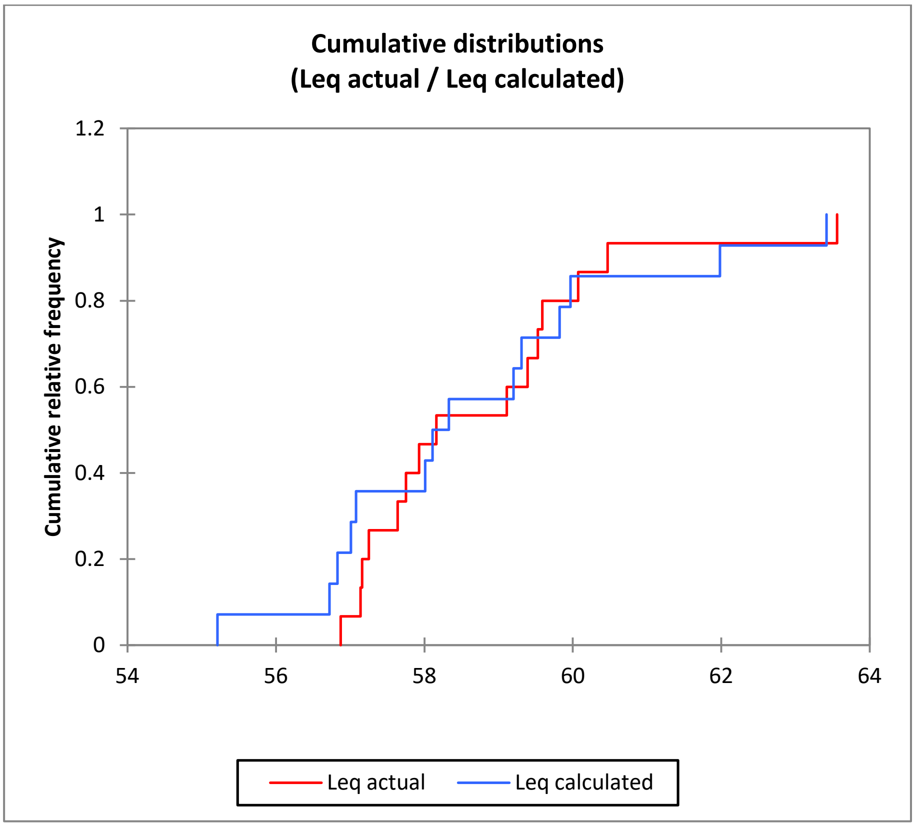


Figure 7.17 Nonlinear regression analysis showing goodness of fit for Leq (calculated) vs. Leq (actual) for Punjabi Bagh.

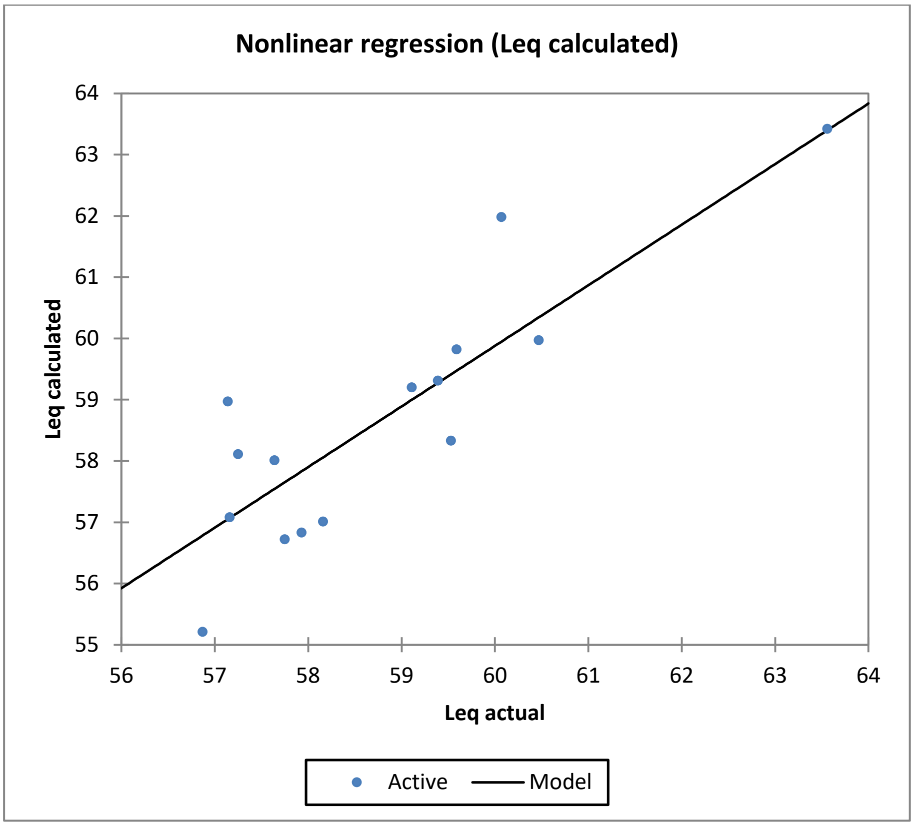


Figure 7.18 Regression test to check the validation of the model for Punjabi Bagh.

Nonlinear regression of variable Leq calculated:

Goodness of fit statistics:

Observati	15.000
DF	13.000
R²	0.748
SSE	15.863
MSE	1.220
RMSE	1.105
Iterations	2.000

Model parameters:

Parameter	Value
pr1	0.989
pr2	0.543

Equation of the model:

Leq calculated = 0.988926968681948*Leq actual+0.543041431202113

In the above analysis it is observed that the value of R^2 is 0.85 which is close to 1. Hence the goodness of fit of the model is under confidence limit which can be seen in Figure.34 and Figure.35. The modeled equation can be used with corrections ie,

$$L_{eq(calculated)} = 1.2(L_{eq(actual)}) - 1.3 \quad (7.5)$$

This will be applied to our main equation to give the final equation of R.K.Puram for odd-even days.

Similarly for Anand Vihar the R^2 is 0.837 which is good for model to fit and hence the correction to be applied will be

$$L_{eq(calculated)} = 0.98(L_{eq(actual)}) + 0.53 \quad (7.6)$$

And for Punjabi Bagh R^2 is 0.74 which is also acceptable for fit. Hence the correction applied is

$$L_{eq(calculated)} = 0.99(L_{eq(actual)}) + 0.54 \quad (7.7)$$

Now the final set of modeled equation for all 3 sites with corrections and all assumptions is given as

$$\mathbf{L_{eq}=12.1(log\ A) + 39.6(log\ (V+40+500/V)) + 12.1(log\ (1+5B/V) – 27.92} \quad (7.8)$$

$$\mathbf{L_{eq}=9.8(log\ A) + 32.34(log\ (V+40+500/V)) + 9.8(log\ (1+5B/V) – 26.07} \quad (7.9)$$

$$\mathbf{L_{eq}=9.9(log\ A) + 32.67(log\ (V+40+500/V)) + 9.9log\ (1+5B/V) – 26.06} \quad (7.10)$$

Equation (7.8), (7.9), (7.10) is for R.K.Puram, Anand Vihar and Punjabi Bagh respectively which can be used further for calculation of true Leq.

CHAPTER VIII

CONCLUSION

On the basis of thoughtful analysis the study concludes to bestow significant results in areas of noise level determination and forecasting from the combined efforts of previous researches and present study. Determination of noise level and forecasting initiates to establish subsequent results. The present work and collected data on noise generating parameters was applied to evaluate the vehicular traffic noise, and to suggest suitable model based on Indian conditions. From the study of previous chapters and results following points are concluded:

1. It is clear from the present study that all selected sites were exposed to higher noise level as compared to Indian standard noise level approved by CPCB (Central Pollution Control Board), New Delhi, India. In spite of efforts made by the Government of Delhi in odd-even program the effects were quite low as compared to the effect in other countries. Though the levels of noise had decreased a bit but odd-even program seemed ineffective seeing the results of the study. The noise levels were still above the prescribed limits and the reduction percentage was very low.
2. To reduce noise pollution several measures can be implemented such as proper maintenance of vehicles and roads, plantation of trees and electricity generator should be covered under silencer, traffic movements should be maintained or control effectively by traffic police and to aware the people about noise pollution.
3. To trounce these tribulations many efforts have been made in the past. Development in noise control strategy has vividly grown at a rapid rate creating sophisticated techniques and modern methods. Basically, diminution in noise is the only way to control it. Noise control technique in contemporary time refers to optimization of noise level keeping efficient and outfitted considerations in mind. However, even as such domination and management measures are complex to uphold, the benefits made from these trial actions will only diminish over time. Long-term actions with strong monetary impetus to ensure beneficial results are crucial for superior quality of environment.

SCOPE FOR FUTURE WORK

A retrospective view of noise policies and ordinances in India and proposes revisions in them for noise abatement and control based on the available knowledge on noise policies and regulations followed in other countries is provided here. The work focused on inclusion of noise limits for construction activities, and domestic appliances apart from revision in ambient noise standards and National Building Codes for enhancing the sound insulation of building elements for protection against noise pollution. The noise limits for domestic appliances, motor vehicles and construction equipment at the manufacturing stage and enforcement of ambient noise standards shall be helpful in controlling noise pollution in India. The implementation of noise pollution control measures essentially requires a strategic noise abatement planning with enforcement of proposed ambient standards, revision in National Building Codes, exercising control limits on all the noisy sources and formulation of noise abatement goal. The suggested flow chart for reducing the ambient noise levels and targeting a noise abatement goal shall be a vital step in this regard for environmental protection in future. Identification of noisy hot spots having higher Leq, 24h sound levels than the recommended limits and implementing suitable noise abatement measures shall be indispensable for noise pollution control. Provision for the erection of noise barriers, especially for sensitive areas like hospitals, schools, colleges, old-age homes, religious institutions, etc. and other areas lying in the silence zone should be made in future projects planned. Studies on socio-acoustic surveys with an objective of correlating the noise annoyance with exposure, effect of noise levels on the human body and hearing loss, on workers in industry, effect of noise exposure on traffic policeman and workers at construction sites, etc. should also be conducted in parallel for increasing awareness of society towards controlling noise pollution levels in the country. It is envisaged that the proposed standards, revision in National Building Codes and noise control measures shall be indispensable in the development of ‘smart cities’ concept proposed by the Government. The major objectives of a noise control programme should be to identify areas having high ambient noise levels in each part of the city, and evaluating the efficacy and suitability of noise abatement measures for bringing these levels below the ambient noise standards. An appropriate noise policy suitable for controlling the noise exposure of various sources is necessary. Noise zoning based on land-use criteria, noise monitoring and noise impact assessment using a validated model and implementation of policies and ordinances for noise control are the various aspects of the noise control programme to be emphasized. Noise mapping of the cities and ascertaining the compliance of ambient noise standards should be the major objective of such a programme. Development of noise maps, setting up of expert committee for progress review and analysis like the National Committee for Noise Pollution Control (NCNPC), and targeting a noise abatement goal shall be key steps for controlling the noise pollution levels in the country. Besides all, public awareness and mass exposure is necessary to fight this problem so that each and every individual feels responsible towards minimizing the noise level at production stage.

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